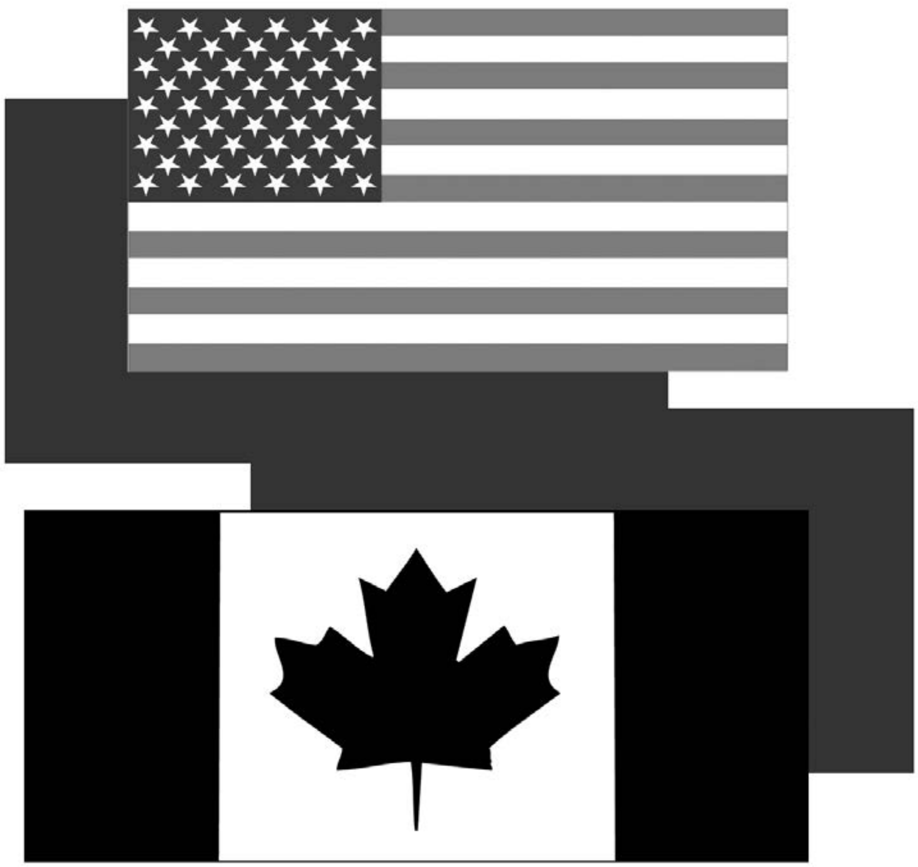
Report of the Technical Subcommittee
of the
Canada-United States Groundfish Committee

2020



Appointed by the Second Conference on Coordination of Fisheries Regulations between Canada and the United States

Compiled by the Pacific States Marine Fisheries Commission

History of TSC Meeting Locations, Hosts and Chairpersons

YEAR	DATES	LOCATION	HOST	CHAIR
1984	June 20-22	British Columbia	Westrheim	Rigby
1985	June 25-27	Juneau, AK	Morrison	Westrheim
1986	June 19-19	Ashland, OR	Demory	Westrheim
1987	June 9-11	Seattle, WA	Jagielo	Demory
1988	June 7-9	Carmel, CA	Henry	Demory
1989	June 6-9	Ladysmith, BC	Saunders	Jagielo
1990	June 5-7	Sitka, AK	Bracken	Jagielo
1991	June 4-6	Newport, OR	Barss	Wilkins
1992	May 5-7	Seattle, WA	Jagielo	Wilkins
1993	May 5-7	Point Lobos, CA	Thomas	Saunders
1994	May 3-5	Nanaimo, BC	Saunders	Saunders
1995	May 2-3	Seattle, WA	O'Connell	Bracken
1996	May 7-9	Newport, OR	Barss	O'Connell
1997	May 6-8	Tiburon, CA	Thomas	Barss
1998	May 5-7	Olympia, WA	Jagielo	Barss
1999	May 4-6	Seattle, WA	Methot	Barnes
2000	May 9-10	Nanaimo, BC	Saunders	Barnes
2001	May 8-10	Newport, OR	Schmitt	Schmitt
2002	May 7-8	Point Lobos, CA	Barnes	Methot
2003	May 6-7	Sitka, AK	O'Connell	Jagielo
2004	May 4-5	Coupeville, WA	Wilkins	Jagielo
2005	May 3-4	Parksville, BC	Stanley	Stanley
2006	May 2-3	Otter Rock, OR	Parker	Stanley
2007	April 24-25	Santa Cruz, CA	Field	Brylinsky
2008	May 6-7	Seattle, WA	Wilkins	Brylinsky
2009	May 5-6	Juneau, AK	Clausen	Clausen
2010	May 5-6	Nanaimo, BC	Stanley	Clausen
2011	May 3-4	Astoria, OR	Phillips	Clausen
2012	May 1-2	Newport Beach, CA	Larinto	Clausen
2013	April 30-May 1	Seattle, WA	Palsson	Larinto
2014	April 29-30	Seattle, WA	Dykstra	Larinto
2015	April 28-29	Sidney, BC	Yamanaka	Larinto
2016	April 26-27	Newport, OR	Whitman	Yamanaka
2017	April 25-26	Juneau, AK	Heifetz	Yamanaka
2018	April 24-25	Santa Cruz, CA	Field	Lowry
2019	April 23-24	Olympia, WA	Lowry	Lowry
2020	No Meeting Held Due to COVID - 19			

Table of Contents

A. History and Purpose

Purpose:

The Technical Subcommittee (TSC) of the Canada-U.S. Groundfish Committee was formed in 1960 out of a need to coordinate fishery and scientific information resulting from the implementation of commercial groundfish fisheries operating in US and Canadian waters off the West Coast. Today, representatives from Canadian and American state and federal agencies meet annually to exchange information and to identify data gaps and information needs for groundfish stocks of mutual concern from California to Alaska. Each agency prepares a comprehensive annual report highlighting survey and research activities, including stock assessments. These reports are compiled into an annual TSC report that is published online (www.psmfc.org/tsc2). The TSC reviews agency reports and recommends collaborative work or plans workshops on topics of shared interest. Historically, the TSC has prepared catch databases that led to the development of the Pacific Fisheries Information Network (PacFIN) catch reporting system, hosted 24 scientific/management workshops, organized 25 working groups, and created the Committee for Age Reading Experts (CARE). Each year the committee discusses and recommends actions to improve and coordinate groundfish science among agencies and these recommendations are sent to agency heads and managers to inform research and management priorities.

History:

Before the U.S. and Canada implemented exclusive domestic fisheries off their respective coasts, commercial fishers from either country could fish in both American and Canadian waters. In 1959, an International Trawl Fishery Committee (later renamed the Canada-U.S. Groundfish Committee) was established by groundfish management and research agencies to track transboundary fisheries and examine biological questions pertinent to the stocks and fisheries. This committee established the Technical Subcommittee (TSC), which held its first meeting in 1960 and has held annual meetings ever since. Initial activities and concerns focused on reporting and resolving catch estimates, stock identification and assessment, tagging, ageing techniques, and hydroacoustic techniques. These earlier studies focused on Petrale, Rock, and English Soles; Lingcod; Pacific Ocean Perch; and Sablefish. The TSC has fostered new science and improved methodologies by forming workgroups to focus on specific problems and by holding workshops to bring scientists and managers together to discuss aspects of groundfish science that are of mutual concern. Some recent workshops include Trawl and Setline Survey Methods, Catch Reconstruction, Visual Survey Methods, Developing Electronic Data Capture Systems, and Descending Device Policy and Science.

Evolution:

Over time, the TSC's role has changed with the implementation of new management and legislative authorities but the annual reports provide a common and concise forum to both disseminate information on current groundfish science and to learn about agency programs and activities. The TSC continues to highlight timely research topics, hold workshops, and establish workgroups, as well as send their recommendations to agency directors, fishery managers, and program managers to lay the foundation for trans-boundary coordination through open communication.

September 5, 2018

B. Executive Summary

The annual meeting of the TSC scheduled for the 23rd and 24th of April 2020 in Victoria, British Columbia was cancelled due to COVID - 19. We hope to meet in person in 2021, most likely April 20-21 in Victoria. **Agency reports for 2020 were submitted and can be found below.**

XIX. Parent Committee Minutes

The Parent Committee did not meet in 2020

Report of the Technical Subcommittee of the Canada-United States Groundfish Committee

AGENCY REPORTS

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1. ALASKA FISHERIES SCIENCE CENTER, NATIONAL MARINE FISHERES SERVICE

2. CANADA, BRITISH COLUMBIA GROUNDFISH FISHERIES

3. INTERNATIONAL PACIFIC HALIBUT COMMISSION (IPHC)

4. NORTHWEST FISHERIES SCIENCE CENTER, NATIONAL MARINE FISHERIES SERVICE

5. SOUTHWEST FISHERIES SCIENCE CENTER, NATIONAL MARINE FISHERIES SERVICE

6. STATE OF ALASKA – ALASKA DEPARTMENT OF FISH AND GAME

8. STATE OF CALIFORNIA – DEPARTMENT OF FISH AND GAME

7. STATE OF OREGON – OREGON DEPARTMENT OF FISH AND WILDLIFE

8. STATE OF WASHINGTON – WASHINGTON DEPARTMENT OF FISH AND WILDLIFE

Return to the Table of Contents for Navigation

Alaska Fisheries Science Center of the National Marine Fisheries Service
2019 Agency Report to the Technical Subcommittee of the Canada-US Groundfish Committee
April 2020

Compiled by Wayne Palsson, Cara Rodgveller, and Olav Ormseth

TABLE OF CONTENTS

VIII. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT IN 2019

I. Agency Overview

Groundfish research at the Alaska Fisheries Science Center (AFSC) is conducted within the following Divisions: Resource Assessment and Conservation Engineering (RACE) Resource Ecology and Fisheries Management (REFM), Fisheries Monitoring and Analysis (FMA), and the Auke Bay Laboratories (ABL). All Divisions work closely together to accomplish the mission of the Alaska Fisheries Science Center. In 2019 our activities were guided by our Strategic Science Plan (www.afsc.noaa.gov/GeneralInfo/FY17StrategicSciencePlan.pdf) with annual priorities specified in the FY19 Annual Guidance Memo (https://www.afsc.noaa.gov/program_reviews/2017/2017_Core_Documents/FY18%20AFSC%20AGM.pdf). A review of pertinent work by these groups during the past year is presented below. A list of publications relevant to groundfish and groundfish issues is included in Appendix I. Lists of publications, posters and reports produced by AFSC scientists are also available on the AFSC website at http://www.afsc.noaa.gov/Publications/yearlylists.htm, where you will also find a link to the searchable AFSC Publications Database. **Note that NOAA-Fisheries Science Center web materials can be found on the national NOAA-Fisheries web site after April 30, 2019 (https://www.fisheries.noaa.gov); they may no longer be available on the afsc.noaa.gov web site. Users should be able to find the same materials on the new national site.**

Lists or organization charts of groundfish staff of these four Center divisions are included as Appendices II - V.

. GAP also carried out the biennial Gulf of Alaska Bottom Trawl Survey.

A. RACE DIVISION

The core function of the Resource Assessment and Conservation Engineering (RACE) Division is to conduct quantitative fishery-independent surveys and related research on groundfish and crab in Alaska. Our efforts are directed at supporting implementation of the U.S. Magnuson-Stevens Fishery Conservation and Management Act and other enabling legislation for the wise stewardship of living marine resources. Surveys and research are principally focused on species from the five large marine ecosystems of Alaska (Gulf of Alaska, Aleutian Islands, eastern Bering Sea, northern Bering and Chukchi Seas, Beaufort Sea). Our surveys often cover the entire life history of the focal species, from egg to adult. All surveys provide a rich suite of environmental data that are key to practicing an ecosystem approach to fisheries management (EBFM: https://www.fisheries.noaa.gov/insight/understanding-ecosystem-based-fisheries-management) . In addition, the Division works collaboratively with Industry to investigate ways to reduce bycatch, bycatch mortality, and the effects of fishing on habitat.

RACE staff is composed of fishery and oceanography research scientists, geneticists, technicians, IT Specialists, fishery equipment specialists, administrative support staff, and contract research associates. The status and trend information derived from regular surveys are used by Center stock assessment scientists to develop our annual Stock Assessment & Fishery Evaluation (SAFE) reports for 46 unique combinations of species and regions. Research by the Division increases our understanding of what causes population fluctuations. This knowledge and the environmental data we collect are used in the stock assessments, and in annual ecosystem status and species-specific ecosystem and socioeconomic reports. The understanding and data enable us to provide to our stakeholders with strong mechanistic explanations for the population trajectories of particular species. RACE Division science programs include: Fisheries Behavioral Ecology (FBE), Groundfish Assessment (GAP), Midwater Assessment and Conservation Engineering (MACE), Recruitment Processes (RPP), Shellfish Assessment Program (SAP), and Research Fishing Gear/Survey Support. These Programs operate from three locations: Seattle, WA, Newport, OR, and Kodiak, AK.

One of the primary activities of the RACE Division continued to be fishery-independent stock assessment surveys of important groundfish and crab species of the northeast Pacific Ocean and Bering Sea. Regularly scheduled bottom trawl surveys in Alaskan waters include an annual survey of the crab and groundfish resources of the eastern Bering Sea shelf and biennial surveys of the Gulf of Alaska (odd years) and the Aleutian Islands and the upper continental slope of the eastern Bering Sea (even years). In summer 2019, RACE Groundfish Assessment Program (GAP) and Shellfish Assessment Program (SAP) scientists conducted a bottom trawl survey of Alaskan groundfish and invertebrate resources over the eastern and northern Bering Sea shelf
The Midwater Assessment and Conservation Engineering (MACE) Program conducted echo integration-trawl (EIT) surveys of midwater pollock and other pelagic fish abundance in the Gulf of Alaska (winter) and the western and central Gulf of Alaska (summer). A collaborative cruise to test the efficacy of a new type of trawl excluder to minimize salmon bycatch was accomplished, as well. MACE and GAP continue to collaboratively design an acoustical-optical survey for fish in grounds that are inaccessible to fisheries research trawls (e.g. Gulf of Alaska or Aleutian Islands). Once implemented, the survey will reduce bias in our survey assessments of particular taxa such as rockfish.

The Recruitment Processes Alliance (RPA: RACE RP and ABL EMA Programs) conducted Gulf of Alaska surveys on the early life history stages of groundfish species in the spring and summer, as well as the environmental conditions necessary to explain growth and mortality of fish. Spring surveys focus on winter and early spring spawners such as Walleye Pollock, Pacific cod, Arrowtooth Flounder, and Northern & Southern Rock Sole. Summer surveys concentrate on the age-0 and age-1 juvenile stages of the winter/spring spawners as well as summer spawners (e.g. forage fishes including Capelin, Eulachon, and Pacific Herring). This survey also estimates whether or not age-0 fish have sufficient energy reserves to survive their first winter.

Research on environmental effects on groundfish and crab species such as the impacts of ocean acidification on early life history growth and survival continue at our Newport, Oregon and Kodiak facilities. Similarly, the Newport lab is engaged in a novel line of research to examine oil toxicity for arctic groundfish (e.g. arctic cod). This effort is to understand risks associated with oil and natural gas extraction as well as increased maritime traffic across the arctic ocean.

In 2019 RACE scientists continued research on essential habitats of groundfish including: identifying suitable predictor variables for building quantitative habitat models, developing tools to map these variables over large areas, including the nearshore areas and early life history stages of fishes in Alaska's subarctic and arctic large marine ecosystems; estimating habitat-related survival rates based on individual-based models; investigating activities with potentially adverse effects on EFH, such as bottom trawling; determining optimal thermal and nearshore habitat for overwintering juvenile fishes; benthic community ecology, and juvenile fish growth and condition research to characterize groundfish habitat requirements.

Groundfish surveys by the RACE Division have been increasingly challenged by climate-mediated ocean warming and loss of sea ice. These phenomena are likely directly related to changes in fish distribution, particularly the northern summer expansion of pollock and cod stocks. During the 2019 summer survey we observed one of the smallest cold pool extents in the history of our time series. Movement of fish outside of our historical survey boundaries challenges the assumption that our surveys capture an invariant fraction of the population from one year to the next. These distributional changes are occurring at exactly the same time as our survey and science resources are declining. The RACE Division is collaborating with an international team of scientists to examine the impacts of reduced survey effort on the accuracy and precision of survey biomass estimates and stock assessments. AFSC hosted an ICES workshop on the impacts of unavoidable survey effort reduction (ICES WKUSER) in the winter 2019/2020. Work on the topic began in late 2018 and substantial progress was made before the 2020 meeting. A workshop report will soon be available on the ICES web page (https://www.ices.dk/community/groups/Pages/WKUSER.aspx). Similarly, current research by RACE and other Center scientists will examine the efficacy of model-based survey estimates to supplement our current design-based surveys.

For more information on overall RACE Division programs, contact Division Director Jeffrey Napp at (206) 526-4148 or Deputy Director Michael Martin at (206) 526-4103.

B. REFM DIVISION

The research and activities of the Resource Ecology and Fisheries Management Division (REFM) are designed to respond to the needs of the National Marine Fisheries Service regarding the conservation and management of fishery resources within the US 200-mile Exclusive Economic Zone (EEZ) of the northeast Pacific Ocean and Bering Sea. The activities of REFM are organized under several programs that have specific responsibilities but also interact:

- The Age and Growth Studies program performs production ageing of thousands of otoliths each year and performs research regarding new technologies, reproductive biology, and enhancing age and growth data for less well known species.
- Economics and Social Sciences Research (ESSR) performs analyses of fisheries economics as well as sociological studies of Alaska fishing communities, and produces an annual economic report on federal fisheries in Alaska.
- The Resource Ecology and Ecosystem Modeling (REEM) program maintains an ever-growing database of groundfish diets, constructs ecosystem models, and produces an extensive annual report on the status of Alaska marine ecosystems.
- Status of Stocks and Multispecies Assessment (SSMA), in collaboration with the Auke Bay Laboratories, prepares annual stock assessment documents for groundfish and crab stocks in Alaska and conducts related research. Members of REFM provide management support through membership on regional fishery management teams.

For more information on overall REFM Division programs, contact Division Director Ron Felthoven (ron.felthoven@noaa.gov). For more information on REFM assessment reports contact Olav Ormseth (olav.ormseth@noaa.gov).

C. AUKE BAY LABORATORIES

The Auke Bay Laboratories (ABL), located in Juneau, Alaska, is a division of the NMFS Alaska Fisheries Science Center (AFSC). ABL's Marine Ecology and Stock Assessment Program (MESA) publishes groundfish stock assessments for rockfish in the Gulf of Alaska, sharks, sablefish, and grenadiers. MESA also conducts biological research, such as movement, growth, stock structure, ageing, maturity, and the effects of barotrauma. Presently, the program is staffed by 8 full time scientists and in 2020 three new positions will be filled. ABL's Ecosystem Monitoring and Assessment Program (EMA), Recruitment Energetics and Coastal Assessment Program (RECA), and Genetics Program also conduct groundfish-related research and capture groundfish in their surveys in the Bering Sea and the Arctic Ocean. The ABL genetics program conducts research on cod, pollock, and forage fish stock structure and distribution. All programs have contributed to this report.

In 2019 the ABL Division conducted the following surveys that sample groundfish: 1) the AFSC's annual longline survey in Alaska, 2) the northern Bering Sea surface trawl survey, and 3) the Arctic Integrated Ecosystem Survey.

Projects at ABL included: 1) tagging sablefish, Greenland turbot, and shortspine thornyhead on the longline survey, 2) ageing and movement studies of sharks, 3) researching copepods as an indicator of walleye pollock recruitment, 4) predicting survival and recruitment of Walleye pollock from energetics, temperature, or copepod abundance, 5) population structure and distribution of forage fish and Arctic cod, 6) a lab study on the effects of temperature and diet on juvenile Pacific cod condition, 7) the creation of new nation-wide Ecosystem and Socioeconomic reports for use in stock assessment, 8) tagging juvenile sablefish nearby Sitka, AK, and 9) the continuation of a sablefish coast-wide assessment and research group (CA, OR, WA, BC, AK).

In 2019 ABL prepared eleven stock assessment and fishery evaluation reports for Alaska groundfish: Alaska sablefish, Gulf of Alaska (GOA) Pacific Ocean perch (POP), GOA northern rockfish, GOA dusky rockfish, GOA rougheye/blackspotted rockfish, GOA shortraker rockfish, GOA "Other Rockfish", GOA thornyheads, and GOA and Bering Sea/Aleutian Islands sharks.

For more information on overall programs of the Auke Bay Laboratories, contact the ABL Laboratory Director Dana Hanselman at (907) 789-6626, Dana.Hanselman@noaa.gov. For more information on the ABL reports contact Cara Rodgveller (cara.rodgveller@noaa.gov).

D. FMA DIVISION

The Fisheries Monitoring and Analysis Division (FMA) monitors groundfish fishing activities in the U.S. Exclusive Economic Zone (EEZ) off Alaska and conducts research associated with sampling commercial fishery catches, estimation of catch and bycatch mortality, and analysis of fishery-dependent data. The Division is responsible for training, briefing, debriefing and oversight of observers who collect catch data onboard fishing vessels and at onshore processing plants and for quality control/quality assurance of the data provided by these observers. Division staff process data and make it available to the Sustainable Fisheries Division of the Alaska Regional Office for quota monitoring and to scientists in other AFSC divisions for stock assessment, ecosystem investigations, and an array of research investigations.

For further information or if you have questions about the North Pacific Groundfish and Halibut Observer Program please contact Jennifer Ferdinand, (206) 526-4194.

E. HEPR

The Habitat and Ecological Processes Research Program focuses on integrated studies that combine scientific capabilities and create comprehensive research on habitat and ecological processes. The HEPR Program focuses on four main research areas.

Loss of Sea Ice

Climate change is causing loss of sea ice in the Bering, Chukchi and Beaufort Seas. Addressing ecosystem-related shifts is critical for fisheries management, because nationally important Bering Sea commercial fisheries are located primarily within the southeastern Bering Sea, and for successful co-management of marine mammals, which at least thirty Alaska Native communities depend on.

Essential Fish Habitat

Alaska has more than 50 percent of the U.S. coastline and leads the Nation in fish habitat area and value of fish harvested, yet large gaps exist in our knowledge of Essential Fish Habitat (EFH) in Alaska.

Habitat Research in Alaska

Major research needs are

1. to identify habitats that contribute most to the survival, growth, and productivity of managed fish and shellfish species; and
2. to determine how to best manage and protect these habitats from human disturbance and environmental change.

Essential Fish Habitat Research Plan in Alaska

Project selection for EFH research is based on research priorities from the EFH Research Implementation Plan for Alaska. Around $300,000 is spent on about six EFH research projects each year. Project results are described in annual reports and the peer-reviewed literature. Study results contribute to existing Essential Fish Habitat data sets.

For more information, contact Dr. James Thorson (james.thorson@noaa.gov).

II. Surveys

2019 Eastern Bering Sea Continental Shelf and Northern Bering Sea Bottom Trawl Surveys – RACE GAP

The thirty-eighth in a series of standardized annual bottom trawl surveys of the eastern Bering Sea (EBS) continental shelf was completed on 27 July 2019 aboard the AFSC chartered fishing vessels *Vesteraalen* and *Alaska Knight*, which together bottom trawled at 376 stations over a survey area of 492,898 km^2. Researchers processed and recorded the data from each trawl catch by identifying, sorting, and weighing all the different crab and groundfish species and then measuring samples of each species. Supplementary biological and oceanographic data collected during the bottom trawl survey was also collected to improve the understanding of groundfish and crab life histories and the ecological and physical factors affecting distribution and abundance.

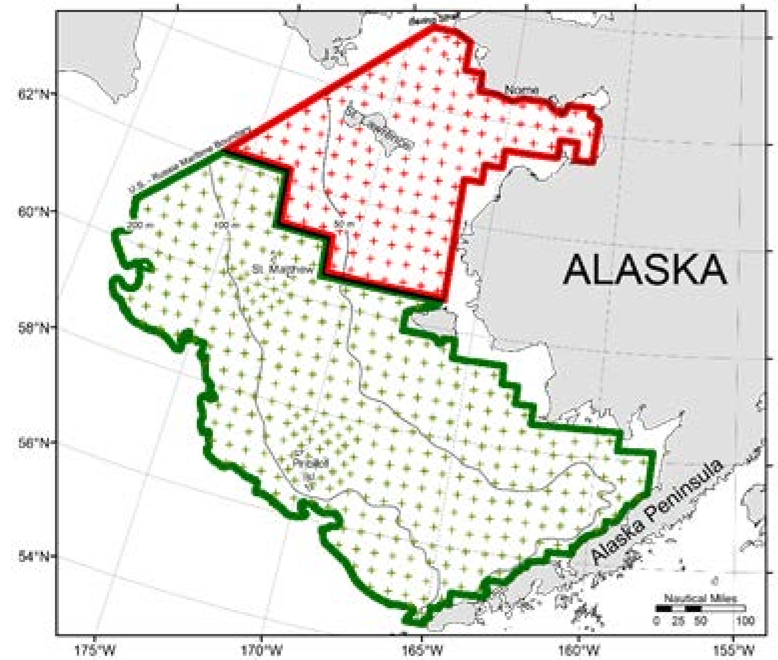

Fig. 1. Map showing survey stations sampled during the 2019 eastern and northern Bering Sea shelf bottom trawl survey.

Survey estimates of total biomass on the eastern Bering Sea shelf for 2019 were 5.5 million metric tons (mt) for walleye pollock, 516.9 thousand mt for Pacific cod, 2.0 million mt for yellowfin sole, 976.7 thousand mt for northern rock sole, 16.0 thousand mt for Greenland turbot, and 113.9 thousand mt for Pacific halibut. There were increases in estimated survey biomass for most major fish taxa compared to 2018 levels. Pacific cod biomass increased 2%, walleye pollock 75%, yellowfin sole 6%, and arrowtooth flounder 13%. Northern rock sole biomass decreased 7%, Greenland turbot 11%, Pacific halibut 10 %, and Alaska plaice 12%.

The summer 2019 survey period was warmer than the long-term average for the sixth consecutive year. The overall mean bottom temperature was 4.35°C in 2019, which was slightly warmer than 2018 (4.16 °C); however, the mean surface temperature was 9.23°C in 2019, which was 1.65 degrees warmer than 2018 (7.58°C).

After the completion of the EBS shelf survey, which started for both vessels in Dutch Harbor on 3 June 2019, both vessels transitioned into sampling survey stations in the southwest corner of the NBS survey region. After a crew change, the F/V *Alaska Knight* sampled the stations west of Norton Sound moving to the Bering Strait and working south. The F/V *Vesteraalen* conducted sampling in the Norton Sound area traveling east to west. The F/V *Vesteraalen* and the F/V *Alaska Knight* conducted sampling in the NBS from 29 July to 20 August. A total of 520 20 x 20 nautical mile sampling grid stations in the combined EBS and NBS were successfully sampled in 2019.

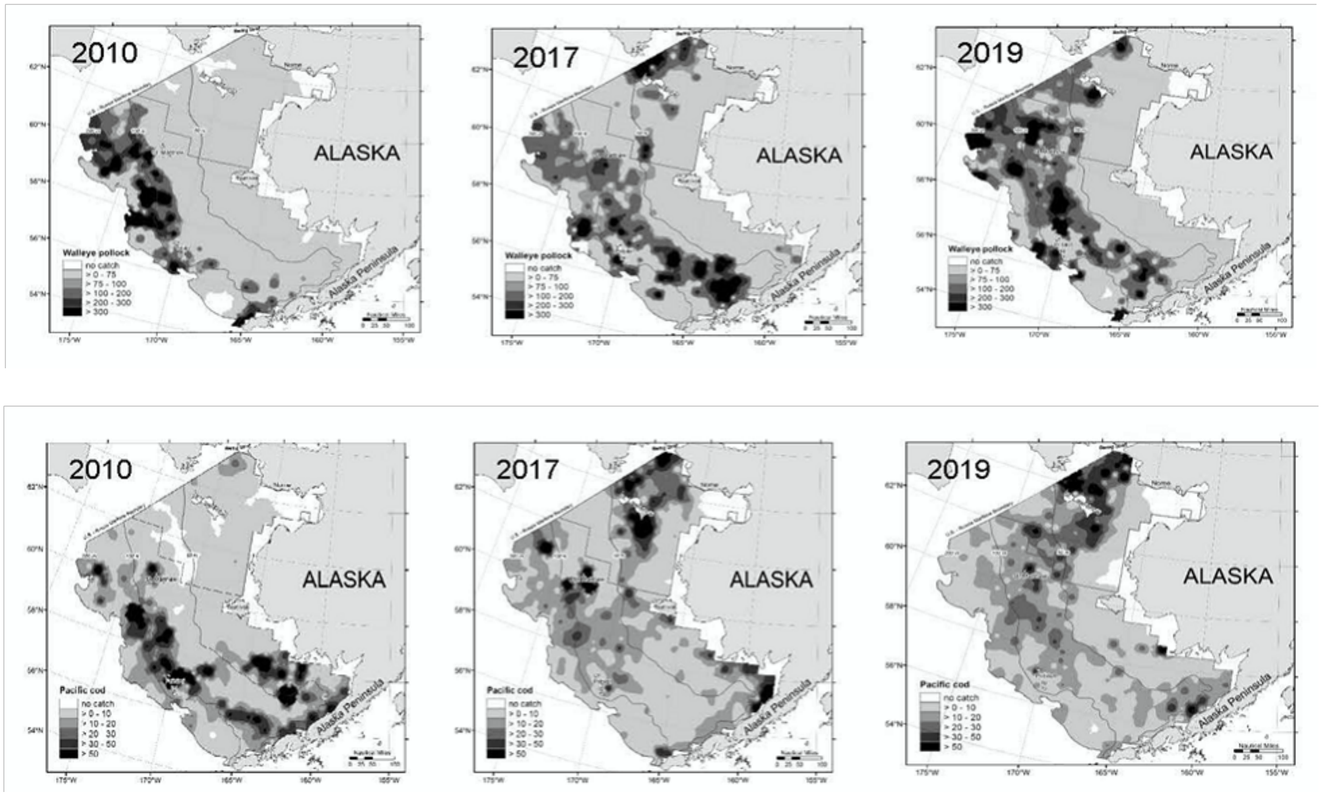

Fig. 2. Spatial distribution of large gadids, in terms of mean CPUE (kg/ha), observed during the 2010, 2017, and 2019 bottom trawl surveys of the EBS and NBS: Top left is walleye pollock in 2010, top middle is walleye Pollock in 2017, and top right is walleye pollock in 2019; bottom left is Pacific cod in 2010, bottom middle is Pacific cod in 2017, and bottom right is Pacific cod in 2019.

The NBS region was fully surveyed using the same standardized protocols and sampling resolution as the EBS survey in 2010, 2017, and 2019. The 2017 distributions of walleye pollock and Pacific cod were completely different than those observed in 2010. In 2010, pollock was mostly concentrated on the outer shelf at depths of 70–200 m north of 56°N (Fig. 2, top left). Pollock biomass was consistently low on the inner and middle shelf, and pollock were almost completely absent from the NBS.

In 2017, pollock biomass in the EBS was concentrated mostly on the middle shelf. In the NBS, there was a high concentration of pollock biomass to the north of St. Lawrence Island (Fig. 2, top middle). The total pollock biomass in 2018 from the EBS was 3.11 million mt. Pollock biomass from the NBS in 2017 was 1.32 million mt. In 2019, pollock distributions were quite different to 2017, 2018 and 2010. In 2018, the EBS pollock were densest in the south east corner of Bristol Bay, in small clusters along the Aleutian chain, and near the shelf break between 59°N and 60°N. During the 2019 EBS, pollock were densest north and west of the Pribilof Islands and the north west survey area in the NBS, pollock were concentrated directly south of St. Lawrence Island and north of the island near the Bering Strait (Figure. 2, top right). The total pollock biomass from EBS was 5.5 million mt, while pollock biomass from the NBS was 1.2 million mt in 2019.

In 2010, Pacific cod biomass in the EBS was concentrated in Bristol Bay and on the middle and outer shelf from the Pribilof Islands north to St. Matthew and cod biomass was low throughout the NBS (Fig. 2, bottom. left). Total cod biomass from the EBS was 8.7 thousand mt, while biomass from the NBS was only 2.9 thousand mt. In contrast, the 2017 Pacific cod densities in the NBS were high both to the north and south of St. Lawrence Island. The 2018 Pacific cod biomass was again concentrated in only a few areas of the EBS. Total estimated cod biomass from the EBS was 5.1 thousand mt during 2018 and biomass from the NBS during 2017 was 2.9 thousand mt. In 2019, Pacific cod biomass was again concentrated in only a few areas of the EBS, but the majority of the biomass was concentrated to the north, east, and south of St. Lawrence Island in the NBS (Fig. 2, bottom. right). Total estimated cod biomass from the EBS was 517 thousand mt, while biomass from the NBS was 365 thousand mt in 2019. In all survey years, Pacific cod were concentrated in areas with bottom temperatures >0°C.

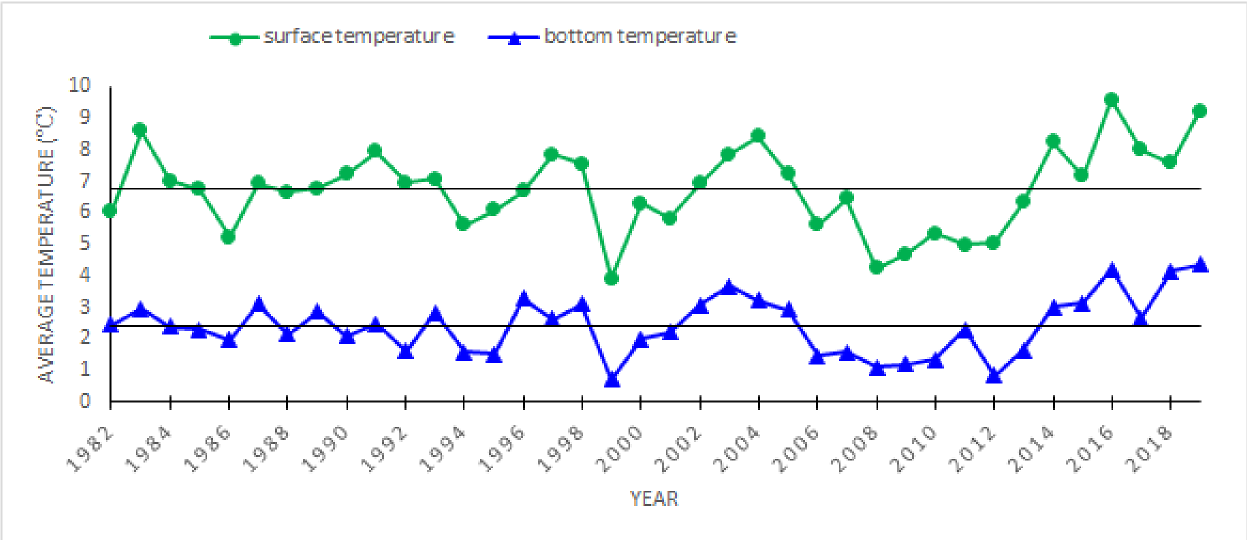

Figure 3: Average annual surface and bottom temperature during the survey period for the eastern Bering Sea shelf survey with the survey mean temperature (1982-2019).

The surface and bottom temperature mean for 2019 eastern Bering Sea shelf increased from 2018 estimates. Both were warmer than the long-term time-series mean (Fig. 3). The 2019 mean surface temperature was 9.2°C, which was 1.6°C higher than 2017 and 2.5°C above the time-series mean (6.7°C). The mean bottom temperature was 4.4°C, which was 0.2°C above the mean bottom temperature in 2018, but 1.6°C above the time-series mean (2.8°C). The 'cold pool', defined as the area where temperatures <2°C, appeared in stations to the west and southwest of St. Lawrence Island (Figure 4). The southern extent in 2019 reached to just south of St. Matthew Island. However, bottom temperatures along the entire length of the inner shelf from Bristol Bay to Chirikov Basin were warm (>6°C) and more developed than in 2017 when the cold pool only reached into a few stations west of St. Lawrence Island.

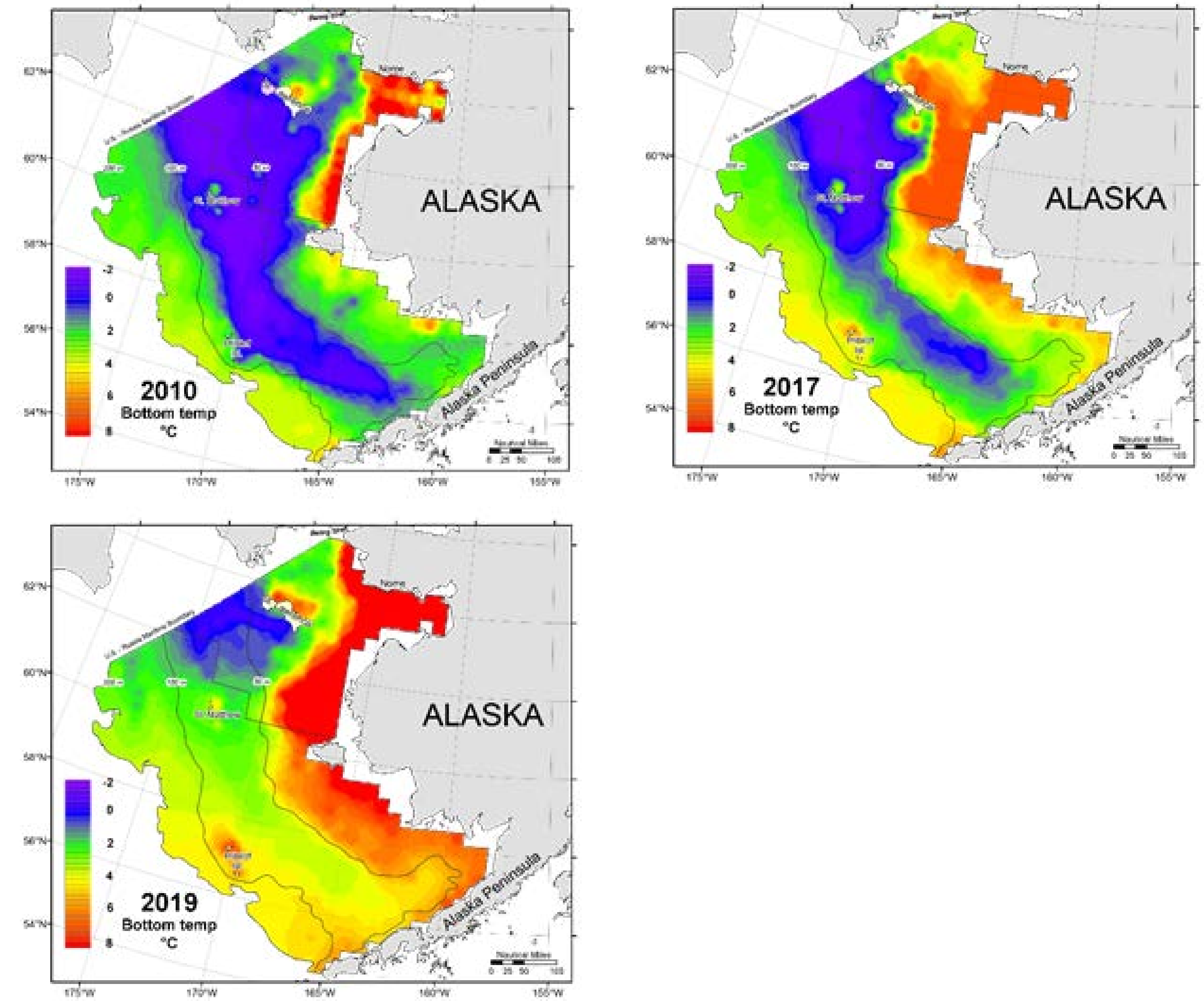

Figure 4: Distribution of survey bottom temperatures for 2010 (top left), 2017 (top right), and 2019 (lower left), the three years that the EBS survey was expanded to comprehensively include the northern Bering Sea shelf.

2019 Gulf of Alaska Biennial Bottom Trawl Survey of Groundfish and Invertebrate Resources-RACE GAP

AFSC's Resource Assessment and Conservation Engineering (RACE) Division chartered the fishing vessels *Ocean Explorer* and *Sea Storm* to conduct the 2019 Gulf of Alaska Biennial Bottom Trawl Survey of groundfish resources. This was the sixteenth survey in the series which began in 1984, was conducted triennially for most years until 1999, and then biennially since. The two vessels were each chartered for 75 days. The cruise originated from Dutch Harbor, Alaska on May 21st and concluded at Ketchikan, Alaska on August 3rd. After the vessels were loaded and other preparations (*e.g.,* wire measuring, wire marking, and test towing) were made before the first survey tows were conducted on 23 May. The vessels surveyed from the Island of Four Mountains (170° W longitude) proceeded eastwards through the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern management areas. Sampled depths ranged from approximately 15 to 700 m. The cruise was divided into four legs with breaks in Sand Point, Kodiak, and Seward to change crews and re-provision.

The primary objective of this survey is to monitor trends in distribution and abundance of important groundfish species. During these surveys, we measure a variety of physical, oceanographic, and environmental parameters while identifying and enumerating the fishes and invertebrates collected in the trawls. Specific objectives of the 2019 survey include: define the distribution and estimate the relative abundance of principal groundfish and important invertebrate species that inhabit the Gulf of Alaska, measure biological parameters for selected species, and collect age structures and other samples. The survey design is a stratified-random sampling scheme based 54 strata of depths and regions and applied to a grid of 5x5 km^2 cells. Stations that were previously identified as untrawlable were excluded from the sampling frame. Stations were allocated amongst the strata using a Neyman scheme weighted by stratum areas, cost of conducting a tow, past years' data, and the ex-vessel values of key species. Stations were sampled with the RACE Division's standard four-seam, high-opening Poly Nor'Eastern survey trawl equipped with rubber bobbin roller gear. This trawl has a 27.2 m headrope and 36.75 m footrope consisting of a 24.9 m center section with adjacent 5.9 m "flying wing" extensions. Accessory gear for the Poly Nor'Eastern trawl includes 54.9 m triple dandylines and 1.8 ´ 2.7 m steel V-doors weighing approximately 850 kg each. The charter vessels conducted 15-minute trawls at pre-assigned stations. Catches were sorted, weighed, and enumerated by species. Biological information (sex, length, age structures, individual weights, stomach contents, etc.) were collected for major groundfish species. Specimens and data for special studies (*e.g.*, maturity observations, tissue samples, photo vouchers) were collected for various species, as requested by researchers at AFSC and other cooperating agencies and institutions. Specimens of rare fishes or invertebrates, including corals, sponges, and other sessile organisms were collected on an opportunistic basis.

Biologists completed 541 of 550 planned stations in the entire shelf and upper slope to a depth of 700 m (Figure 1). Biologists collected 184 fish taxa that weighed 242 mt and numbered 464,000 individuals. There were 401 invertebrate taxa collected that weighed a total of 12.4 mt. Biologists collected 84 taxa of fish and invertebrates as 127 vouchered lots for identification, permanent storage, or other laboratory studies. Other collected samples included over 11,275 otoliths for ageing, special collections for ecological studies, and other samples for life history characterization. A validated data set was finalized on 30 September and final estimates of abundance and size composition of managed species and species groups were delivered to Groundfish Plan Team of the NPFMC. The survey data and estimates are available through the AKFIN system (www.psmfc.org). The Plan Team incorporated these survey results directly into Gulf of Alaska stock assessment and ecosystem forecast models that form the basis for groundfish harvest advice for ABCs and TAC for 2019. Of particular note during this survey was an approximate 80% decline in the survey biomass estimate of Pacific cod. This result combined with others in the stock assessment led to substantial reductions in the amount of fish available for commercial fisheries in the Gulf of Alaska (see Pacific cod stock assessment below).

For further information contact Wayne Palsson (206) 526-4104, Wayne.Palsson@noaa.gov

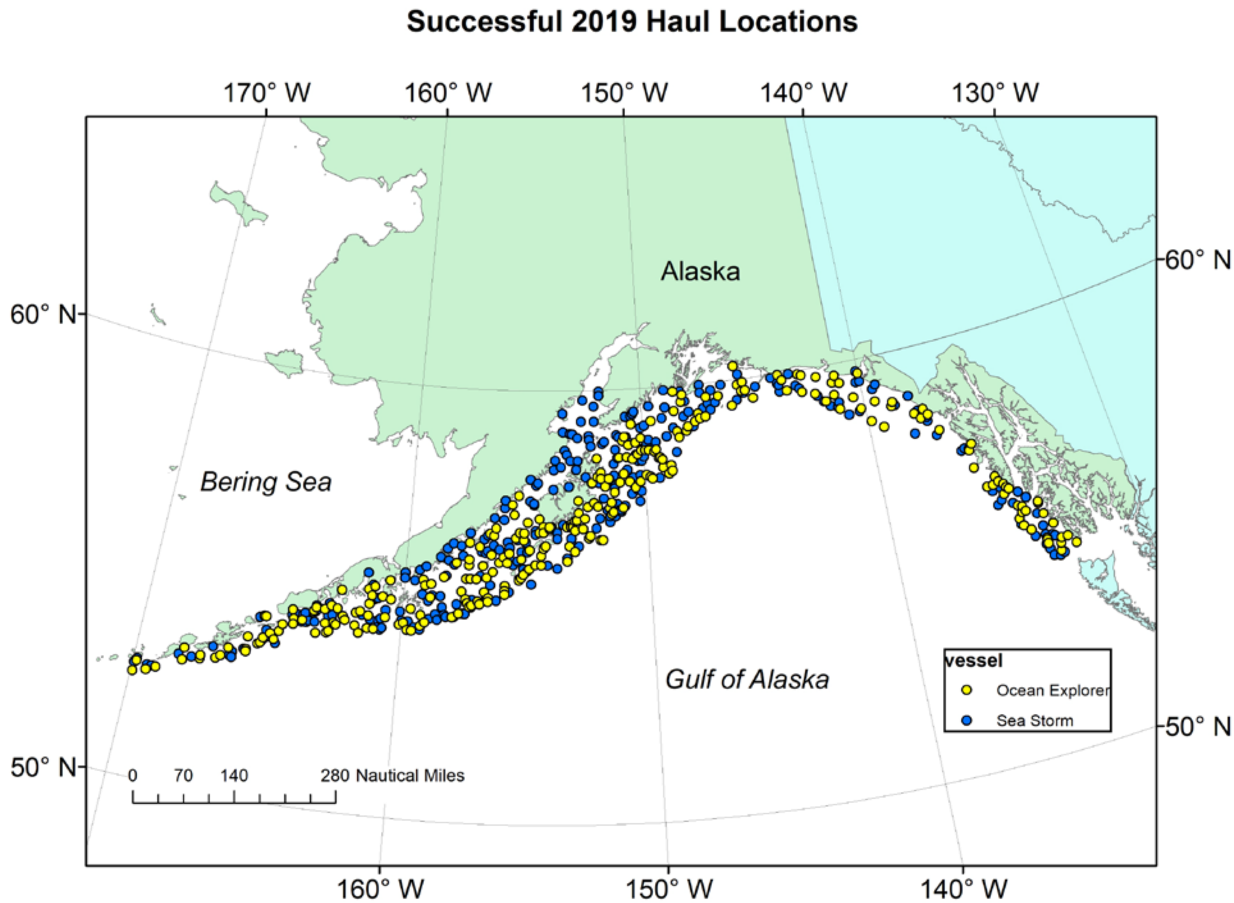

Figure 1. Successful stations occupied during the 2019 Gulf of Alaska Biennial Bottom Trawl Survey by vessel.

Winter Acoustic-Trawl Surveys in the Gulf of Alaska - MACE
One cruise was conducted to survey several GOA walleye pollock (*Gadus chalcogrammus*) spawning areas in the winter of 2019. The survey (SH1904) covered Shelikof Strait (7-16 March), Chirikof shelf break (16-18 March) and Marmot Bay (19-20 March). The cruise was conducted aboard the NOAA ship Bell Shimada, a 64-m stern trawler equipped for fisheries and oceanographic research. Midwater and near-bottom acoustic backscatter at 38 kHz sampled using an Aleutian Wing 30/26 Trawl (AWT) and a poly Nor'eastern (PNE) bottom trawl was used to estimate the abundance of walleye pollock. Backscatter data were also collected at 4 other frequencies (18-, 70-, 120-, and 200-kHz) to support multifrequency species classification techniques.

In the Shelikof Strait sea valley, acoustic backscatter was measured along 1654 km (893 nmi) of transects spaced 13.9 km (7.5 nmi) apart. Walleye pollock with lengths 9-14 cm FL, indicative of age-1 pollock, accounted for 69% of the numbers but only 4.8% of the biomass of all pollock observed in Shelikof Strait. Pollock 16-29 cm FL, indicative of age-2s, accounted for 15.7% by numbers and 7.9% by biomass. Larger pollock 30-61 cm FL accounted for 15.2% and 87.3% of the numbers and biomass, respectively. Pollock of most ages were smaller when compared to the same age group from previous winter acoustic-trawl surveys. Adult pollock were detected throughout the Strait, with most distributed along the west side from Cape Nukshak to Cape Kekurnoi and in the center of the sea valley south of Cape Kekurnoi, as is typical for most previous Shelikof surveys. Juveniles (< 30 cm FL) along with relatively few older fish were detected as multiple midwater layers throughout the water column. Dense aggregations of adult pollock (≥ 30 cm FL) were encountered deeper in the water column, generally 180-300 m and were observed mostly within 100 m of the bottom, computed from bottom-referenced analysis. Adult pollock aggregations were observed to be deeper than the past 4 years. Only about 10% of biomass was observed within 3 m of the seafloor, and 80% percent of biomass was within about 60 m of the seafloor. The maturity composition in the Shelikof Strait area of males > 40 cm FL (n = 503) was 0% immature, 0% developing, 9% pre-spawning, 87% spawning, and 4% spent. The maturity composition of females > 40 cm FL (n = 592) was 0% immature, 3% developing, 77% pre-spawning, 11% spawning, and 10% spent, based on data from specimens collected from 19 AWT and 7 PNE hauls. The biomass estimate of 1,281,083 t (with a relative estimation error of 6.6%) is 97% of that observed in 2018 (1,320,867 t) and almost twice the historic mean of 704,627 t. Survey biomass estimates from 2017-2019 are the largest since the mid-1980s.

In the Chirikof shelf break region, acoustic backscatter was measured along 307 km (166 nmi) of transects spaced 11.1 km (6 nmi) apart. Walleye pollock ranged between 27 and 66 cm FL as one primary adult mode. The majority of pollock biomass in the Chirikof region consisted of low-density aggregations distributed along the shelf break. The pollock aggregations were indistinguishable from POP aggregations on the echosounder records, based on the catches being a mixture of both species. The pollock aggregations were mainly in midwater about 200-300 m and relatively evenly distributed 0-300 m height off the bottom, which contrasted with 2015 when pollock were very close to the bottom. The maturity composition for Chirikof males > 40 cm FL (n = 17) was 0% immature, 0% developing, 19% pre-spawning, 58% spawning, and 23% spent. The maturity composition for females > 40 cm FL (n = 69) was 0% immature, 2% developing, 89% pre-spawning, 0% spawning, and 8% spent. based on data from specimens collected from three AWT hauls. The biomass estimate of 9,907 t was almost four times the 2017 estimate of 2,485 t but much less than the historic mean of 35,184 t for this survey.

In Marmot Bay, acoustic backscatter was measured along 133.3 km (72 nmi) of transects spaced 1.75 km (1.0 nmi) apart in inner Marmot Bay, and 184.4 km (99.6 nmi) of transects spaced 3.5 km (2.0 nmi) in outer Marmot Bay. Walleye pollock ranged between 28 and 64 cm FL with three modes at 10, 26 and 48 cm FL. Walleye pollock with lengths 9-14 cm FL, indicative of age-1 pollock, accounted for 83% of the numbers but only 13.8% of the biomass of all pollock observed in this area. Pollock with lengths 15-30 cm FL, indicative of age-2s and age-3s, accounted for 12.6% by numbers and 25.7% by biomass. A diffuse scattering layer near the seafloor in the inner Bay was attributed to a mix of age-1 and adult pollock. Age-1 pollock were observed in the outer part of the Bay while pollock with lengths 15-30 cm FL, indicative of age-2 and age-3s, were present as a strong near-surface layer in the inner Bay. Most juvenile pollock (< 30 cm FL) were observed between the surface and 100 m, similar but slightly higher off-bottom than 2015 juveniles. Adult pollock (≥ 30 cm FL) were primarily detected in the Spruce Gully (inner portion of the outer Bay) in dense schools around 130 m deep and between 70 and 150 m above the seafloor, which contrasted from the previous 4 years when pollock were distributed much closer to the bottom. The maturity composition in Marmot Bay of males > 40 cm FL (n = 62) was 0% immature, 0% developing, 11% pre-spawning, 84% spawning, and 6% spent. The maturity composition of females > 40 cm FL (n = 133) was 1% immature, 3% developing, 81% pre-spawning, 9% spawning, and 7% spent, based on data from specimens collected from 5 AWT hauls. The biomass estimate of 6,275 t was about half of the 2018 estimate of 13,521 t and the historic mean of 14,203 t.

Summer acoustic-trawl surveys of walleye pollock in the Gulf of Alaska - MACE
The MACE Program completed a summer 2019 acoustic-trawl (AT) survey of walleye pollock (*Gadus chalcogrammus*) across the Gulf of Alaska (GOA) shelf from the Islands of Four Mountains eastward to Yakutat Trough aboard the NOAA ship *Oscar Dyson*. The summer GOA shelf survey also included smaller-scale surveys in several bays and troughs. Previous surveys of the GOA have also been conducted during the summers of 2003 (partial), 2005 (partial), 2011, 2013, 2015, and 2017 by MACE. Mechanical and personnel issues during legs 1 and 3 of the summer 2019 survey resulted in the need to alter plans for the third leg to assure that the survey covered the entire shelf to Yakutat Trough. Altered plans included dropping surveys of Kenai Peninsula Bays except for Resurrection Bay, and reducing the number of survey tracklines within Prince William Sound.

Midwater and near-bottom acoustic backscatter were sampled using an LFS1421 and an Aleutian Wing 30/26 Trawl (AWT). The LFS1421 is replacing the AWT as the primary sampling trawl for the survey and species composition and size distribution in the catches of the two nets were compared between paired trawls (n = 26) in similar locations and acoustic sign to determine if there are any significant differences in catch. To gauge escapement of smaller fishes from the nets, recapture (or pocket) nets were placed at several locations along both the LFS1421 (n = 9) and AWT (n = 8) nets. A trawl-mounted stereo camera ("CamTrawl") was used during the survey to aid in determining species identification and size of animals encountered by the trawls at different depths. A Methot trawl was used to target midwater macro-zooplankton. Conductivity-temperature-depth (CTD) casts (n = 53) were conducted to characterize the physical oceanographic environment across the surveyed area. Nighttime operations consisted of lowered stereo-video camera deployments (n = 77) to estimate species abundance and groundtruth the trawlability designation were conducted across the shelf in areas determined to be untrawlable based on a combination of metrics.

The estimated abundance of age-1+ pollock for the entire surveyed area was 4.64 billion fish weighing 593,587 metric tons (t), less than half of the 2017 estimated biomass. The majority of the pollock biomass was observed on the continental shelf (72%), Shelikof Strait (17%), the Shumagin Islands area (3%), and south of Kodiak Island in Barnabas Trough (6%). Across the entire survey, walleye pollock of three year classes accounted for the majority of the biomass: age-7 fish (34%; 41-64 cm fork length (FL), mean 48 cm FL), age-2 fish (31%; 20-37 cm FL, mean 27 cm FL), and age-1 fish (18%; 13-23 cm FL, mean 18 cm FL). Surface water temperatures across the GOA shelf averaged 12.0° C, approximately 0.4° C warmer than in 2017 (mean 11.6° C). Abundance and biomass estimates were calculated for Pacific ocean perch (*Sebastes alutus*; 215.6 million fish weighing 140,688 t), capelin (*Mallotus villosus*; 5.29 billion fish weighing 16,588 t), and Pacific herring (*Clupea pallasii*; 1.77 billion fish weighing 136,963 t), and backscatter distribution and abundance relative to previous surveys was estimated for euphausiids.

The survey of the GOA shelf and shelfbreak was conducted between 4 June and 4 August 2019 and consisted of 41 transects spaced 25 nautical miles (nmi) apart. Walleye pollock were distributed across the shelf, with areas of greatest density between the Shumagin Islands and Shelikof Strait south of Mitrofania Island, and east of Kodiak Island on the western portion of Portlock Bank. Based on catch data from 41 LFS hauls, Age-1+ walleye pollock observed on the GOA shelf ranged in length from 13 to 66 cm FL with modes at 18, 29, and 47cm FL. The walleye pollock biomass estimate for the GOA shelf of 418,185 t from the 1,790 nmi of trackline surveyed was approximately 70% of the total walleye pollock biomass observed for the entire survey and is roughly 37% the 2017 shelf estimate.

Sanak Trough was surveyed 9-10 June along transects spaced 4 nmi apart. The backscatter attributed to walleye pollock in Sanak Trough was sparse with the greatest abundance in the southern portion of the surveyed area of the 45 nmi of transects surveyed. Pollock captured in the two LFS hauls in Sanak Trough ranged in length from 12 to 51 cm FL with a major mode at 16 cm FL and smaller modes at 25 and 47 cm FL, resulting in a biomass estimate of 1,317 t, approximately 36% of the 2017 estimate.

Morzhovoi Bay was surveyed 10 June along transects spaced 4 nmi apart. Backscatter in Morzhovoi Bay attributed to walleye pollock was light and evenly scattered throughout the bay. Walleye pollock captured in one LFS haul in Morzhovoi Bay ranged from 13 to 57 cm with modes at 15, 33, and 51 cm FL. The biomass estimate for the 21 nmi of trackline surveyed in Morzhovoi Bay was 1,592 t, similar to the estimate for Morzhovoi Bay in 2017.

Pavlof Bay was surveyed 13 June along transects spaced 4 nmi apart. The acoustic backscatter attributed to walleye pollock in Pavlof Bay was light but fairly evenly scattered throughout the survey area with one area of greater abundance in the north near the mouth of the bay. No trawls were conducted in Pavlof Bay because of mechanical issues with the trawl warp that occurred during that part of the survey so catch and composition information from the nearest haul conducted in the Shumagin Islands was applied to backscatter in Pavlof Bay. The biomass estimate in Pavlof Bay from the 27 nmi of trackline surveyed was 1,666 t, slightly higher than the estimate for Pavlof Bay in 2017.

The Shumagin Islands area was surveyed on 13-18 June along transects spaced 3.0 nmi apart in West Nagai Strait, Unga Strait, and east of Renshaw Point, and 6 nmi apart in Shumagin Trough. In the Shumagin Islands walleye pollock were most abundant in the Unga Strait area and in Shumagin Trough near the mouth of Stepovak Bay. Walleye pollock from 9 AWT hauls ranged in length from 14 to 55 cm FL with a dominant mode at 47 cm FL. The biomass estimate for the Shumagin Islands along the 187 nmi of tracklines surveyed was 17,256 t, a slight increase (1%) from the 2017 estimate.

Mitrofania Island was surveyed 5 July along transects spaced 8 nmi apart. The acoustic backscatter attributed to walleye pollock was patchy with the greatest abundance on the northern transects and decreasing as the survey progressed to the south. Lengths of walleye pollock captured in the one LFS haul near the island ranged from 33 to 56 cm FL with a mode at 47 cm FL. The biomass estimate in Mitrofania along the 31 nmi of tracklines surveyed was 1,604 t, less than 4% of the amount that was seen in 2017 in the area.

Shelikof Strait was surveyed from 26 June to 7 July along transects spaced 15 nmi apart. Walleye pollock were predominantly distributed in the central portion of Shelikof Strait off the northwest corner of Kodiak Island and in the southern portion of the Strait between the Semidi Islands and Chirikof Island. Lengths were obtained from 12 LFS trawls and were divided between primary length groups, one ranging from 13 to 19 cm FL and the other from 20 to 39 cm FL with respective modes at 15 and 24 cm FL. The biomass estimate for the 527 nmi of trackline surveyed in Shelikof Strait was 106,343 t, a 38% increase over the 2017 estimate, and accounted for approximately 17% of the entire GOA summer survey pollock biomass.

Alitak and Deadman Bays were surveyed 30 June along a zig-zag pattern into the narrow inner bay area. From one LFS haul conducted in the area walleye pollock ranged in length from 17 to 63 cm FL with a major mode at 28 cm FL. The biomass estimate along the 39 nmi of trackline surveyed in the Alitak/Deadman Bay area was 1,893 t, nearly 3 times greater than the Alitak/Deadman Bay estimate for 2017.

Barnabas Trough was surveyed 10 to 13 July along transects spaced 6 nmi apart. Aggregations of adult walleye pollock were evenly distributed throughout Barnabas Trough. Walleye pollock caught in 8 LFS trawls in Barnabas Trough ranged in length from 15 to 62 cm FL and had modes at 19, 30, and 48 cm FL. The biomass estimate for the 148 nmi of trackline surveyed in Barnabas Trough was 35,685 t, a 29% decrease from the 2017 estimate but still approximately 6% of the entire GOA summer survey biomass estimate.

Chiniak Trough was surveyed 14-16 July along transects spaced 6 nmi apart. Backscatter attributed to walleye pollock was lightly distributed throughout Chiniak Trough. Walleye pollock caught in 4 LFS hauls in Chiniak Trough ranged in length from 16 to 54 cm FL, with a dominant mode at 29 cm FL and smaller modes at 19 cm and 49 cm FL. The biomass estimate for the 54 nmi of trackline surveyed in Chiniak Trough was 4,922 t, a decrease of approximately 84% from the 2017 estimate.

Marmot Bay was surveyed 20-22 July along transects spaced 2 nmi apart in the inner bay and Spruce Gully, and 4 nmi apart in the outer bay. Walleye pollock backscatter was light but evenly distributed in Marmot Bay with the greatest amounts found in the outer bay. Walleye pollock caught in the 5 LFS trawls in the area ranged in length from 12 to 51 cm FL with a primary mode at 19 cm FL and a secondary mode at 28 cm FL. The biomass estimate for Marmot Bay along the 110 nmi of trackline surveyed was 2,792 t, only slightly higher than the 2017 estimate.

The Resurrection Bay was the only Kenai Peninsula Bay that was surveyed and which occurred on 28-29 July using a zig-zag pattern because of the narrowness of the bay. Backscatter was relatively low in Resurrection Bay and was greatest in the outer area near the mouth of the bay. Walleye pollock caught in 1 LFS haul ranged in length from 14 to 54 cm FL with a major mode at 17 cm and a smaller mode at 27 cm FL. The biomass estimate for the 43 nmi of trackline surveyed in Resurrection Bay was 316 t, only 16% of what was detected in Resurrection Bay in 2015, the only other survey that has been conducted in the Bay during the summer.

Prince William Sound was surveyed 31 July to 1 August along transects spaced 8.0 nmi apart. Backscatter in Prince William Sound was very sparse, with very few fish detected. One LFS haul was conducted within Prince William Sound and only two walleye pollock were caught and were 46 and 51 cm FL. The biomass estimate for the 71 nmi of trackline surveyed in Prince William Sound was only 16 t.

Rapid Larval Assessment in the Gulf of Alaska - RACE RPP (EcoFOCI)

An onboard Rapid Larval Assessment (RLA) was conducted on the EcoFOCI spring larval survey from May 6 to May 22, 2019 in the western Gulf of Alaska. The RLA is designed to provide early abundance and geographic distribution data for larvae of commercially important fish species, prior to in-depth laboratory assessments. While onboard rough counts of Walleye Pollock have been routinely conducted on EcoFOCI surveys, the protocol was expanded in 2019 to include Pacific Cod, Southern Rock Sole, Northern Rock Sole, rockfishes, and Arrowtooth Flounder. The full contribution is available in the 2019 Gulf of Alaska Ecosystem Status Report (page 94) but the results are summarized below.

The abundance of all assessed larval fishes within the main grid area in 2019 was below average, low relative to 2017, and similar to that of 2015 (a "Blob" year; Figure 1) with the exception of larval rockfishes, which had decreased abundance in 2019 compared to 2015. Counts of larval Pollock from 2019 were below average throughout the entire survey grid with frequent zero catches and a distribution similar to that of 2015 (Figure 2). In 2017 larval Pollock catches were average within the main grid area. The 2019 abundance of Pacific Cod was low within the main grid and had a distribution similar to that of 2015. The abundance of larval Arrowtooth Flounder was lower in 2019 relative to 2015 and 2017, with no individuals encountered outside of the main grid. Northern Rock Sole and Southern Rock Sole tend to have similar geographic distributions and abundances throughout the main grid but in 2019, Southern Rock Sole were absent from the main grid.

The decreased abundance of all six taxa assessed in the 2019 RLA suggests that ecosystem conditions were not conducive for the survival of eggs and larvae of a range of species, similar to the "Blob" conditions of 2015. High bottom temperatures may reduce egg viability or early survival due to physiological stress in species that utilize water near the benthos for spawning, such as Pacific Cod (Laurel and Rogers 2020). Warmer temperatures could also result in match-mismatch dynamics depending on the thermal sensitivity of spawning, development, and prey production. Lower abundance of larvae suggests weak 2019 year classes, and reduced future recruitment to the fishery for each assessed species.

References:

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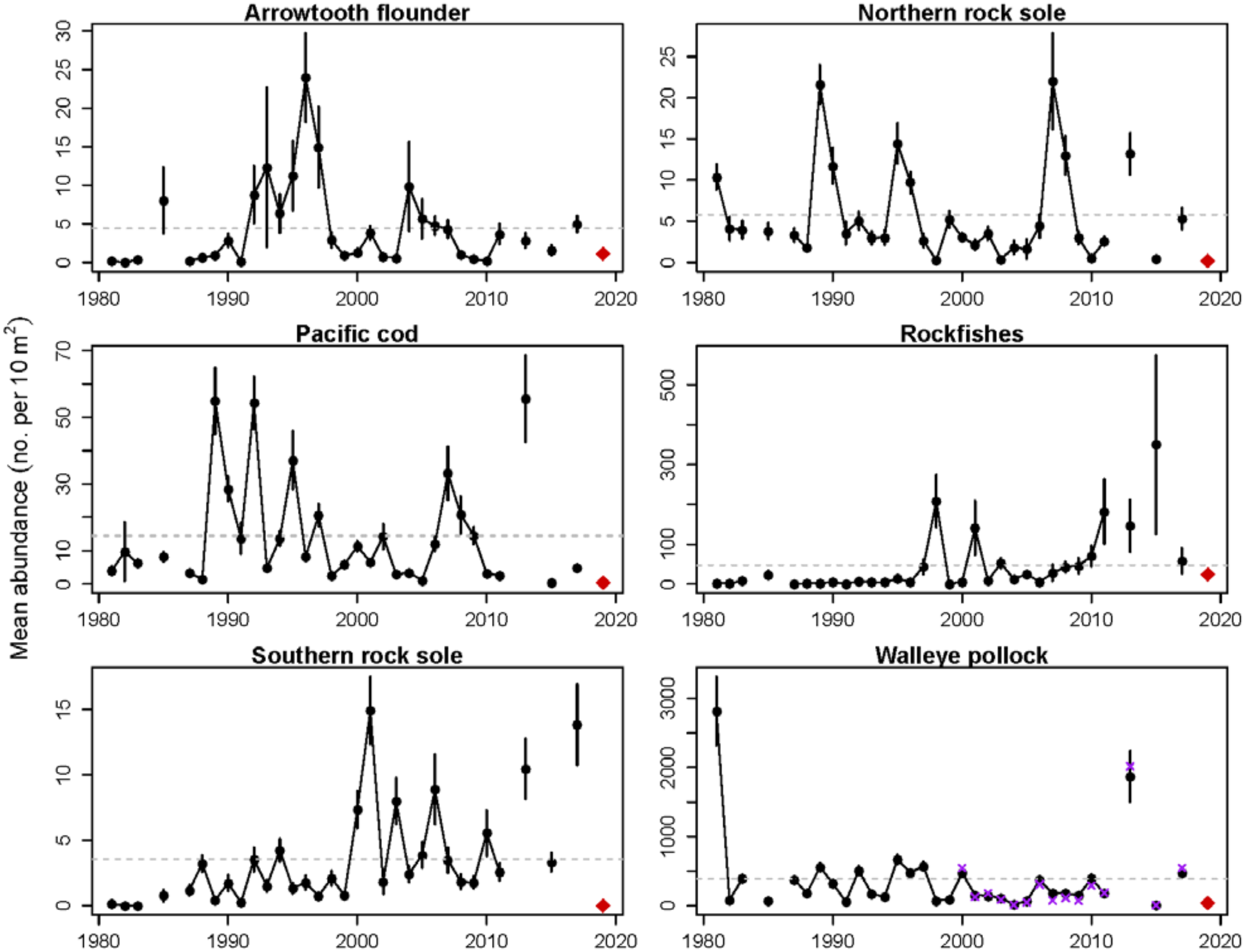

Figure 1. Time-series of mean abundance within the main grid area for species included in the Rapid Larval Assessment (RLA) for 2019. Laboratory counts are denoted by black circles; the RLA estimate is the red diamond. Purple x's denote historical at-sea rough count estimates for Pollock.

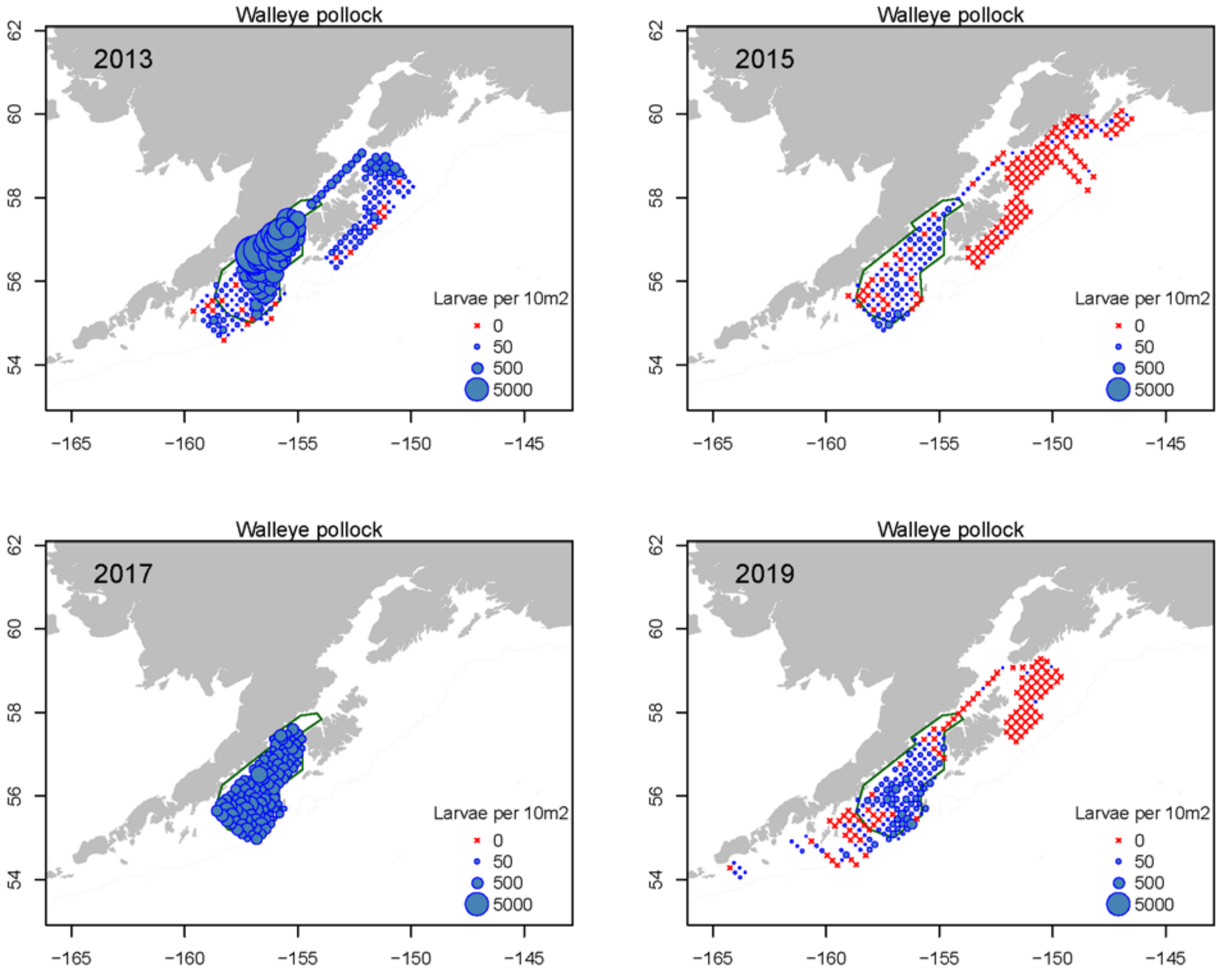

Figure 2. Abundance of larval Pollock on the EcoFOCI spring larval survey for 2013-2019. The at-sea rough counts were used to generate the distribution for 2019 whereas laboratory data are shown for previous years. Main grid area delineated by the green line.

Alison L Deary, Lauren Rogers, Annette Dougherty

Summer 2019 acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye Pollock - MACE

Acoustic backscatter data (Simrad ES60, 38 kHz) were collected aboard two fishing vessels chartered for the AFSC summer 2019 bottom trawl surveys (F/V *Alaska Knight*, F/V *Vesteraalen*). These Acoustic Vessels of Opportunity (AVO) data were processed according to Honkalehto et al. (2011) to provide an index of age-1+ midwater pollock abundance for summer 2019 (Stienessen et al. 2020). The 2019 AVO index of midwater pollock abundance on the eastern Bering Sea shelf increased by 1.3 % from 2018 but decreased 6.8% from 2017. The percentage of pollock backscatter east of the Pribilof Islands was 24%. Although this is larger than the percentage in summer 2018 (15%), it is similar to the mean percentage observed east of the Pribilof Islands in all other years since 2013 (25%).

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Stienessen, S. C., T. Honkalehto, N. E. Lauffenburger, P. H. Ressler, And R. R. Lauth. 2020. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2018-2019. AFSC Processed Rep. 2020-01, 22 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115. https://doi.org/10.25923/5pf5-5707

Longline Survey – ABL

The AFSC has conducted an annual longline survey of sablefish and other groundfish in Alaska from 1987 to 2019. The survey is a joint effort involving the AFSC's Auke Bay Laboratories and Resource Assessment and Conservation Engineering (RACE) Division. It replicates as closely as practical the Japan-U.S. cooperative longline survey conducted from 1978 to 1994 and also samples gullies not sampled during the cooperative longline survey. In 2019, the 42nd annual longline survey sampled the upper continental slope of the Gulf of Alaska and the eastern Bering Sea. One hundred and fifty-two longline hauls (sets) were completed during May 30 – August 26 by the chartered fishing vessel *Ocean Prowler*. Total groundline set each day was 16 km (8.6 nmi) and contained 160 skates with 7,200 hooks, except in the Bering Sea where 18 km (9.7 nmi) of groundline (180 skates) with 8,100 hooks were set.

Sablefish (*Anoplopoma fimbria*) was the most frequently caught species, followed by giant grenadier (*Albatrossia pectoralis*), shortspine thornyhead (*Sebastolobus alascanus*), rougheye/blackspotted rockfish (*Sebastes aleutianus/S. melanostictus*), and Pacific cod (*Gadus macrocephalus*). A total of 124,424 sablefish, with an estimated total round weight of 248,350 kg (547,518 lb), were caught during the survey. This represents increases of 43,559 fish and 73,262 kg (161,515 lb) of sablefish over the 2018 survey catch. Sablefish (5,399), shortspine thornyhead (735), and Greenland turbot (*Reinhardtius hippoglossoides*, 10) were tagged with external Floy tags and released during the survey. Length-weight data and otoliths were collected from 3,502 sablefish. Killer whales (*Orcinus orca*) depredating on the catch occurred at ten stations in the Bering Sea, four stations in the western Gulf of Alaska and three stations in the central Gulf of Alaska. Sperm whales *(Physeter macrocephalus)* were observed during survey operations at 21 stations in 2019. Sperm whales were observed depredating on the gear at seven stations in the central Gulf of Alaska, six stations in the West Yakutat region, and five stations in the East Yakutat/Southeast region.

Several special projects were conducted during the 2019 longline survey. Throughout the survey, stereo cameras were installed outboard of the hauling station to collect imagery that will be used as a training dataset to develop machine learning for length measurements and species identification. Tissue samples were collected from shortspine thornyhead and several rockfish species. These samples will be used to examine stock structure of shortspine thornyhead and for constructing complete reference genomes for ten rockfish (*Sebastes* spp.) species. Longline survey biologists also collaborated with the Alaska Longline Fishermen's Association (ALFA) on a sperm whale detection and location pilot project. A towed hydrophone was deployed at several locations in the eastern Gulf of Alaska as the survey vessel transited between stations. Sperm whale detections and their estimated locations were relayed via satellite to a central processing computer at the University of St. Andrews, Scotland. Once the methods are refined, ALFA may use this technology to inform the fleet and help them avoid depredating whales.

Longline survey catch and effort data summaries are available through the Alaska Fisheries Science Center's website: https://apps-afsc.fisheries.noaa.gov/maps/longline/Map.php. Full access to the longline survey database is available through a password protected website through the Alaska Fisheries Information Network (AKFIN). Catch per unit effort (CPUE) information and relative population numbers (RPN) by depth strata and management regions are available for all species caught in the survey on the AFSC website.

For more information, contact Pat Malecha (pat.malecha@noaa.gov). For data access, contact Cara Rodgveller (cara.rodgveller@noaa.gov).

Northern Bering Sea Integrated Ecosystem Survey – ABL

Auke Bay Laboratory (ABL) Division of the Alaska Fisheries Science Center (AFSC) has conducted surface trawling and biological and physical oceanography sampling in the Northern Bering Sea annually since 2002. The 2019 survey included the collection of data on pelagic fish species and oceanographic conditions from 60°N to 66°N aboard the *F/V Northwest Explorer* from August 27 to September 20 (Fig. 1). The 2019 survey was conducted in partnership with the Alaska Department of Fish and Game (ADFG), United States Fish and Wildlife Service (USFWS), and Alaska Pacific University (APU). Funding support for the survey was provided by AFSC and the Alaska Sustainable Salmon Initiative (AKSSF). Key contributions by ADFG and APU made it possible for AFSC to secure funding from AKSSF. Research objectives of the AKSSF project funds were to evaluate the status of juvenile Chinook salmon in the northern Bering Sea and provide stock-specific forecasts of run size and subsistence harvest for the Yukon River. The research objective by AFSC was to provide an integrated ecosystem assessment of the northeastern Bering Sea.

Sea surface temperatures were above average in 2019 and may have contributed to the above average catch of age-0 pollock and below average catch of saffron cod.

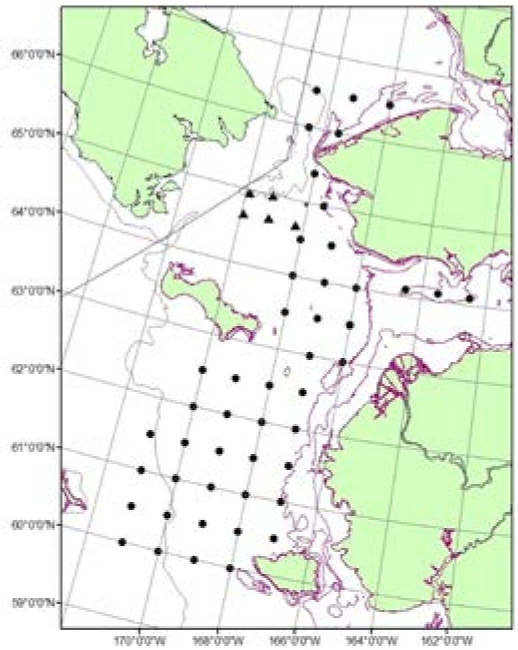


Figure 1. Stations sampled during the August 27 to September 20, 2019 surface trawl survey in the northern Bering Sea.

For more information, contact Jim Murphy 907-789-6651, Jim.Murphy@noaa.gov.

Late-Summer Pelagic Trawl Survey (BASIS) in the Southeastern Bering Sea, August-September 2019 – ABL

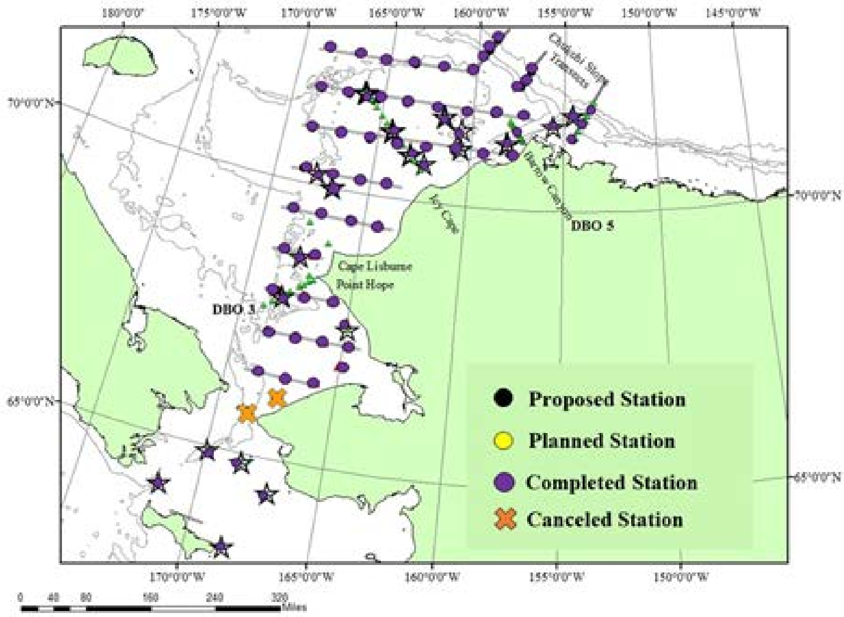
BASIS fisheries-oceanographic surveys in the southeastern Bering Sea have been conducted annually since 2002 (with the exception of 2013) and biennially since 2016. In 2019 there was no survey and results of the 2020 survey will be provided next year.

Contact Alex Andrews with questions (Alex.Andrews@noaa.gov).

Arctic Integrated Ecosystem Survey, August-September 2019 – ABL

From August 1 to October 1, we conducted an integrated ecosystem survey (physical environment, nutrients, phytoplankton, zooplankton, fishes, and seabirds) in the Chukchi and Beaufort seas (see Map). Samples were taken at stations (purple dots) within the Chukchi and Beaufort seas between 65°N and 72.5°N. Mooring deployment and recovery occurred at the stars on the map. Data on sea temperature and salinity was also collected along transects (green triangles). Overall, sea temperatures on the Chukchi Sea shelf were warm and varied between 5.3°C (41.5°F) to 10.9°C (52°F). We note that zooplankton abundances were very low compared to previous years. Age-0 Arctic cod were most abundant in mid water trawl catches; however, their overall abundance was lower when compared with 2017. Of note were the large numbers of age-0 walleye Pollock caught along the 70.25°N transect as well as in the southern Chukchi Sea. Seafloor animals included notched brittlestars, snow crab, northern nutclam, basket stars and common mud stars. There were six dead seabirds seen including two horned puffins, a black-legged kittiwake, a common murre, and two unidentified bird species. This ends the field sampling for the NPRB/BOEM Arctic Integrated Ecosystem Research Program. The scientists will continue to analyze data and consult with indigenous knowledge experts to better understand how loss of seasonal sea ice affects the marine food web.

For more information contact Ed Farley (ed.farley@noaa.gov).



North Pacific Groundfish and Halibut Observer Program (Observer Program) - FMA
The Fisheries Monitoring and Analysis (FMA) Division administers the North Pacific Observer Program (Observer Program) and Electronic Monitoring (EM) Program which play a vital role in the conservation and management of the Bering Sea, Aleutian Islands, and Gulf of Alaska groundfish and halibut fisheries.

FMA observers and EM systems collect fishery-dependent data onboard fishing vessels and at onshore processing plants that is used for in-season management, to characterize interactions with protected resources, and to contribute to assessments of fish stocks, provide data for fisheries and ecosystem research and fishing fleet behavior, and characterize fishing impacts on habitat. The Division ensures that the data collected by observers and through EM systems are of the highest quality possible by implementing rigorous quality control and quality assurance processes.

Information regarding FMA activities in 2019 was not available in time for this report, but please access the AFSC website or contact Jennifer Ferdinand at Jennifer.Ferdinand@noaa.gov.

III. Reserves

IV. Review of Agency Groundfish Research, Assessment, and Management

Note: Management of federal groundfish fisheries in Alaska is performed by the North Pacific Fishery Management Council (NPFMC) with scientific guidance (research and stock assessments) from the Alaska Fisheries Science Center and other institutions. Assessments are conducted annually for major commercial groundfish stocks, with biennial assessments for most of the other stocks. Groundfish populations are typically divided into two geographic stocks: Bering Sea and Aleutian Islands (BSAI) and Gulf of Alaska (GOA). Some BSAI stocks are further divided into Eastern Bering Sea (EBS) and Aleutian Islands (AI). In the GOA, assessment and management for many stocks is structured around large-scale spatial divisions (western, central, and eastern GOA) although the application of these divisions varies by stock. Current and past stock assessment reports can be found by following the "historical groundfish SAFE" link on the NPFMC website (https://www.npfmc.org/safe-stock-assessment-and-fishery-evaluation-reports/). Additional useful information (e.g. fishery management plans) can be found elsewhere at the NPFMC site.

A. Hagfish

There are currently no state or federal commercial fisheries for hagfish in Alaska waters. However, since 2017 the Alaska Department of Fish & Game has been conducting research to explore the potential for small-scale hagfish fisheries.

B. Dogfish and other sharks

1. Research

Ageing of Pacific Sleeper Sharks – ABL

A pilot study is underway by staff at ABL, REFM, the Lawrence Livermore National Laboratory and the American River College to investigate potential ageing methods for Pacific sleeper sharks. A recent study suggested extreme longevity in a closely related species by examining the levels of bomb-derived radiocarbon (14C) in the eye lens. The eye lens is believed to be a metabolically inert structure and therefore the levels of 14C could reflect the environment during gestation, which may be used to compare to existing known age 14C reference curves to estimate either a rough age, or a "at least this old" age estimate. For the pilot study, eyes from six animals were removed whole and stored frozen until lab processing. One lens from each shark was excised and lens layers were removed and cleaned by sonication and dried. For larger sharks, both the lens core (earliest deposited material) and outer layer (most recently deposited material) were saved for analysis. Dry samples were sent to an accelerator mass spectrometry (AMS) facility for carbon isotope analyses (^{14}C, ^{13}C), measurement error, and conventional radiocarbon age, when applicable (pre-bomb (<1950); Gagnon et al. 2000) — it was expected that all outer layer samples would be modern and that some cores could have pre-bomb or early bomb ^{14}C rise levels based on rough estimates of age. Preliminary results demonstrate that ^{14}C is measurable in the eye lens cores and outer layers, and two of the PSS had values that could be correlated with the ^{14}C rise period (late 1950s to mid-1960s; Figure 1). Specifically, results from the largest shark sampled (310 cm TL) indicate the age was not older than 50 years. This is an important observation relative to the previous study on Greenland sharks (Nielsen et al. 2016) because the age-at-length diverges significantly from an estimated age of 105 years using the Greenland shark growth curve. For the pilot study, we assumed that the regional bomb ^{14}C reference curve was from two long-lived teleost fishes from the GOA and that exposure and uptake of ^{14}C by PSS was similar. Both assumptions require further investigation and will be addressed as part of a larger study currently pending funding.

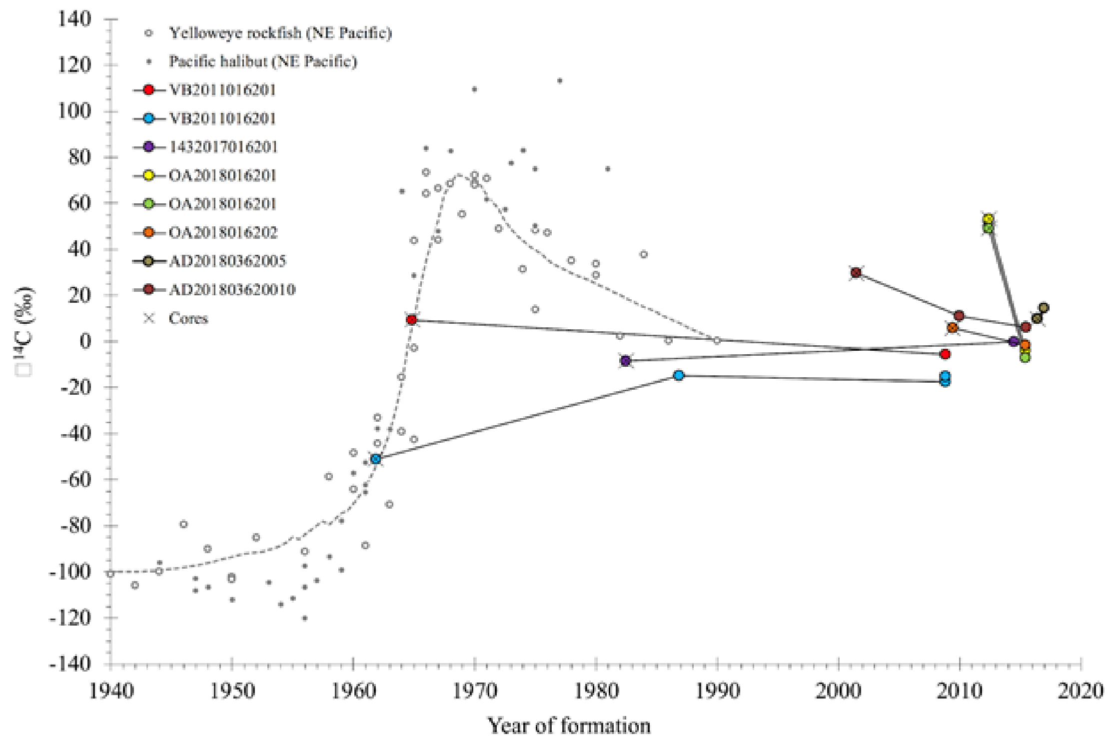


Figure 1. 14C values of the Pacific sleeper shark sampled for the pilot study, the cores are in “x”. Each animal is a different color, some animals had just the core, others had the core and 1-2 layers analyzed. The reference chronologies from yelloweye rockfish and Pacific halibut are included and were used in the pilot study.

For more information, contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

Salmon shark movement – ABL

In addition to normal survey operations, salmon sharks are being opportunistically tagged when captured incidentally during surface trawls. In 2017, a 1.76-m male shark was tagged with an X-Tag (Microwave Telemetry, Inc), which collected depth, temperature, and light level data during its 12-month deployment. The 2017 shark traveled from the Bering Sea to Baja California in the fall and returned to the Bering Sea the following summer. The shark made frequent trips to the surface and had dives up 500 m during which it experienced temperatures between 4°C and 18°C. In 2019, a 2-m male salmon shark was double tagged with an archival PTT-100 tag (Microwave Telemetry, Inc) and a SPOT-257 tag (Wildlife Computers Inc.). The archival tag is collecting depth, temperature, and light level data and is scheduled to pop-off on September 7, 2020. The SPOT tag sends location data when the shark’s dorsal fin breaks the surface (Figure 1). As of March 27, the 2019 salmon shark has traveled 13,000 km since it was tagged on September 7, 2019.

There have been two salmon sharks tagged in the last two years, with plans to continue as tags are available. So far, this tagging effort has resulted in: 1) tagging male salmon sharks, which is rare; 2) the longest deployments of any tags for male salmon sharks; and 3) hopefully the first comprehensive data set with known locations and temp/depth profiles for this species. The goals of these tagging efforts are to investigate predation on Chinook salmon by salmon sharks, identify the migratory patterns of Bering Sea salmon sharks, and compare tag performance between GPS-derived locations and light level geolocation. This work is a collaboration between NOAA-NMFS (Cindy Tribuzio, Jim Murphy), ADF&G (Sabrina Garcia, Dion Oxman), UAF (Andrew Seitz, Michael Courtney), and Kingfisher Marine Research (Julie Nielsen).

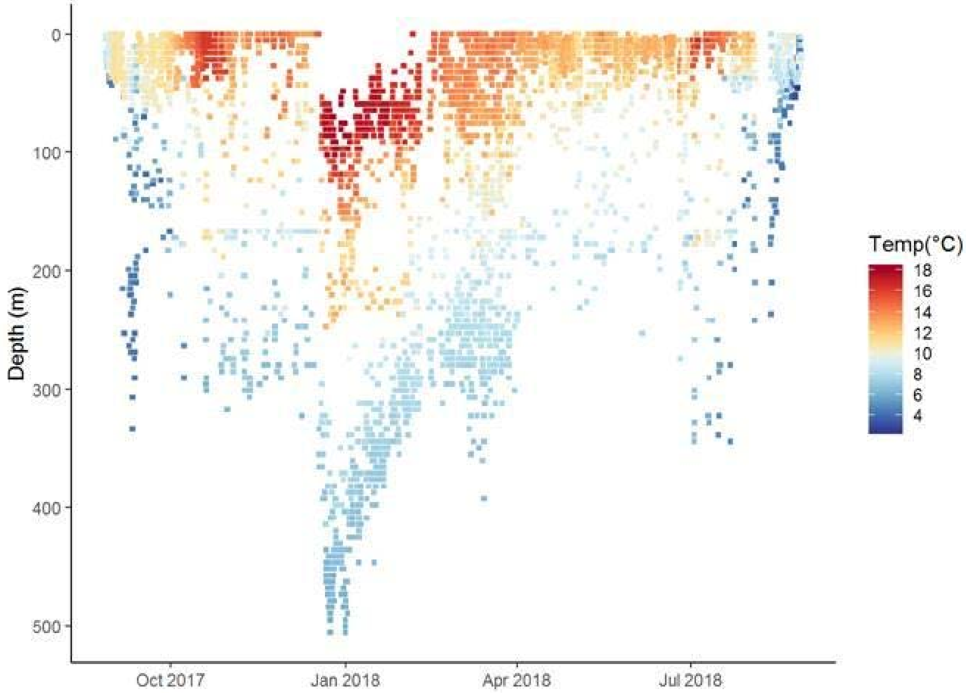


Figure 1. Salmon shark track depth and temperature record for 12 months after being tagged with an X-Tag (Microwave Telemetry, Inc.) on 27 August 2017. Each point represents the average depth and temperature for hourly data where both temperature and depth were recorded.

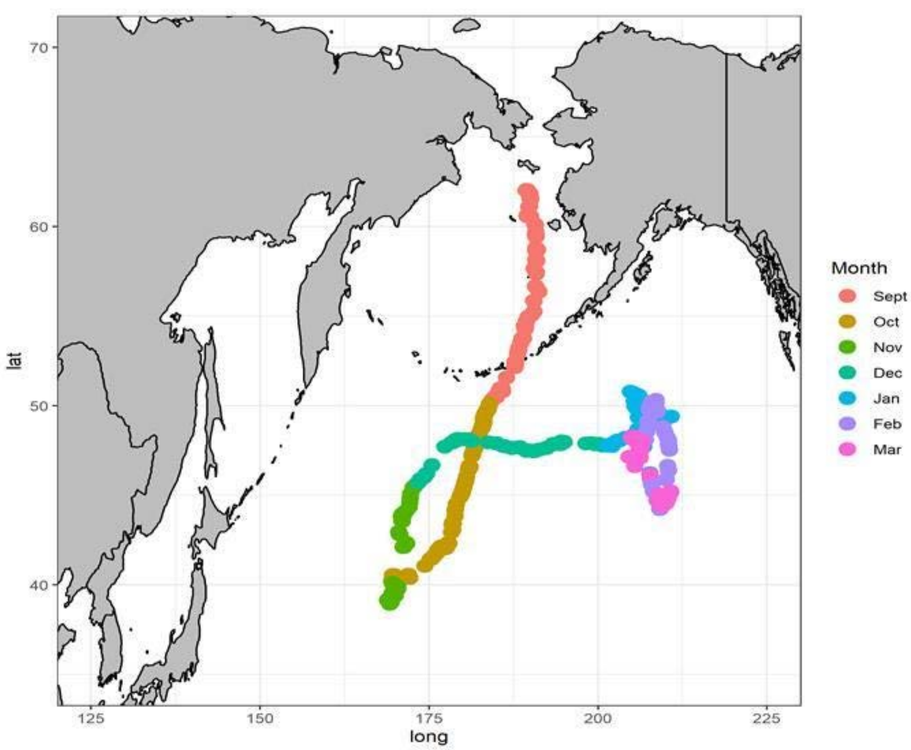


Figure 2. Salmon shark track after being tagged on 7 September 2019. Each point is a GPS location detected when the tag on the shark breaks the surface of the water, providing real-time, nearly daily observations.

2. Stock Assessment

Sharks - ABL
There were no assessments in 2019; both the Bering Sea/Aleutian Islands and the Gulf of Alaska assessments will be conducted in 2020.

C. Skates

1. Research

Genetics work on BSAI skates-REFM
Skate egg nursery sites are specific locations on the ocean floor where some species of skates deposit eggs to incubate up to several years until hatching. Genetic diversity was examined within and among embryos of the Alaska Skate (*Bathyraja parmifera*) and the Aleutian Skate (*B. aleutica*) from egg nursery sites in the eastern Bering Sea to gain a better understanding of how skates utilize these areas. Restriction-site Associated DNA (RAD) sequencing libraries were used to obtain SNP datasets for B. parmifera (5,285 SNPs) and B. aleutica (4,522 SNPs). Spatially distinct nursery areas appear to be utilized by different components of both species, evidenced by significant genetic differentiation among nursery sites. No genetic differentiation was observed between *B. parmifera* from the spatially proximate Pribilof and Bering Canyons, suggesting that this may represent a large contiguous nursery area. Genetic differences between developmental stages within nursery areas were not significant. Adult *B. parmifera* taken from the Bering Sea and Aleutian Islands were genetically distinct from embryo collections, indicating that additional genetic types may exist that were not represented by the nursery areas sampled in this study.

For more information contact ingrid.spies@noaa.gov.

2. Assessment

Bering Sea and Aleutian Islands (REFM)
The Bering Sea and Aleutian Islands (BSAI) skate complex includes at least 13 skate species, which are highly diverse in their spatial distribution. The complex is managed in aggregate, with a single set of harvest specifications applied to the entire complex. However, to generate the harvest recommendations the stock is divided into two units. Harvest recommendations for Alaska skate *Bathyraja parmifera*, the most abundant skate species in the BSAI, are made using the results of an age structured model (Stock Synthesis). The remaining species ("other skates") are managed under Tier 5 (OFL = F * biomass, where F=M; ABC = 0.75 * OFL). The individual recommendations are combined to generate recommendations for the complex as a whole.

The skate complex in the BAI is assessed biennially, with full assessments in even years and partial updates in odd years. For the skate complex as a whole, the ABC for 2020 is 41,543 t and the OFL for 2020 is 49,792 t.

Gulf of Alaska (REFM)
There are currently no target fisheries for skates in the Gulf of Alaska (GOA), and directed fishing for skates is prohibited. Incidental catches in other fisheries are sufficiently high that skates are

considered to be “in the fishery” and harvest specifications are required. The GOA skate complex is managed as three units. Big skate (*Beringraja binoculata*) and longnose skate (*Raja rhina*) have separate harvest specifications, with Gulf-wide overfishing levels (OFLs) and Acceptable Biological Catches (ABCs) specified for each GOA regulatory area (western [WGOA], central [CGOA], and eastern [EGOA]). All remaining skate species are managed as an “other skates” group, with Gulf-wide harvest specifications. All GOA skates are managed under Tier 5, where OFL and ABC are based on survey biomass estimates and natural mortality rate. Effective January 27, 2016 the Alaska Regional Office indefinitely reduced the maximum retainable amount for all skates in the GOA from 20% to 5%.

Following are the main developments in the 2019 skate assessment:

1) Big skate biomass increased relative to 2017 (2019 survey estimate of 43,482 t versus 33,610 in 2017). This resulted in a slight increase in the random-effects model biomass estimate and corresponding increase in the overall recommended harvest. Because the distribution of big skate biomass among areas shifted in 2019, the ABC in the CGOA actually declined and the increased ABC occurred in the WGOA and EGOA.
2) The longnose skate biomass decreased in 2019 (survey biomass estimates of 32,279 t in 2019 versus 49,501 t in 2017). The area ABCs fell in the CGOA and EGOA while increasing slightly in the WGOA.
3) The biomass of other skates continues to decline from a peak in 2013. This resulted in reduced OFL and ABC.
4) The increased biomass of big skates on the eastern Bering Sea shelf observed beginning in 2013 continues. There is strong evidence to suggest that these skates originated in the GOA and that there is exchange between the areas. This movement is likely influencing GOA biomass estimates.

For more information contact Olav Ormseth (206) 526-4242 or olav.ormseth@noaa.gov.

D. Pacific Cod

1. Research

Pacific cod juveniles in the Chukchi Sea-RPP

Dan Cooper, Libby Logerwell, Nissa Ferm, Robert Lauth, Lyle Britt, Jesse Lamb, and Lorenzo Ciannelli.

In recent warm years, catchable-sized Pacific cod have expanded their range from the southeastern Bering Sea into the northern Bering Sea, and possibly into the Chukchi Sea. One question is whether this expansion represents a temporary range shift, or a colonization of northern areas; early life stage abundance and distribution data may offer evidence of local spawning and therefore colonization. Pacific cod juveniles were surveyed in the Chukchi Sea using a small-mesh demersal beam trawl during August and September of three years: 2012 (Arctic EIS), 2017 and 2019 (Arctic IERP; Figure 1). Pacific cod juveniles were present at 11 of 59 stations in 2017, and at 4 of 48 stations in 2019 (Figure 1). Similarly-sized fish in the eastern Bering Sea would be young-of-the-year. Pacific cod juveniles were absent from all 40 stations in 2012, including at 7 stations where Pacific cod were present in 2017 (Figure 1). Although summer bottom temperatures in the Chukchi Sea were generally warmer in 2017 and 2019 than in 2012, the southern and shallow sites with Pacific cod presence in 2017 were warmer in 2012 than in 2017 (Figure 1). If warmer temperatures allowed Pacific cod to survive in 2017 and not in 2012, the temperature effect was likely at an earlier life history stage than the observed benthic juveniles. Pacific cod are able to survive to the transformed juvenile stage in the Chukchi Sea in some years, although this is not the first report of juvenile Pacific cod in the Chukchi Sea. Juvenile Pacific cod were also caught in surface and midwater trawls during the 2017 Arctic IERP Survey, and we are currently collaborating with Kristin Cieciel (EMA), Robert Levine (MACE), Louise Copeman (OSU), and Johanna Vollenweider (EMA) to describe habitat specific abundance, diet, and trophic markers for juvenile Pacific cod.

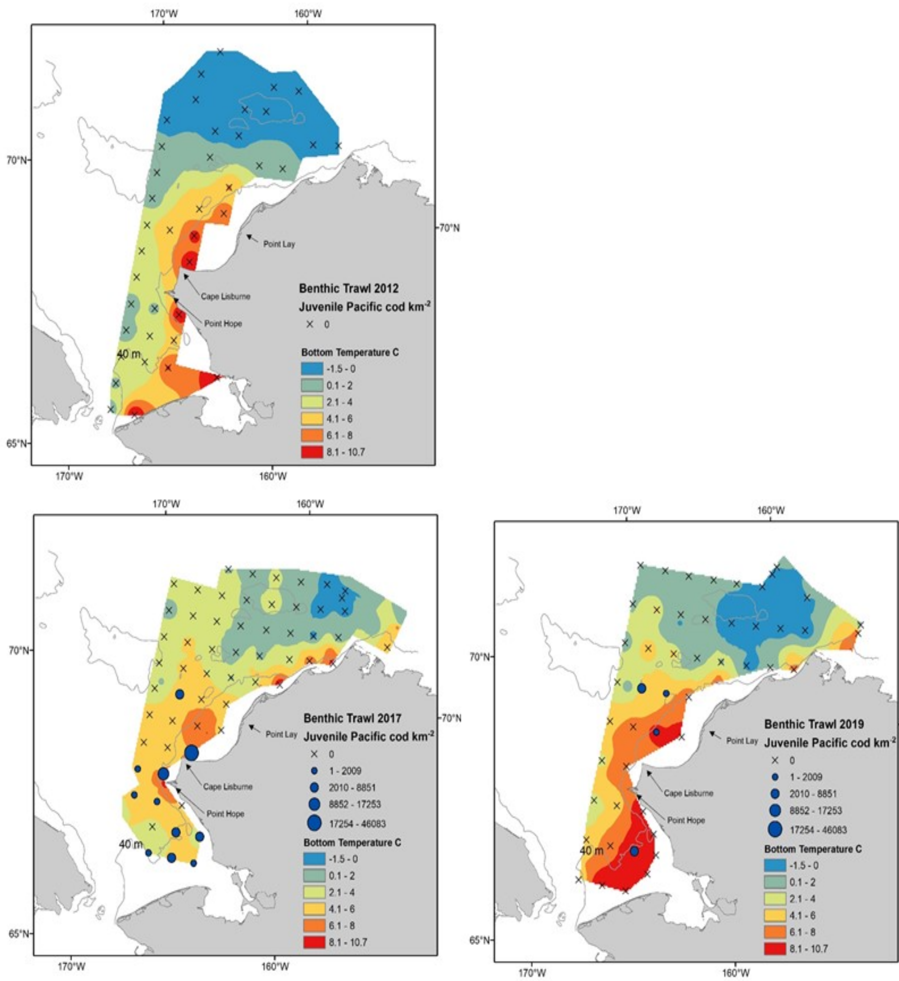


Figure 1. Pacific cod catch per unit effort and bottom temperature interpolations from 2012, 2017, and 2019.

Genetic evidence for a northward range expansion of the eastern Bering Sea Pacific cod stock - REFM

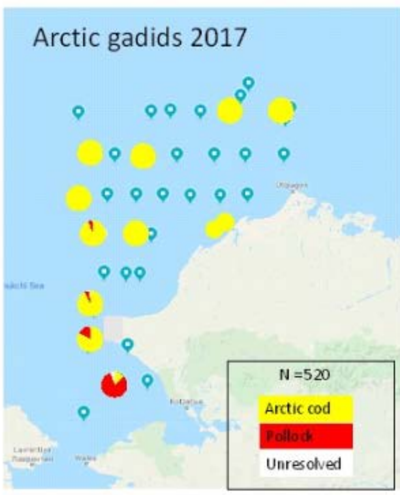
Poleward species range shifts have been predicted to result from climate change, and many observations have confirmed such movement. The abundant center hypothesis predicts that range shifts will take place by movement of individuals from core habitat to marginal habitat. However, poleward shifts may represent a homogeneous shift in distribution, northward movement of specific populations, or colonization processes at the poleward edge of the distribution. The ecosystem of the Bering Sea has been changing along with the climate, moving from an arctic to a subarctic system. Several fish species have been observed further north than previously, replacing marine mammals and benthic prey. We examined Pacific cod in the northern Bering Sea to assess whether they migrated from another stock in the Eastern Bering Sea, Gulf of Alaska, Aleutian Islands, or whether they represent recently established separate populations. Genetic analysis using 3,457 SNP markers indicated that cod collected in August 2017 in the northern Bering Sea were most similar to spawning stocks of cod in the eastern Bering Sea. This result suggests northward movement of the large eastern Bering Sea stock of Pacific cod, and is consistent with the abundant center hypothesis.

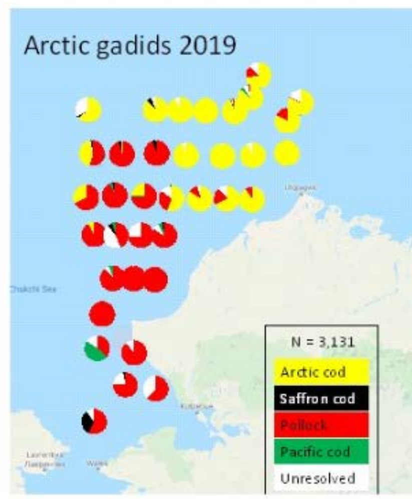
Contact Ingrid Spies (Ingrid.Spies@noaa.gov) for more information.

Cod species and population structure in the Arctic - ABL

Adult gadids were collected in 2012-2013 by the Bering Arctic Subarctic Integrated Survey (BASIS) and age-0 gadids in 2017 and 2019 by the Arctic Integrated Ecosystem Research Program (Arctic IERP). Over 4000 age-0 gadids from the 2019 collection were genetically analyzed with 15 microsatellite markers and mtDNA COI sequences for species ID. Approximately half of the age-0 gadids were initially misidentified morphologically at sea. As a result, an additional 1000 individuals from the 2017 collection will also be examined genetically to verify species ID.

The identification shows a dramatic shift north of primarily walleye pollock and Arctic cod, as well as some Pacific cod and saffron cod. Surveys of the Chukchi Sea in 2012 and 2013 detected just several individual age-0 walleye pollock amidst a sea of Arctic cod. By 2017, age-0 walleye pollock dominated Kotzebue Sound and were detected as far north as latitude 70N. Samples analyzed from 2019 indicate walleye pollock as the dominant species in the Chukchi Sea, and present in the northernmost collection at latitude 73N. Increased numbers of Pacific cod and saffron cod were also detected throughout the survey area. No arctic cod were detected below 70N in collections from 2019.





For more information contact: Sharon.Wildes@noaa.gov

Warm Blob Effects on Juvenile Pacific Cod – ABL

Once supporting a commercial fishery worth $100 million annually, the Pacific cod (*Gadus macrocephalus*) population in the Gulf of Alaska (GOA) is at its lowest level on record. Marine heatwaves in the Gulf of Alaska in 2013-2015 and 2019, also called the "Warm Blob", have been cited as a potential for cod declines as well as other fishes, seabirds, and whales. Blob conditions are associated with changes at the base of the food chain, with warm-water, low-lipid zooplankton assemblages replacing cold-water, high-lipid zooplankton species. In combination with poor-quality prey, Blob temperatures in the GOA exceeded the optimal growth temperature for juvenile Pacific cod, straining their energetic demands. Energy limitations are most influential on juvenile stages of fish, which have high energetic demands to grow to evade predation and simultaneously store lipid to nourish them through winter when food is scarce. To understand how environmental conditions during the Blob may have influenced age-0 Pacific cod mortality, we conducted a laboratory study comparing diets and temperatures before and during the Blob to quantify its effects on fish growth and body condition.

In the summers of 2018 and 2019, we completed two studies of different sized age-0 cod, one in the early summer and one in fall. We fed fish *ad-libatum* high fat (pre-Blob) and low fat (Blob) diets at multiple temperatures from 6-15 °C for two months. Under Blob conditions, fish grew larger but had lower whole-body lipid levels. Juvenile cod store ~43% of their lipid in their liver, and livers were smaller with 10% less lipid under Blob conditions. Cod did not compensate for low-lipid diets, consuming 34% less food under Blob conditions. Preliminary results indicate that Blob conditions hinder the ability for juvenile cod to provision for winter, potentially increasing mortality from predation from risky foraging, or starvation.

This laboratory study is one component of a broader study that seeks to validate a model constructed under the GOAIERP (Gulf of Alaska Integrated Research Program) to predict where larval juvenile Pacific Cod will drift after spawning and settle to the benthos for their first year of life. The Individual Based Model (IBM) predicted rates of dispersal and settlement around the shoreline of the Gulf of Alaska. In the summer of 2021 and 2022, we will be sampling areas the IBM predicts to be habitats with high, medium, and low abundance of juvenile Pacific Cod using video footage. This study is funded by the North Pacific Research Board.

For more information, contact Johanna Vollenweider (907) 789-6612 or Katharine Miller, (907) 789-6410.

2. Stock Assessment

Eastern Bering Sea (REFM)
Pacific cod (*Gadus macrocephalus*) is a transoceanic species, ranging from Santa Monica Bay, California, northward along the North American coast; across the Gulf of Alaska and Bering Sea north to Norton Sound; and southward along the Asian coast from the Gulf of Anadyr to the northern Yellow Sea; and occurring at depths from shoreline to 500 m. The southern limit of the species' distribution is about 34 N latitude, with a northern limit of about 65 N latitude. Pacific cod is distributed widely over the eastern Bering Sea (EBS) as well as in the Aleutian Islands (AI) area. Tagging studies have demonstrated significant migration both within and between the EBS, AI, and Gulf of Alaska (GOA). However, recent research indicates the existence of discrete stocks in the EBS and AI. Research conducted in 2018 indicates that the genetic samples from the NBS survey in 2017 are very similar to those from the EBS survey area, and quite distinct from samples collected in the Aleutian Islands and the Gulf of Alaska. Although the resource in the combined EBS and AI (BSAI) region had been managed as a single unit from 1977 through 2013, separate harvest specifications have been set for the two areas since the 2014 season.

The EBS Pacific cod model has undergone numerous model changes and refinements over the last decade. Preliminary models are reviewed in the spring of each year. The model uses the Stock Synthesis 3 framework. A major issue in recent years has been an apparent shift in the distribution of EBS Pacific cod into the northern Bering Sea (NBS), an area which historically has not been surveyed. Surveys in the NBS were conducted in 2010 and during 2017-2019, and regular NBS surveys are likely to be conducted into the future as EBS groundfish stocks experience changes in distribution. The lack of survey data in the NBS has caused assessment difficulties for Pacific cod and other stocks.

Many changes have been made or considered in the stock assessment model since the 2018 assessment. Seven models (including the current base model) were presented in this year's preliminary assessment. After reviewing the preliminary assessment, the SSC and Team requested that all of the models from the preliminary assessment be presented in the final assessment. In addition, the SSC requested three more new models. Following further explorations by the senior author and consultation with the SSC co-chairs and the Team and SSC rapporteurs assigned to this assessment, a compromise set of ten models (including the current base model) are included here. The nine new models are treated both individually and as an ensemble, with results for the latter presented as both weighted and unweighted averages.

Female spawning biomass for 2020 and 2021 is estimated by ensemble weighted average to be 259,509 t and 211,410 t, respectively, both of which are below the B40% value of 266,602 t. Given this, the ensemble weighted average estimates OFL, maximum permissible ABC, and the associated fishing mortality rates for 2020 and 2021 as follows: in 2020 OFL is 185,650 t and maxABC is155,873 t ; in 2021 OFL is 123,331 t and maxABC is 102,975 t.

Aleutian Islands (REFM)
This stock has been assessed separately from Eastern Bering Sea Pacific cod since 2013, and managed separately since 2014. The stock has been managed under Tier 5 (OFL = F * biomass, where F = M) since it was first assessed separately. No changes were made to assessment methodology, but data were updated with recent observations. Catch data from 1991-2018 were updated by including updated catch for 2017 and preliminary catch data for 2018, and the 2018 biomass point estimate and standard error were added to the survey time series. A random effects model using Aleutian Islands trawl survey biomass observations from 1991 to 2018 was used to estimate the biomass and provide management advice.

After declining by more than 50% between 1991 and 2002, survey biomass has since stayed in the range of 50-90 kilotons. The 2018 Aleutians survey biomass estimate (81,272 t) was down about 4% from the 2016 estimate (84,409 t). The estimate of the natural mortality rate is 0.34, which was taken from the 2018 EBS Pacific cod assessment model. For 2020 and 2021, the recommended ABC is 20,600 t, and OFL is 27,400 t.

Gulf of Alaska (REFM)
The 2019 assessment indicates that the stock has been lower in abundance than previously thought. It shows that the stock was likely below B20% since 2018 and will remain below until 2021. Although the AFSC bottom trawl survey index value did increase, the increase was not as high as last year's model had predicted. To accommodate these new data the model estimated the spawning biomass to have been lower than what was estimated last year relative to the unfished biomass. This not only drove 2018-2019 to be below B20%, but also, despite an increasing trend, predicted that the stock would remain below B20% in 2020. For 2020 the stock is estimated to be at B17.6%, above but very near the overfished determination level. The beginning of the year 2020 spawning biomass level is projected to be the lowest of the time series and with the 2017 and 2018 year classes should see an increase above B20% at the start of 2021.

Spawning biomass for 2020 is estimated by this year's model to be 32,958 t at spawning. This is below the B40% value of 75,112 t, thereby placing Pacific cod in sub-tier "b" of Tier 3. Given this, the model estimates the 2020 OFL at 17,794 t and the maxABC at 14,621.

For further information, contact Dr. Grant Thompson at (541) 737-9318 (BSAI assessment) or Dr. Steve Barbeaux (GOA assessment) (206) 526-4211.

F. Walleye Pollock

1. Research

Pre- and Post-Winter Temperature Change Index and the Recruitment of Bering Sea Pollock - ABL

Description of index: Pelagic fish were sampled using a trawl net towed in the upper 20 m of the north (60 to 65.5 °N, -168 to -172 °E) eastern Bering Sea during the Alaska Fisheries Science Centers' survey, 2002-2019 except 2008. Stations were approximately 30 nautical miles apart and a trawl was towed for approximately 30 minutes. Area swept was estimated from horizontal net opening and distance towed. Fish catch was estimated in kilograms. Five fish groups were commonly caught with the surface trawl: age-0 pollock, herring, juvenile Chinook salmon, juvenile coho salmon, and juvenile chum salmon.

Biomass (metric tonnes) in the area and during the time of the survey was estimated for using the single species model VAST package version 2.8.0 (Thorson 2015; Thorson et al. 2016a, b, c) using Microsoft Open R software version 3.5.3 (R Project 2017). The abundance index is a standardized geostatistical index developed by Thorson et al. (2015, 2016) to estimate indices of abundance for stock assessments. We estimated spatial and spatio-temporal variation for both encounter probability and positive catch rate components at a spatial resolution of 30 knots. Parameter estimates were within the upper and lower bounds and final gradients were less than 0.0005.

Status and trends: Temporal trends in the total estimated biomass of these fish groups indicated a decline in the productivity of fish in pelagic waters of the eastern Bering Sea in 2019. Relative to 2018, the abundance of juvenile chum salmon and herring increased, while there were notable decreases in the biomass of age-0 pollock, juvenile Chinook salmon, and juvenile coho salmon.

Factors causing trends: Biomass of these fish in pelagic waters during 2019, the sixth consecutive warm year, indicate poor environmental conditions for the growth and survival in the eastern Bering Sea during summer. Another possible explanation for decreased abundance is the movement of fish north into the Chukchi Sea. During 2019 surveys Farley et al. (personal communications) found age-0 pollock in this area.

Implications: Lower abundances of groundfish in surface waters during 2019 indicate a change in productivity in pelagic waters. The age-0 pollock abundances increased north of the survey area possibly in search of food during years of low lipid-rich prey such as large zooplankton (Coyle et al. 2011). Herring typically increase in abundance during warm years.

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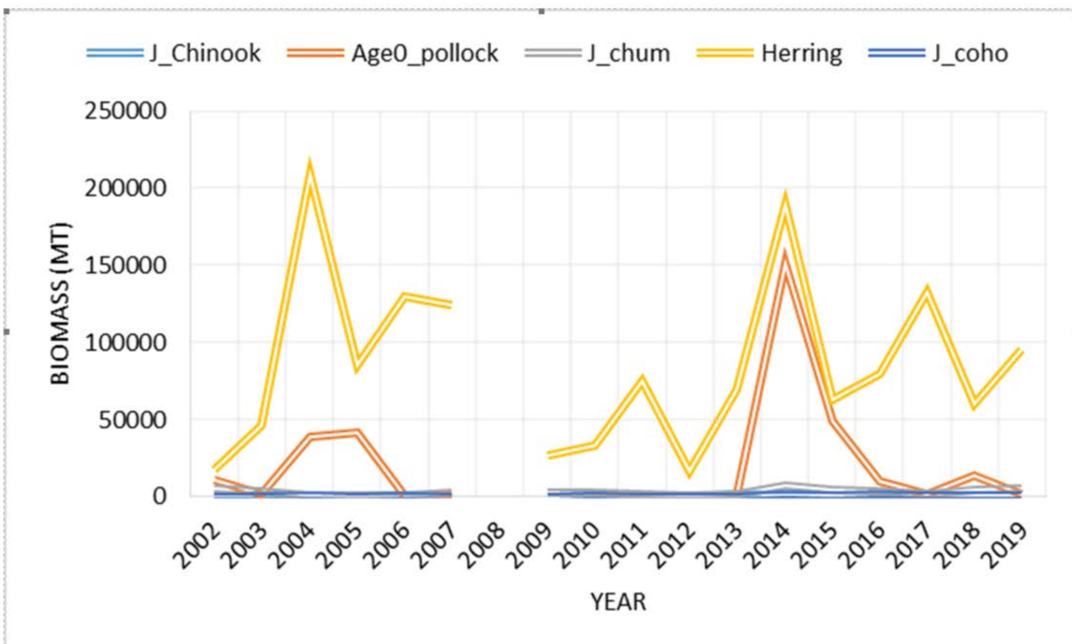

Figure 1. Estimated biomass (metric tonnes) of fish in pelagic waters of the northern Bering Sea, 2002-2019, less 2008.

For more information contact Ellen Yasumiishi (907) 789-6604, ellen.yasumiishi@noaa.gov

Large copepods as leading indicators of walleye pollock recruitment in the southeastern Bering Sea: sample-based and spatio-temporal model (VAST) results - ABL

Interannual variations in large copepod abundance were compared to age-3 walleye pollock (*Gadus chalcogrammus*) abundance (billions of fish) for the 2002-2016 year classes on the southeastern Bering Sea shelf, south of 60°N, < 200 m bathymetry. The large copepod index sums the abundances of *Calanus marshallae/glacialis* (copepodite stage 3 (C3)-adult), *Neocalanus* spp. (C3-adult), and *Metridia pacifica* (C4-adult), taxa typically important in age-0 pollock diets. Zooplankton samples were collected with oblique bongo tows over the water column using 60 cm, 505 µm mesh nets for 2002-2011, and 20 cm, 153 µm mesh and 60 cm, 505 µm nets, depending on taxa and stage for 2012-2016. Over the time period there were four warm years (2002-2005), followed by one average (2006), six cold (2007-2012), and three warm years (2014-2016). Zooplankton data was not available for 2013. Age-3 pollock abundance was obtained from the stock assessment report for the 2002-2015 year classes (Ianelli et al., 2018). Two estimates of a time series of large copepod abundances were calculated: the first used sample-based means of abundance data (number m^{-2}) and the second used the means estimated from the geostatistical model, Vector Autoregressive Spatial Temporal (VAST) package version 8_2_0 (Thorson et al., 2016). We specified 50 knots, a log normal distribution, and the delta link function between probability or encounter and positive catch rate in VAST.

Linear relationships were stronger for VAST modeled than sample-based mean abundances of large copepods collected during the age-0 stage of pollock, and stock assessment estimates of age-3 pollock for the 2002-2015 year classes (R^2= 0.74 and 0.43, respectively, Figure 1). Significant positive linear relationships were also observed between the bottom cold pool (< 2°C) area (indicative of sea ice coverage in the prior winter) during the age-0 year and subsequent age-3 pollock abundance (R^2 = 0.56) and ln(age-3 abundance /spawning stock biomass) (R^2 = 0.77). Our results suggest that a decrease in the availability of large lipid-rich copepod prey is unfavorable for age-0 pollock overwinter survival and recruitment to age-3. If the relationship between large copepods and age-3 pollock remains significant in our analysis, the index can be used to predict the recruitment of pollock three years in advance of recruiting to age-3. Results also provide support for the revised oscillating control hypothesis that suggests as the climate warms, reductions in sea ice (and reduced availability of ice-associated algae, an early spring food source) could be detrimental to large copepods and recruitment of the pollock stock in the region.

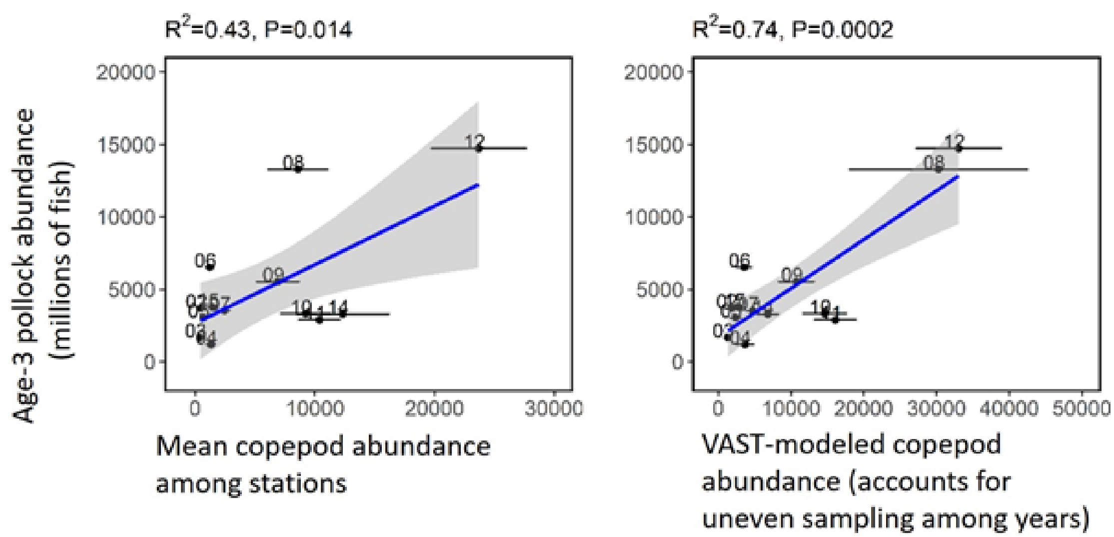

Fig. 1. Linear least squares regressions relating age-3 pollock abundance to sample-based and VAST model-based estimates of large copepod mean abundance in the southeastern Bering Sea, 2002–2015 (excluding 2013).

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Ianelli, J.N., Kotwicki, S., Honkalehto, T., McCarthy, A., Stienessen, S., Holsman, Siddon, E.C., K., Fissel, B., 2018. Assessment of walleye pollock stock in the Eastern Bering Sea, in: Stock Assessment and Fishery Evaluation Report for the Groundfish Resources of the Bering Sea/Aleutian Islands Regions. Anchorage: North Pacific Fisheries Management Council.

Thorson, J.T., Pinsky, M.L., Ward, E.J., 2016. Model-based inference for estimating shifts in species distribution, area occupied and centre of gravity. Methods Ecol. Evol. 7(8), 990–1002.

For more information contact Lisa Eisner at (206) 526-4060, lisa.eisner@noaa.gov or Ellen Yasumiishi at (907) 789-6604, ellen.yasumiishi@noaa.gov

RACE Recruitment Processes Program (RPP)
The Recruitment Processes Program's (RPP) overall goal is to understand the mechanisms that influence the survival of young marine fish to recruitment. Recruitment for commercially fished species occurs when they grow to the size captured or retained by the nets or gear used in the fishery. For each species or ecosystem component studied, we attempt to learn what biotic and abiotic factors cause or contribute to the observed fishery population fluctuations. These population fluctuations occur on many different time scales (for example, between years, between decades). The mechanistic understanding that results from our research is used to better manage and conserve the living marine resources for which NOAA is the steward.

For more information contact Janet Duffy-Anderson at: Janet.Duffy-Anderson@noaa.gov

Gulf of Alaska

Why location matters in predicting recruitment to a fish population in an advective marine system - Recruitment Processes Program - EcoFOCI
Matthew T. Wilson, Ned Laman
Many coastal marine fish populations inhabit advective environments and produce larvae that drift downstream. We examined walleye pollock *Gadus chalcogrammus*, a semipelagic gadid, in the western Gulf of Alaska (GOA) to advance our understanding of recruitment-cycle sensitivity to variation in flow. The coastal GOA is considered to be a downwelling system with intermittent upwelling; flow is driven by wind and freshwater input. We used time series of surface wind, hydrography, and fish distribution of abundance (Fig. 1) to 1) examine empirical support for the model-based hypothesis of downstream transport of propagules, including export from the GOA, 2) determine the relevance of surface wind, as indicators of advection, to geographic distributions of age-0 juveniles, and 3) test the relationship between surface wind and recruitment. First, year classes with high population density of larvae in the Shelikof core area corresponded with high abundance as age-0 juveniles in downstream regions adjacent to the southwest exit from the GOA; however, high age-0 abundance did not translate to high year class abundance as subadults (age-2 or -3) (Fig. 2). Second, upwelling-favorable wind was associated with greater offshore extent of relatively low-salinity surface water and age-0 juvenile abundance that was either high downstream or low overall. Third, 84% of the variation in recruitment over 12 year classes was explained by

surface wind vectors averaged for April-September when early life stages of walleye pollock are planktonic and susceptible to transport. Recruitment was favored by northeasterly wind just upstream of the main spawning area in Shelikof Strait. Furthermore, recruitment also increased with population density of age-0 juveniles in the Kodiak Island vicinity. Although preliminary, we hypothesize that the optimal wind for strong recruitment is moderate northeasterly because it favors downwelling and retention of planktonic propagules in the Kodiak vicinity. Resolving direct causal links from meteorology to recruitment is critical for anticipating marine resource response to climate forcing.

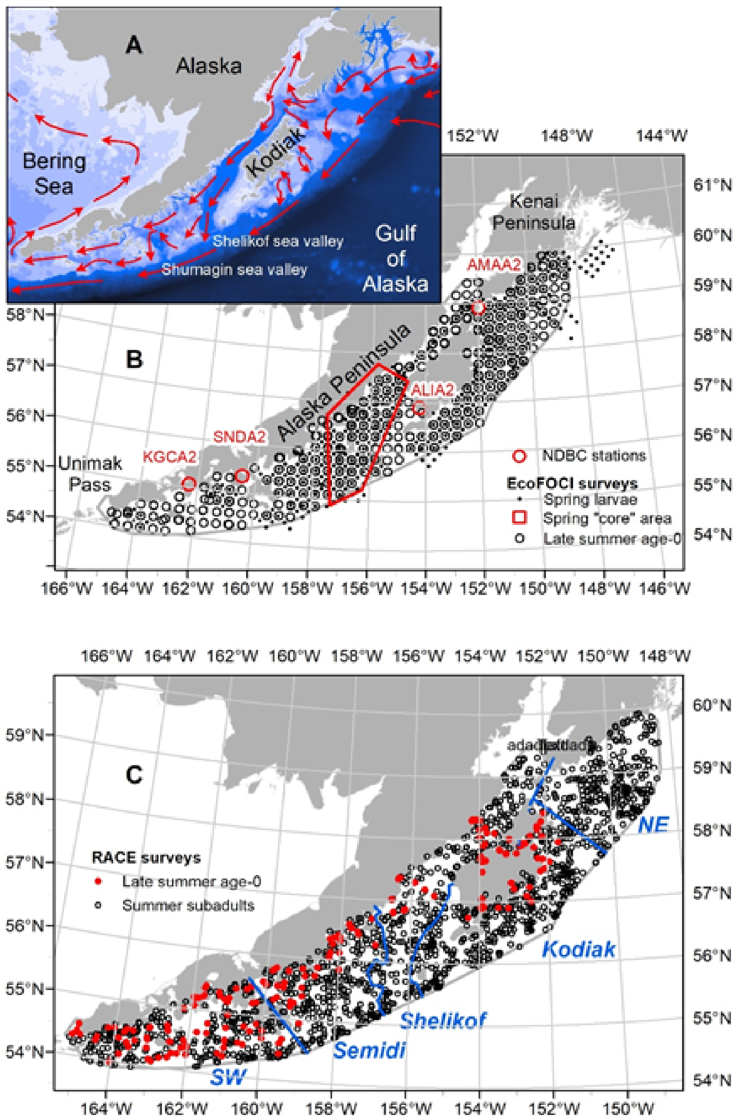


Figure 1. (A) Generalized flow over and along the shelf in the western Gulf of Alaska (Reed and Schumacher, 1986). (B) Location of four NDBC stations where wind vectors were recorded, and of EcoFOCI stations sampled during spring (larval walleye pollock, red polygon represents the "core" area) and late-summer (age-0 juveniles) in 2013, 2015, and 2017. (C) Location of RACE stations sampled during late-summer 1987 and 1988 (age-0 juveniles) and during summer bottom-trawl surveys during 1990, 2015, 2017, and 2019. Blue lines and labels depict the geographic stratification scheme. Grey polygon encompasses all age-0 collection sites (EcoFOCI and RACE).

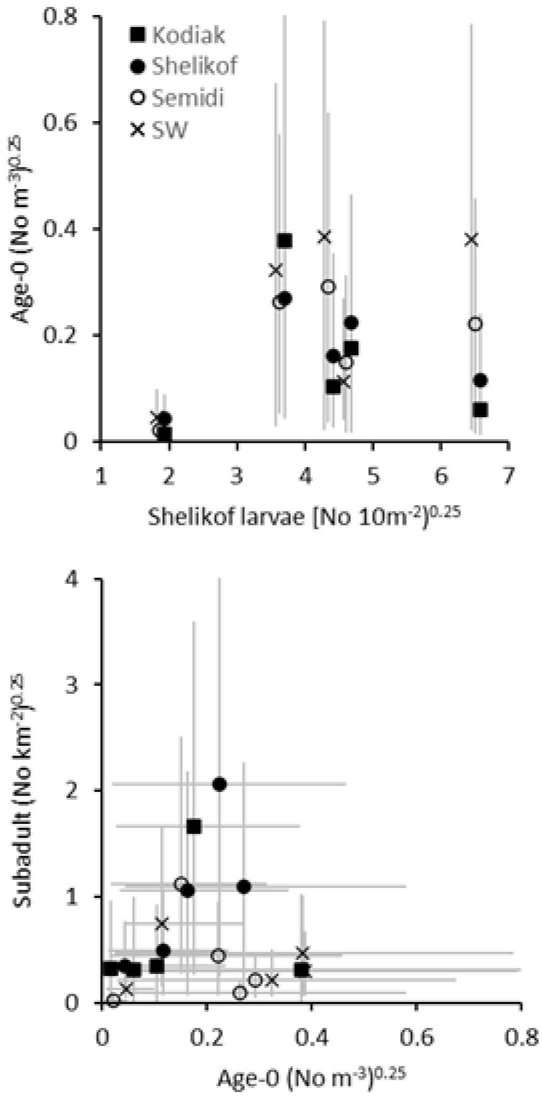


Figure 2. Region- and year-specific mean (± se) population density of age-0 juvenile walleye pollock during late summer in relation to population density of larvae in the EcoFOCI "core" area from Dougherty et al. (2019) (top, points are offset to show error bars), and to region- and year-specific mean population density of subadult walleye pollock (bottom).

For More Information Contact Matt Wilson at: Matt.Wilson@noaa.gov

Prey availability and prey selection resulted in regional differences in size and abundance in the 2013 year class of Gulf of Alaska walleye pollock- EcoFOCI

A survey-based time series (2001-2019) of abundance showed that age-0 walleye pollock (*Gadus chalcogrammus*) occurred in very high abundances in 2013 compared to other years, however recruitment of the 2013 year-class to age-1 was lower than average. To assess the potential for resource competition, diets of age-0 fish were examined from the 2013 year class. High abundances of smaller age-0 fish were found at stations southwest of the Shumagin Islands (domain A) compared to low abundances of larger fish found near and around Kodiak Island (domain C). Fish in the Shumagin Islands region showed a higher intake of low-quality food items such as pteropods and larvaceans compared to fish from the Kodiak Island region that had consumed mostly higher quality prey such as large copepods and euphausiids (Fig 1). No significant differences were found in fish condition throughout the study region. However, Prey-specific Index of Relative Importance analysis showed Shumagin region fish selected from a larger suite of prey items, where fish from the rest of the study area primarily selected large copepods and euphausiids as preferred prey (Fig 2). These results suggest that very high abundances of smaller pollock found near the Shumagin Islands experienced resource limitation inhibiting overwinter survival, had potentially increased mortality through competition, and potential cannibalism from the strong prior year class.

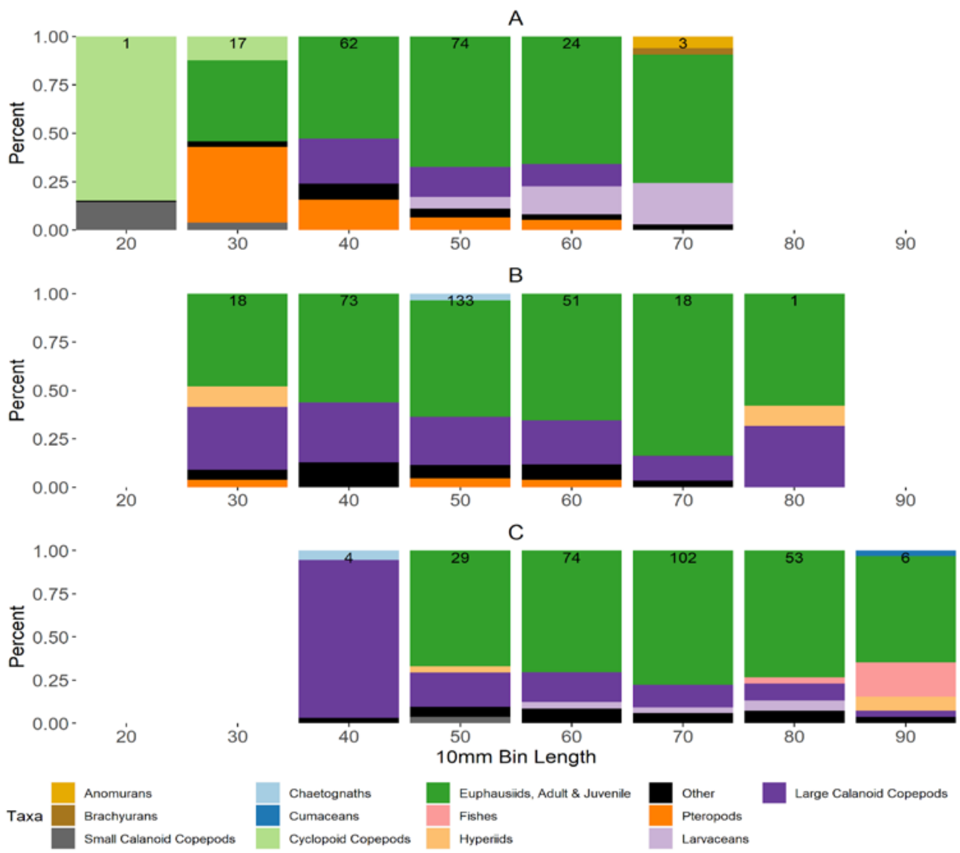


Figure 1. Age-0 pollock diet composition (percent weight) by 10mm length bins. The “Other” prey category was the sum total of prey categories that comprised less than 3% of the total prey weight in both regions.

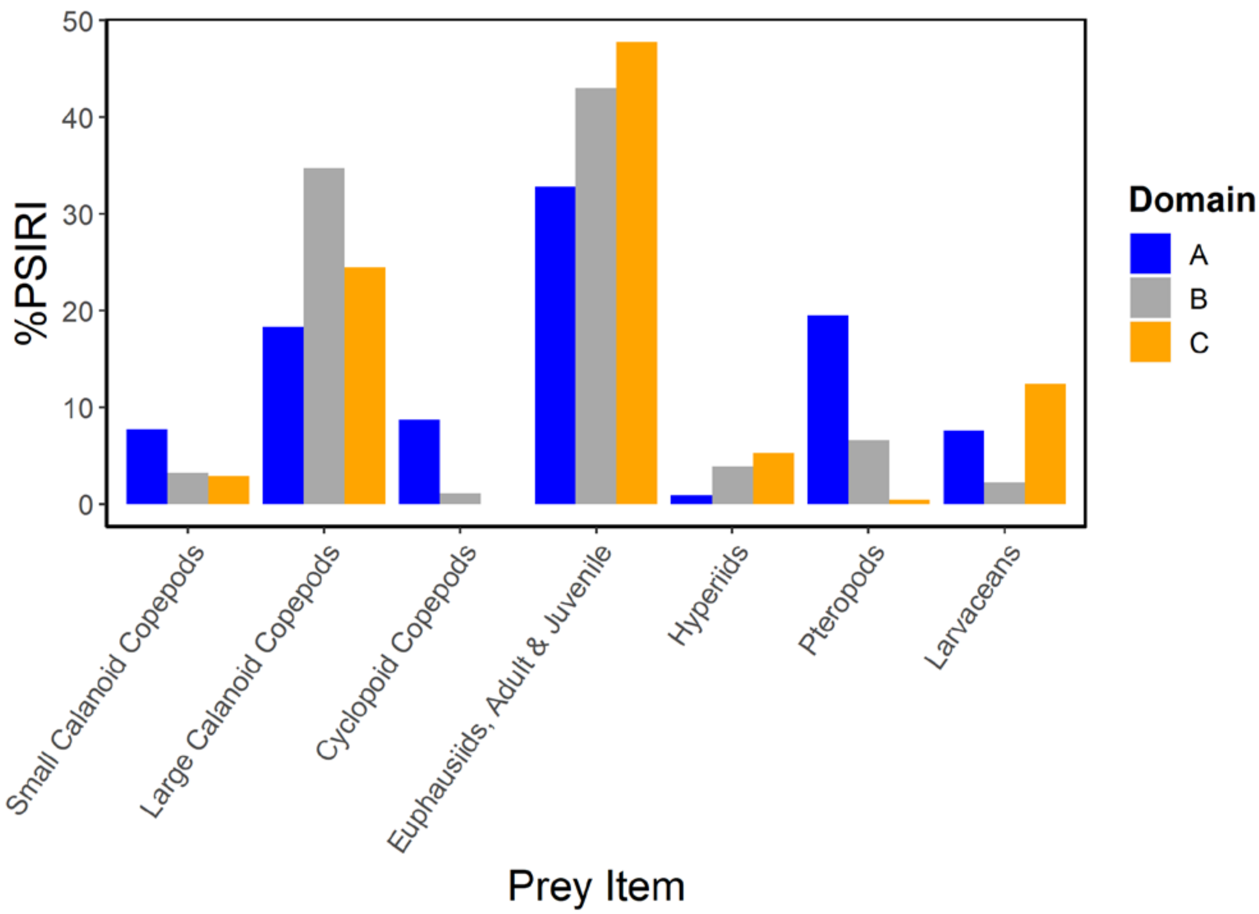


Figure 2. The top five selected prey taxa as determined by the PSIRI for stations southwest of Shumagin Is. (Domain A), between the Shumagin Is. and Kodiak Is. (Domain B) and stations surrounding and to the northeast of Kodiak Isl. (Domain C).

For more information please contact Jesse Lamb at: Jesse.F.Lamb@noaa.gov or David G. Kimmel

Bering Sea

Vertical Distribution of age-0 walleye pollock in the eastern Bering Sea - RPP/EcoFOCI

As part of the Bering Arctic Subarctic Integrated Survey (BASIS), we analyzed acoustic –trawl (AT) survey data collected on the Oscar Dyson during routine research surveys over the SEBS shelf. A cold year (2012), an intermediate year (2011), and 2 warm years (2014-2016) were included in the analysis to compare the vertical distribution of age-0 Walleye Pollock (*Gadus chalcogrammus*) during different temperature regimes. Surface, midwater, and oblique tows were conducted using the Cantrawl, Marinovich, and Nets-156 trawls. Age-0 pollock AT data collected during intermediate and cold years showed a deeper vertical distribution, while age-0 pollock AT data collected during warm years showed a shallower, more surface oriented distribution (Figure 1). Juvenile pollock that were caught in deeper depths were more energy dense, than fish caught in the surface, in both warm and cold years (Figure 2). Shifts to deeper, colder water during warm years could provide a metabolic refuge from warm surface waters (see Duffy-Anderson et al., 2017), as well as an improved prey base as age-0 pollock follow the diel vertical migration patterns of major prey species (copepods, euphausiids) to promote continued vertical overlap with prey.

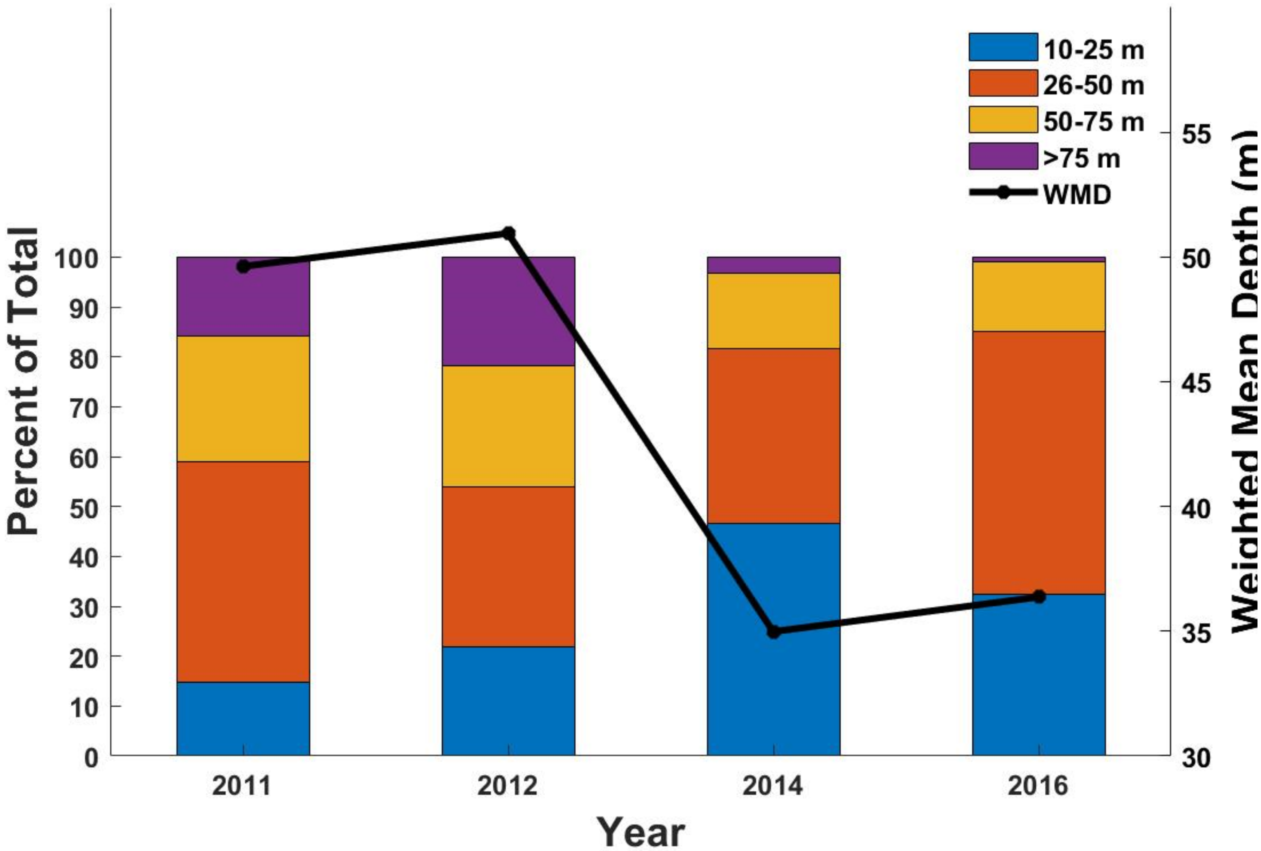


Figure 1. Depth distribution as percent of total abundance (fish nmi^{-2}) and weighted mean depth of age-0 pollock estimated by acoustic-trawl methods in 2011,2012, 2014,2016.

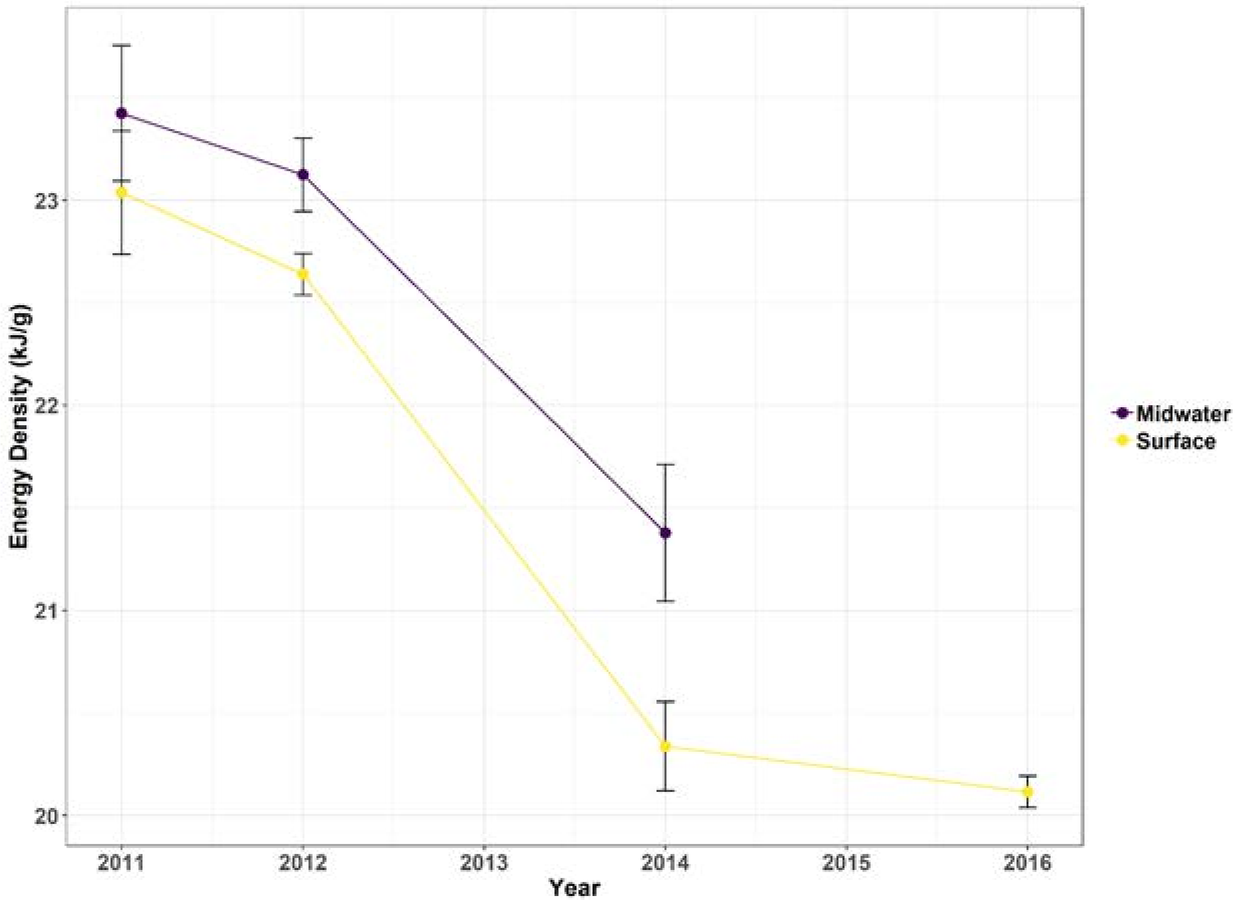


Figure 2. Energy density (± S.E.) for age-0 pollock caught in surface and midwater trawls.

Duffy-Anderson, J.T, Stabeno, P.J., Siddon, E.C., Andrews, A., Cooper, D., Eisner, L., Farley, E., Harpold, C., Heintz, R., Kimmel, D., Sewall, F., Spear, A., and Yasumishii, E. 2017. Return of warm conditions in the southeastern Bering Sea: phytoplankton- fish. *PLOS ONE*. https://doi.org/10.1371/journal.pone.0178955

For more information please contact Adam Spear at: Adam.Spear@noaa.gov or Alex Andrews.

Management strategies for the eastern Bering Sea pollock fishery with climate change -- ESSR
Recent studies indicate that rising sea surface temperature (SST) may have negative impacts on eastern Bering Sea walleye pollock stock productivity. A previous study (*Ianelli et al 2011 ICES J Mar Sci 68: 1297–1304*) developed projections of the pollock stock and alternative harvest policies for the species, and examined how the alternative policies perform for the pollock stock with a changing environment. The study, however, failed to evaluate quantitative economic impacts. The present study showcases how quantitative evaluations of the regional economic impacts can be applied with results evaluating harvest policy trade-offs; an important component of management strategy evaluations. In this case, we couple alternative harvest policy simulations (with and without climate change) with a regional dynamic computable general equilibrium (CGE) model for Alaska. In this example we found (i) that the status quo policy performed less well than the alternatives (from the perspective of economic benefit), (ii) more conservative policies had smaller regional output and economic welfare impacts (with and without considering climate change), and (iii) a policy allowing harvests to be less constrained performed worse in terms of impacts on total

regional output, economic welfare, and real gross regional product (RGRP), and in terms of variability of the pollock industry output. The results of this project are summarized in Seung and Ianelli (2017), which is currently under review / revision at a peer-reviewed journal. For further information, contact Chang.Seung@noaa.gov

An examination of size-targeting in the Bering Sea pollock catcher processor fishery -- ESSR
Weight-based harvest quota regulations do not restrict the size of individual fish that fill that quota, although fish of different sizes may present varying fishery profit opportunities and have different impacts on the stock's growth potential. This paper empirically links revenue per unit of quota and fish size by investigating the catcher-processor fleet of the U.S. Bering Sea pollock fishery, where larger fish can be made into higher-value fillets, instead of surimi that is lower value on average. We then use a dynamic age-structured model to illustrate how some harvesters target smaller fish to decrease their own harvesting costs, which imposes a stock externality on the fleet. This is a working paper that is being revised for submission to a peer-reviewed journal. We estimate the potential increase in profit if a manager hypothetically controls for the size of fish caught in the pollock fishery. Fishers benefit due to higher prices coming from higher-value products, and greater catches because of a larger biomass. For further information contact Alan.Haynie@noaa.gov.

2. Stock Assessment

Eastern Bering Sea (REFM)
Walleye pollock (Gadus chalcogrammus; hereafter referred to as pollock) are broadly distributed throughout the North Pacific with the largest concentrations found in the Eastern Bering Sea. Also known as Alaska pollock, this species continues to play important roles ecologically and economically. This is a mature assessment done annually with new catch, survey, and composition information. For the 2019 assessment this included data from the 2019 NMFS bottom-trawl (BTS) and acoustic-trawl (ATS) surveys as well as total catch through 2019. In addition, opportunistic acoustic data from vessels (AVO) conducting the 2019 BTS was used as an added index of pollock biomass in mid- water. Observer data for catch-at-age and average weight-at-age from the 2018 fishery were finalized and included.

Spawning biomass in 2008 was at the lowest level since 1981 but had increased by a factor of 2.52 by 2017, and has now started trending downward again. The 2008 low was the result of extremely poor recruitments from the 2002-2005 year classes. Recent increases were fueled by recruitment from the very strong 2008, 2012, and 2013 year classes along with spawning exploitation rates below 20% since 2008. Spawning biomass is projected to be well above BMSY in 2020. The 2020 OFL is 4,273,000 t and the maximum ABC is 3,578,000 t.

In addition to the ecosystem considerations listed in the SAFE chapter, an appendix to the SAFE chapter describes a multi-species model ("CEATTLE") involving walleye pollock, Pacific cod, and arrowtooth flounder. The authors view this as a "strategic" model rather than a model that would be used for setting annual harvest specifications.

Aleutian Islands (REFM)
The Aleutian Islands (AI) pollock stock assessment has changed to a biennial cycle with full assessments in even years timed with the Aleutian Islands bottom trawl survey, and partial assessments in odd years. Partial assessments include updated harvest recommendations; the 2020

OFL is 66,973 t and 2020 maximum ABC is 55,120 t.

Bogoslof Island (REFM)

Assessments for Bogoslof-area pollock are performed in even years and the harvest recommendations are not revised in off years. Harvest recommendations for Bogoslof-area pollock are made by multiplying the biomass estimate from the NMFS acoustic-trawl survey by an estimate of natural mortality. The biomass estimate is made using a random effects model used widely in AFSC assessments. Natural mortality was re-evaluated using the age-structured model presented in previous assessments (unchanged except for new survey, fishery, and age composition data from the survey).

Between 1997 and 2016, biomass estimates varied between 508,051 t and 67,063 t. The most recent acoustic-trawl survey of the Bogoslof spawning stock was conducted in March of 2018 and estimated a biomass estimate of 663,070 t, resulting in a random-effects survey average of 610,267 t. Assuming FOFL = M = 0.3 and FABC = 0.75 x M = 0.225, OFL for 2020 is 183,080 t and the maximum permissible ABC for 2020 is 137,310 t.

Gulf of Alaska (REFM)

The base model projection of female spawning biomass in 2020 is 206,664 t, which is 42.6% of unfished spawning biomass (based on average post-1977 recruitment) and above B40% (194,000 t), thereby placing GOA pollock in sub-tier “a” of Tier 3. New survey data in 2019 continue to show strong contrast, with the 2019 Shelikof Strait acoustic survey indicating high biomass, and the 2019 NMFS bottom trawl survey indicating relatively low biomass (the second lowest in the time series). The 2019 ADF&G bottom trawl is also low, while the 2019 summer acoustic survey is intermediate.

The authors’ 2020 ABC recommendation for pollock in the Gulf of Alaska west of 140° W longitude (the main portion of the GOA pollock stock) 108,494 t, which is a decrease of 20% from the 2019 ABC, but very close to the projected 2020 ABC in last year’s assessment. The author’s recommended ABC was obtained by applying a 10% buffer to the maximum permissible ABC, based on the concerns about the stock assessment detailed above. A buffer of 10% to address substantially increased concerns is slightly lower than the buffer that was applied last year (14%) to address slightly more elevated concerns, and seemed an appropriate starting point for Plan Team and SSC deliberations. The author’s recommended ABC for 2021 is 111,888 t, using the same 10% buffer to the maximum permissible ABC in 2021. The OFL in 2020 is 140,674 t, and the OFL in 2021 if the ABC is taken in 2020 is 149,988 t. It should be noted that the ABC is projected to stabilize over the next few years, due recruitment of the strong 2018 year class into the fishery.

For further information regarding BSAI pollock contact Dr. James Ianelli (jim.ianelli@noaa.gov); for further information regarding GOA pollock contact Dr. Martin Dorn (martin.dorn@noaa.gov).

G. Pacific Whiting (hake)

There are no hake fisheries in Alaska waters.

H. Rockfish

1. Research

Rockfish Reproductive Studies - RACE GAP Kodiak

RACE groundfish scientists initiated a multi-species rockfish reproductive study in the Gulf of Alaska with the objective of providing more accurate life history parameters to be utilized in stock assessment models. Another goal of this project is to examine the variability of rockfish reproductive parameters over varying temporal and spatial scales. The analysis of maturity for three deep water rockfish species, blackspotted rockfish, *Sebastes melanostictus,* rougheye rockfish, *S. aleutianus,* and shortraker rockfish, *S. borealis,* has been complicated by the presence of a significant number of mature females that skip spawning. Additional data are needed to determine if skip spawning rates and other maturity parameters vary with time. Recent studies suggest variation in size and age at maturity may occur for the three most commercially important species, Pacific ocean perch, *S. alutus,* northern rockfish, *S. polyspinis,* and dusky rockfish *S. variabilis.* Researchers at the AFSC Kodiak Laboratory will be examining annual differences in reproductive parameter estimates of Pacific ocean perch and northern rockfish in the upcoming years. Sampling for this study was initiated in 2009 and opportunistically continues with the anticipation that sampling will be sustained at least through the 2021 reproductive season.

Northern and Dusky Rockfishes

The reproductive potential of northern rockfish (*Sebastes polyspinis*) and dusky rockfish (*S. variabilis*) in the Gulf of Alaska was examined by measuring the success of oocyte and embryo development. The potential annual fecundity, annual failure rates, and relationships of these parameters to maternal size were examined. Both species have a seasonally synchronous reproductive cycle with parturition occurring in the late spring to early summer. Northern rockfish had a mean relative fecundity of 165.1 oocytes/g for samples captured in December and 109.6 embryos/g for samples captured in May. Dusky rockfish had a mean relative fecundity of 152.1 oocytes/g for samples collected in December and 108.1 embryos/g for samples captured in May. Reproductive failure was easiest to discern for the May samples with both partial and total failure primarily occurring due to lack of oocyte development or fertilization failure. Northern rockfish had a total reproductive failure or skipped spawning rate of 16.3% and dusky rockfish had total reproductive failure rate of 15.6% during this period. Larger dusky and northern rockfish had higher relative fecundities and lower rates of reproductive failure. In the upcoming year historic samples of northern rockfish will be examined to see if there have been temporal changes in maturity, fecundity, and reproductive failure.

Conrath, C. 2019. Reproductive Potential of Dusky and Northern Rockfish within the Gulf of Alaska. Fishery Bulletin 117: 140-150.

Rougheye and blackspotted rockfish

The recent discovery that rougheye rockfish are two species, now distinguished as ‘true’ rougheye rockfish, *Sebastes aleutianus*, and blackspotted rockfish, *Sebastes melanostictus* further highlights the need for updated reproductive parameter estimates for the members of this species complex. Current estimates for age and length at maturity for this complex in the GOA are derived from a study with small sample sizes, few samples from the GOA, and an unknown mixture of the two species in the complex. A critical step in improving the management of this complex is to understand the reproductive biology of the individual species that comprise it. This study re-examined the reproductive biology of rougheye rockfish and blackspotted rockfish within the GOA utilizing histological techniques to microscopically examine ovarian tissue. Maturity analyses for these species and other deepwater rockfish species within this region are complicated by the presence of mature females that are skip spawning. Results from this study indicate age and length at 50% maturity for rougheye rockfish are 19.6 years and 45.0 cm FL with 36.3% of mature females not developing or skip spawning. Samples of blackspotted rockfish were also collected and analyzed during this time period. This study found age and length at 50% maturity for blackspotted rockfish are 27.4 years and 45.3 cm FL with 94% of mature females collected for this study skip spawning. The analyses of these data is complicated by the presence of both skip spawning individuals within the sample as well as a large number of large and/or old immature individuals. More samples are needed to clarify the reproductive parameters of this species. These updated values for age and length at maturity have important implications for stock assessment in the GOA. Additional samples of rougheye and blackspotted rockfish have been collected from the 2016 reproductive season and are being analyzed to compare temporal differences in reproductive parameters and rates of spawning omission. Initial analyses of rougheye rockfish collected during this later reproductive season indicate that the length at maturity values were similar to the earlier period but skipped spawning rates were about 15% lower for this species. This study will be concluded within the upcoming year.

For further information please contact Christina Conrath (907) 481-1732.

Shortraker rockfish
Currently stock assessments for shortraker rockfish, *Sebastes borealis* utilize estimates of reproductive parameters that are problematic due to limited sample sizes and samples taken during months of the years that may not be optimum for reproductive studies. The current study results indicate a length of 50% maturity of 49.9 cm which is a larger than the value currently used in the stock assessment of this species (44.5 cm). In addition, this study found a skip spawning rate of over 50% for this species during the sampling period. Length at maturity data for this species were later utilized to derive an indirect age at 50% maturity for this species based on converting the length at maturity to an age at maturity. However, the ages used for this conversion were considered experimental, and additional samples are needed for updated, direct determination of the age at 50% maturity when the aging methodology for shortraker rockfish becomes validated. Researchers at the AFSC Age and Growth lab have initiated a study to initiate the aging of shortraker rockfish. Due to difficulties with aging this species which attains very old ages, additional collaborative work with other agencies is being pursued to develop a consistent methodology for aging this species. Additional samples of shortraker rockfish have been collected from the 2016 reproductive season and are being analyzed to compare temporal differences in reproductive parameters and rates of spawning omission. Preliminary analyses of these samples indicate that the length at maturity values are similar to the earlier time period but rates of skipped spawning were about 15% lower. This study will be concluded within the upcoming year.

For further information please contact Christina Conrath (907) 481-1732.

2. Assessment

Pacific Ocean Perch (POP) – Bering Sea and Aleutian Islands - REFM
In 2005, BSAI rockfish were moved to a biennial assessment schedule with full assessments in even

years to coincide with the occurrence of trawl surveys in the Aleutian Islands (AI) and the eastern Bering Sea (EBS) slope. In odd years, partial assessments include revised harvest recommendations. The 2020 OFL is and the 2020 maximum ABC is 58,956 t and the 2020 OFL is 48,846 t.

For more information contact Paul Spencer,(206) 526-4248 or paul.spencer@noaa.gov.

Pacific Ocean Perch -- Gulf of Alaska - ABL
In 2019, an assessment was conducted for Gulf of Alaska Pacific ocean perch. New data in the 2019 assessment included updated 2018 catch and estimated 2019 catch, survey biomass estimates for 2019, survey age compositions for 2017, and fishery age composition for 2018. No changes were made to the assessment model and the model used in 2019 was the same as in 2017.

Spawning biomass was above the $B_{40\%}$ reference point and projected to be 201,518 t in 2020 and to decrease to 194,795 t in 2021. The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying Pacific ocean perch for management under Tier 3. The current estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are 127,935 t, 0.09, and 0.108, respectively. Spawning biomass for 2020 is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier "a" of Tier 3. The 2020 and 2021 catches associated with the $F_{40\%}$ level of 0.094 are 31,238 t and 29,983 t, respectively, and were the authors' and Plan Team's recommended ABCs. The 2020 and 2021 OFLs are 37,092 t and 35,600 t.

A random effects model was used to set regional ABCs based on the proportions of model-based estimates for 2020: Western GOA = 1,437 t, Central GOA = 23,678 t, and Eastern GOA = 6,123 t. The Eastern GOA is further subdivided into west (called the West Yakutat subarea) and east (called the East Yakutat/Southeast subarea, where trawling is prohibited) of 140° W longitude using a weighting method of the upper 95% confidence of the ratio in biomass between these two areas. For W. Yakutat the ABC in 2020 is 1,470 t and for E. Yakutat/Southeast the ABC in 2020 is 4,653 t. The recommended OFL for 2020 is apportioned between the Western/Central/W. Yakutat area (31,567 t) and the E. Yakutat/Southeast area (5,525 t). Pacific ocean perch is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

A new addition to the assessment in 2019 was the risk table requested by the Plan Teams and SSC. This addition was requested to highlight concerns with the assessment and other environmental and ecological concerns that may not be encapsulated in the assessment and would cause concern about the recommended reference points. The overall score for GOA Pacific ocean perch was ranked at level 2, substantially increased concerns, because of the consistent underestimation by the assessment model of bottom trawl survey biomass since 2013. It was noted that while the risk table has been commonly used to recommend reductions in ABC, in this particular case it indicates that an increase in ABC could be warranted due to the model's consistent underestimation.

For more information contact Pete Hulson, ABL, at (907) 789-6060 or pete.hulson@noaa.gov.

Dusky Rockfish-- Gulf of Alaska - ABL

In 2019, the 2018 full assessment for GOA dusky rockfish was updated with new catch data and projections were re-run to provide estimates of total & spawning biomass, biological reference points, and OFL and ABC for 2020 and 2021. Estimates of female spawning biomass for 2020 and 2021 from the updated projections were 20,116 t and 19,631 t, respectively. Both estimates are above the B40% estimate of 18,535 t. The dusky rockfish stock is in Tier 3a and the recommended maximum permissible 2020 ABC was 3,676 t from the updated projection model. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching an overfished condition. The following table shows the recommended ABC apportionment (t) for 2020 and 2021.

For more information, contact Kari Fenske, ABL, at (907) 789-6653 or kari.fenske@noaa.gov.

Northern Rockfish – Bering Sea and Aleutian Islands - REFM

A full assessment for BSAI northern rockfish was performed in 2019. The stock is not overfished or approaching an overfished condition. The recommended 2020 ABC and OFL are 16,243 t and 19,751 t, which are 30% and 31% increases from the values specified last year for 2020 of 12,396 t and 15,180 t. The reason for the increase in the harvest level is updated data showing larger weight at age for the fishery than was used in previous assessments, and a change in the estimated survey selectivity curve that scaled the population higher than previous assessments.

For further information, contact Paul Spencer at (206) 526-4248

Northern Rockfish – Gulf of Alaska-ABL

This chapter was presented in executive summary format, as a scheduled “off-year” assessment. Therefore, only the projection model was run, with updated catches. New data in the 2019 assessment included updated 2018 catch and estimated 2019 and 2020 catches. No changes were made to the assessment model.

Spawning biomass is above the $B_{40\%}$ reference point and projected to be 34,410 t in 2020 and to decrease to 32,435 t in 2021. The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying northern rockfish for management under Tier 3. The current estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are 30,480 t, 0.061, and 0.073, respectively. Spawning biomass for 2020 is projected to exceed $B_{40\%}$, thereby placing northern rockfish in sub-tier “a” of Tier 3. The 2020 and 2021 catches associated with the $F_{40\%}$ level of 0.061 are 4,312 t and 4,107 t, respectively, and were the authors’ and Plan Team’s recommended ABCs. The recommended 2020 and 2021 OFLs were 5,143 t and 4,898 t.

A random effects model was used to set regional ABCs based on the proportions of model-based estimates for 2020: Western GOA = 1,133 t, Central GOA = 3,178 t, and Eastern GOA = 1 t (note that the small ABC in the Eastern GOA is included with ‘other rockfish’ for management purposes). The recommended OFL for 2020 and 2021 is not regionally apportioned. Northern rockfish is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

For more information, contact Pete Hulson, ABL, at (907) 789-6060 or pete.hulson@noaa.gov.

Shortraker Rockfish - - Bering Sea and Aleutian Islands - REFM

No assessment for this stock was performed in 2019, so the OFL and ABC for 2020 is the same as for 2019: 722 t and 541 t, respectively.

Shortraker Rockfish – Gulf of Alaska – ABL

The Gulf of Alaska (GOA) shortraker rockfish are assessed on a biennial stock assessment schedule with a full stock assessment produced in odd years and no stock assessment produced in even years. For this on-cycle year, we incorporated Relative Population Weights (RPWs) from the 1992 – 2019 longline surveys, incorporated new trawl survey biomass, and updated catch.

Shortraker rockfish has always been classified into "tier 5" in the North Pacific Fishery Management Council's (NPFMC) definitions for ABC and overfishing level. Following the recommendation of the NPFMC for all Tier 5 stocks, we continue to use a random effects (RE) model fit to survey data to estimate exploitable biomass and determine the recommended ABC, but a new method of combining the AFSC longline survey Relative Population Weight (RPW) index (1992 - 2019) with the AFSC bottom trawl survey biomass index (1984 – 2019) within the random effects model was used to estimate the exploitable biomass that is used to calculate the ABC and OFL values for the 2020 fishery. Estimated shortraker biomass is 31,465 mt, which is a decrease of 18% from the 2017 estimate. This is the second substantial decline in biomass since seeing a progressive increase in biomass since 1990. The NPFMC's "tier 5" ABC definitions state that $F_{ABC} \leq 0.75M$, where *M* is the natural mortality rate. Using an *M* of 0.03 and applying this definition to the exploitable biomass of shortraker rockfish results in a recommended ABC of 708 t for the 2020 fishery. Gulfwide catch of shortraker rockfish was 763 t in 2018 and estimated at 536 t in 2019. Shortraker rockfish in the GOA is not being subjected to overfishing. It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

For more information contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

Other Rockfish – Gulf of Alaska – ABL

The Other Rockfish complex in the Gulf of Alaska (GOA) is comprised of 27 species, but the composition of the complex varies by region. The species that are included across the entire GOA are the 17 rockfish species that were previously in the "Other Slope Rockfish" category together with yellowtail and widow rockfish, formerly of the "Pelagic Slope Rockfish" category. Northern rockfish are included in the Other Rockfish complex in the eastern GOA and the Demersal Shelf rockfish species are included west of the 140 line (i.e. all of the GOA except for NMFS area 650). The primary species of "Other Rockfish" in the GOA are sharpchin, harlequin, silvergray, redstripe and yelloweye rockfish; most of the others are at the northern end of their ranges in Alaska and have a relatively low abundance here. Rockfish in the GOA have been moved to a biennial stock assessment and the "Other Rockfish" stock complex is assessed in odds years. The last full assessment was in 2019 for the 2020 fishery and the next full assessment will be completed in 2021.

This complex consists of species assessed as Tier 4, Tier 5 or Tier 6, based on data availability. The complex is managed as a whole and the acceptable biological catch (ABC) and overfishing level (OFL) for each species are summed to create the ABC/OFL for the complex. The Tier 4/5 species ABC/OFLs are based on a random effects model applied to the biennial GOA trawl survey data. This results in a current exploitable biomass of 96,107 t for "Other Rockfish". Applying either an $F_{ABC} \leq F_{40\%}$ rate for sharpchin rockfish or an $F_{ABC} \leq 0.75M$ (*M* is the natural mortality rate) for the tier 5 species to the exploitable biomass for Other Rockfish results in a recommended ABC in the

GOA of 3,847 t, which was combined with the tier 6 ABC of 193 t for a total complex ABC of 4,040 t for 2019 and 2020.

Gulfwide catch of Other Rockfish was 1,205 t and 957 t in 2018 and 2019, respectively. Other rockfish is not considered overfished in the Gulf of Alaska, nor is it approaching overfishing status. However, the apportioned ABC for the Western GOA has often been exceeded. Beginning in 2014, the Western and Central GOA apportioned ABCs were combined. This was not deemed a conservation concern because the combined catch of the Western and Central GOA does not always exceed the combined ABC of the two areas, nor is the catch of Other Rockfish approaching the complex ABC.

For more information contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

Blackspotted/rougheye Rockfish Complex – Bering Sea and Aleutian Islands - REFM
Fish previously referred to as rougheye rockfish are now recognized as consisting of two species, rougheye rockfish (*Sebastes aleutianus*) and blackspotted rockfish (*Sebastes melanostictus*). The current information on these two species is not sufficient to support species-specific assessments, so they are combined as a complex in one assessment. In 2005, BSAI rockfish were moved to a biennial assessment schedule with full assessments in even years to coincide with the occurrence of trawl surveys in the Aleutian Islands (AI) and the eastern Bering Sea (EBS) slope. In odd years, partial assessments include revised harvest recommendations. The 2020 maximum ABC is 817 t and the 2020 OFL is 675 t.

For more information contact Paul Spencer, (206) 526-4248 or paul.spencer@noaa.gov.

Blackspotted/rougheye Rockfish Complex – Gulf of Alaska - ABL
Rougheye (*Sebastes aleutianus*) and blackspotted rockfish (*S. melanostictus*) have been assessed as a stock complex since the formal verification of the two species in 2008. We use a statistical age-structured model as the primary assessment tool for the Gulf of Alaska rougheye and blackspotted rockfish (RE/BS) stock complex, which qualifies as a Tier 3 stock. In accordance with the new assessment schedule frequency, we conducted a full assessment for RE/BS in 2019 with updated assessment and projection model results to recommend harvest levels for the next two years.

Please refer to this year's full stock assessment and fishery evaluation (SAFE) report for further information regarding the stock assessment (Shotwell et al., 2019, available online at https://archive.afsc.noaa.gov/refm/docs/2019/GOArougheye.pdf).

We use a statistical age-structured model as the primary assessment tool for the Gulf of Alaska rougheye and blackspotted (RE/BS) rockfish complex that qualifies as a Tier 3 stock. This assessment consists of a population model, which uses survey and fishery data to generate a historical time series of population estimates, and a projection model, which uses results from the population model to predict future population estimates and recommended harvest levels. The data sets used in this assessment include total catch biomass, fishery age and size compositions, trawl and longline survey abundance estimates, trawl survey age compositions, and longline survey size compositions.

There were no changes made to the assessment model as we continue to use the full assessment base model from 2015. New data added to the model included updated and new catch estimates, new fishery lengths, new trawl and longline survey estimates, new trawl survey ages, and new longline survey lengths.

The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. The 2019 trawl survey estimate increased 39% from the 2017 estimate and is now 22% above average. The 2018 longline survey abundance estimate (RPN) decreased about 31% from the 2017 estimate and the 2019 longline RPN estimate decreased about 11% from the 2017 estimate and increased 29% from the 2018 estimate. The longline survey is now 13% above average. Since 2005, the total allowable catches (TACs) for RE/BS rockfish have not been fully taken, and are generally between 20-60% of the TAC and is at 40% as of October 1, 2019. This ratio has been declining in the eastern GOA (by about 20%) and increasing in the central GOA (by about 20%) since 2012, whereas catches in the western GOA have been relatively steady over time (about 40% of regional apportionment).

For the 2019 fishery, the Plan Team accepted the authors' recommended maximum permissible ABC of 1,209 t ($F_{ABC} = F_{40\%} = 0.04$) and OFL of 1,452 t ($F_{OFL}=F_{35\%} = 0.048$).

The apportionment percentages have changed this year and now use a version of the random effects model incorporating both the longline and trawl survey relative abundance indices (equally weighted). Please refer to the full stock assessment document for information regarding the apportionment rationale for RE/BS rockfish. Area apportionments based on the new two survey random effects method are as follows for 2020: Western GOA = 168 t, Central GOA = 455 t, and Eastern GOA = 586 t.

Shotwell, S.K. and D.H. Hanselman. 2019. Assessment of the Rougheye and Blackspotted Rockfish stock complex in the Gulf of Alaska. *In* Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Mngt. Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

I. <u>Thornyheads</u>

1. Research

None at present.

2. Stock Assessment

Gulf of Alaska - ABL

Rockfish in the Gulf of Alaska (GOA) have historically been assessed on a biennial stock assessment schedule to coincide with the availability of new trawl survey data (odd years). In 2017, the Alaska Fisheries Science Center participated in a stock assessment prioritization process. It was recommended that the Gulf of Alaska (GOA) thornyhead complex remain on a biennial stock assessment schedule with a full stock assessment produced in even years and no stock assessment or document produced in odd years. Because this is an "off year," the 2019 values are rolled over for the 2020 fishery.

Estimated thornyhead rockfish biomass is 89,609 t. The NPFMC's Tier 5 ABC definitions state that $F_{ABC} \leq 0.75M$, where *M* is the natural mortality rate. Using an *M* of 0.03 and applying this definition to the exploitable biomass of shortraker rockfish results in a recommended ABC of 2,016 t for the 2020 fishery. Gulfwide catch of thornyhead was 777 t in 2019. This is down from 1,183 t in 2018.

For more information please contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

J. Sablefish

1. Research

Groundfish Tag Program - ABL
The ABL MESA Tag Program continued the processing of groundfish tag recoveries and administration of the tag reward program and Groundfish Tag Database during 2019. While sablefish is the primary species tagged, tags from shortspine thornyheads, Greenland turbot, Pacific sleeper sharks, lingcod, spiny dogfish, and rougheye rockfish are also maintained in the database. Total tag recoveries for the year were ~675 sablefish, 16 thornyhead, and 3 Greenland turbot. Twenty four percent of the recovered sablefish tags in 2019 were at liberty for over 10 years. About 39 percent of the total 2019 recoveries were recovered within 100 nautical miles (nm; great circle distance) from their release location, 35 percent within 100 – 500 nm, 18 percent within 500 – 1,000 nm, and 9 percent over 1,000 nm from their release location. The tag at liberty the longest was for approximately 44 years, and the greatest distance traveled of a 2019 recovered sablefish tag was 1,913 nm. Three juvenile sablefish and one shortspine thornyhead tagged with archival tags were recovered in 2019.

Releases in 2019 on the AFSC groundfish longline survey totaled 5,410 adult sablefish, 736 shortspine thornyheads, and 10 Greenland turbot. An additional 719 juvenile sablefish were tagged during two juvenile sablefish tagging cruises in 2019.

For more information, contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

Juvenile Sablefish Studies – ABL
Juvenile sablefish tagging studies have been conducted by the Auke Bay Laboratories in Alaska since 1984 and were continued in 2019. ABL staff coordinated with a University of Alaska Fairbanks (UAF) graduate project to collect stomach contents, genetic samples, and to tag juvenile sablefish in St. John Baptist Bay near Sitka, AK over 5 days (July 15 – July 19). A total of 708 juvenile sablefish were caught and tagged and released, up from 36 in 2018. Average length of fish during July sampling was down from the historical average, at 31 cm. The UAF also sampled in March 16-18 for seasonal comparisons and experienced much lower catch rates, tagging just 8 fish. The average length of tagged fish was 29 cm, with a total length range of 26 – 31 cm.

For more information, contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

2. Stock Assessment

Sablefish in the Bering Sea, Aleutian Islands, and Gulf of Alaska - ABL

A full sablefish stock assessment was produced for the 2020 fishery. New data included in the assessment model were relative abundance and length data from the 2019 longline survey, relative abundance and length data from the 2018 fixed gear fishery, length data from the 2018 trawl fisheries, age data from the 2018 longline survey and 2018 fixed gear fishery, updated catch for 2019, and projected 2019 - 2021 catches.

The longline survey abundance index in numbers increased by 47% from 2018 to 2019, following at 14% increase in 2018. The fishery catch-rate/abundance index stayed level from 2017 to 2018 and is still at the time series low (the 2019 data are not available yet). In 2018, the 2014 year class was estimated to be 2 times higher than any other year class observed in the current recruitment regime (1977 – 2014); however the estimate of this year class decreased 56% over the period from 2017 to 2019. Because of this large year class, the maximum permissible yield under Tier 3a was calculated to be 44,065 mt, which is a 292% increase from 2019. However, there are reasons to be conservative and so instead of maximum permissible, a 25% increase from the 2019 ABC was adopted for the 2020 fishery, from 15,069 mt to 18,763 mt.

Tier 3 stocks have no explicit method to incorporate the uncertainty of this extremely large year class into harvest recommendations. While there are clearly positive signs of strong incoming recruitment, there are concerns regarding the lack of older fish and low spawning biomass, the uncertainty surrounding the estimate of the strength of the 2014 year class, and the uncertainty about the environmental conditions that may affect the success of the 2014 year class in the future. These concerns warrant additional caution when recommending the 2019 and 2020 ABCs. Future surveys will help determine the magnitude of the 2014 year class and will help detect additional incoming large year classes other than the 2014 year class; there are indications that subsequent year classes may also be above average.

The author recommended ABCs for 2019 and 2020 were lower than maximum permissible ABC for several important reasons:

1. The estimate of the 2014 year class strength declined 56% from 2017 to 2019. A decline of this magnitude illustrates the uncertainty in these early recruitment estimates.

2. Fits to abundance indices are poor for recent years, particularly fishery CPUE and the GOA trawl survey.

3. The AFSC longline survey Relative Population Weight index, though no longer used in the model is still only just above average.

4. The retrospective bias is positive (i.e., historical estimates of spawning biomass increase as data is removed).

5. Mean age of spawners has decreased dramatically since 2017 and continues a downward trend, suggesting higher importance of the contribution of the 2014 year class to adult spawning biomass; however, age-4 body condition of this year class was poor, and much lower than during the last period of strong recruitments

6. The very large estimated year classes for 2014 and 2016 are expected to comprise about 33% and 14% of the 2020 spawning biomass, respectively. The 2014 year class is about 50% mature while the 2016 year class should be less than 15% mature in 2020.

7. The projected increase in future spawning biomass is highly dependent on young fish maturing in the next few years; results are very sensitive to the assumed maturity rates.

8. Evenness in the age composition has dramatically declined, which means future recruitment and fishing success will be highly dependent on only a few cohorts of fish.

9. Spatial overlap between sablefish returning to adult slope habitat and the arrowtooth flounder population may have increased resulting in potentially higher competition and predation

10. Another marine heat wave formed in 2018, which may have been beneficial for sablefish recruitment in 2014 - 2016, but it is unknown how it will affect fish in the population or future recruitments.

11. Fishery performance has been very weak in the directed fishery with CPUE at time-series lows in 2018.

12. Small sablefish are being caught incidentally at unusually high levels shifting fishing mortality spatially and demographically, which requires more analysis to fully understand these effects.

Recommending an ABC lower than the maximum should result in more of the 2014 and 2016 year classes entering into the spawning biomass and becoming more valuable to the fishery. This precautionary ABC recommendation buffers for uncertainty until more observations of these potentially large year classes are made. Because sablefish is an annual assessment, we will be able to consider another year of age composition data in 2020 and allow this extremely young population to further mature and more fully contribute to future spawning biomass.

For more information contact Chris Lunsford (chris.lunsford@noaa.gov) or Cara Rodgveller (cara.rodgveller@noaa.gov).

Coastwide research discussions for sablefish – ABL

Since 2017, scientists from DFO, NWFSC, Alaska Department of Fish and Wildlife, and AFSC have met to discuss ongoing sablefish research, sablefish assessment models, and opportunities for collaboration. Sablefish stock assessments are conducted independently for the U.S. West Coast (California-Oregon-Washington), Canada, and both Alaska State and Alaska Federal management areas. The assessment model platforms and data available differ between areas but similar trends in population dynamics have been observed throughout the sablefish range in the northeast Pacific. A post-doctoral researcher and a PhD student have joined the team and are leading progress on analyzing spatial growth patterns, estimating movement rates using tag data from the U.S. and Canada, and developing a single index of abundance using data from multiple regions and gear types. A comprehensive examination of the availability and utility of maturity data across regions was also conducted. The team plans to meet again in 2020 to discuss specifications for a coastwide operating model that would be used to examine coastwide research questions.

For more information, contact Kari Fenske at (907) 789-6653 or kari.fenske@noaa.gov

K. Lingcod

There are no federally-managed lingcod fisheries in Alaska waters. Recreational and small-scale commercial fisheries are managed by the Alaska Department of Fish & Game.

L. Atka Mackerel

1. Research

2. Stock Assessment

Bering Sea and Aleutian Islands - REFM
The BSAI Atka mackerel assessment uses the Assessment Model for Alaska (AMAK), a statistical catch-at-age-model. No changes to the base model were made this year. New data for 2019 included catch through 2019 (2019 projected) and 2018 fishery age compositions.

In the 2019 assessment, the addition of the 2018 fishery age composition information impacted the estimated magnitude of the 2011 year class which decreased 2%, relative to last year's assessment, and the magnitude of the 2012 and 2013 year classes which increased 10 and 12% respectively, relative to last year assessment. The 2011 and 2013 year classes are about 10% below average, and the 2012 year class is estimated to be 28% above average. Estimated values of B100%, B40% , B35% are 3% higher relative to last year's assessment. Projected 2020 female spawning biomass (109,900 t) is 3% higher relative to last year's estimate of 2019 female spawning biomass, and 7% higher relative to last year's projection for 2020.

Projected 2020 female spawning biomass is below B40% (116,600 t) at B38%, thereby placing BSAI Atka mackerel in Tier 3b. The current estimate of F40% adj= 0.41 is 7% lower relative to last year's estimate of F40% adj due to changes in the fishery selectivity used for projections. The projected 2020 yield at maxFABC = F40% adj = 0.41 is 70,100 t, which is 2% higher relative to last year's estimate for 2019. The projected 2020 overfishing level at F35% adj = 0.48 is 81,200 t, which is 2.5% higher than last year's estimate for 2019.

Gulf of Alaska (REFM)
A full assessment was conducted for Atka mackerel in 2019, but due to data limitations the harvest recommendations remain the same as in previous years. The very patchy distribution of GOA Atka mackerel results in highly variable estimates of abundance. Therefore, survey biomass estimates are considered unreliable indicators of absolute abundance or indices of trend, and harvest recommendations are based on historical catches. Since 1996, the maximum permissible ABC has been 4,700 t and the OFL has been 6,200 t.

For more information, contact Sandra.Lowe@noaa.gov.

M. Flatfish

1. Research

Yellowfin sole and northern rock sole habitat - GAP

Research continues in characterizing and assessing the productivity of the habitats of juvenile yellowfin sole (Limanda aspera; YFS) and northern rock sole (Lepidopsetta polyxystra; NRS) in the Bering Sea. Field sampling with beam trawl that targets juveniles in shallow, nearshore areas has been conducted with the eastern Bering Sea (EBS) annual bottom trawl survey in 2016-2019, and with the northern Bering Sea (NBS) bottom trawl survey in 2017 and 2019. During this period, the Bering Sea has experienced anomalously high summer bottom temperature. The research focuses on the latitudinal variation in juvenile abundance, growth and body condition under this continuing warm stanza.

Analysis of the 1982-2017 bottom trawl survey time series showed that warm stanzas were correlated with high abundance of juvenile NRS and the northward expansion of their distribution, but seemed not to significantly affect juvenile YFS. However, the latter could be an artifact of the relatively low availability of juvenile YFS to sampling (Yeung and Cooper 2019). Prey appeared to be abundant across the entire inner shelf. With suitable temperature, a northward expansion in juvenile flatfish habitat may increase overall productivity.

Effort continued in 2019 to develop the beam trawl as a complementary gear to the bottom trawl in the annual survey for better assessment of juvenile fish and nearshore areas. In 2019, the abundance of juvenile YFS was at least as high in Norton Sound of the NBS as in the EBS, and a northward expansion of juvenile NRS distribution was evident. Juvenile flatfish were collected at 16 beam trawl stations across the Bering Sea shelf, when available, for diet, otolith, lipids and biomarkers, and calorimetry analyses. Benthic grab samples were collected at 8 stations to analyze sediment grainsize, infauna prey composition, their energy content, and their lipids content and biomarkers to correspond with flatfish diet and condition.

For further information, contact Cynthia Yeung, (206) 526-6530, cynthia.yeung@noaa.gov.

Yeung, C., and Cooper, D. W. 2019. Contrasting the variability in spatial distribution of two juvenile flatfishes in relation to thermal stanzas in the eastern Bering Sea. ICES Journal of Marine Science, fsz180, https://doi.org/10.1093/icesjms/fsz180.

2. Assessment

Yellowfin sole - Bering Sea and Aleutian Islands -REFM

The yellowfin sole fishery in the EBS is the largest flatfish fishery in the world. This stock is assessed using an age-structured population dynamics model implemented in the software program AD Model Builder. Survey catchability (q) has been shown to be linked to bottom water temperatures, so in the model q is estimated as a function of an included bottom temperature index. In 2019 a new model was introduced based on the 2018 model that retains female natural mortality fixed at 0.12 while allowing the model to estimate male natural mortality.

An unexpected 32% decrease in the NMFS eastern Bering Sea survey biomass was observed in

2018. In 2019 the survey biomass was 6% higher than in 2018 at 2,006,510 t. Spawning biomass estimated by Model 18.2 remained high at 1.94 * BMSY . Therefore, Yellowfin Sole continues to qualify for management under Tier 1a. Similar to recent years, the 1978-2013 age-1 recruitments and the corresponding spawning biomass estimates were used to fit the stock recruitment curve and determine the Tier 1 harvest recommendations.

This assessment updates last year's assessment with results and management quantities that are higher than the 2018 assessment. This is due to a higher 2019 survey biomass point estimate, 6% higher than the 1 2018 estimate. Secondarily, the model estimated male natural mortality slightly higher than female natural mortality, 0.135, which increased biomass estimates.

Catch as of October 28, 2019 was 109,620 t. Over the past 5 years (2014 - 2018), 92.4% of the catch has taken place by this date. Therefore, the full year's estimate of catch in 2019 was 118,642 t. Future catch for the next 10 years, 2020 - 2029 was estimated as the mean of the past 10 years catch, 137,230 t.

Yellowfin Sole continue to be above BMSY and the annual harvest remains below the ABC level. The projected estimate of total biomass for 2020 was higher by 17% from the 2018 assessment of 2,331,500 t, to 2,726,370 t. The model projection of spawning biomass for 2020, assuming catch for 2019 as described above, was 1,051,050 t, 132% of the projected 2020 spawning biomass from the 2018 assessment of 796,600 t. The 2020 and 2021 ABCs using FABC from this assessment model were higher than the 2018 ABC of 249,100 t; 296,060 t and 296,793 t. The 2020 and 2021 OFLs estimated in this assessment were 321,794 t and 322,591 t.

Greenland turbot - Bering Sea and Aleutian Islands - REFM
The BSAI Greenland turbot assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 11,319 t and the maximum ABC is 9,625 t.

For further information contact Meaghan Bryan (206) 526-4694

Arrowtooth flounder - Bering Sea and Aleutian Islands - REFM
The BSAI arrowtooth flounder assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 82,860 t and the maximum ABC is 70,606 t.

Arrowtooth flounder - Gulf of Alaska - REFM
A full assessment was performed for GOA Arrowtooth Flounder in 2019. Biomass estimates in the current model have changed relative to previous assessments. The model projection of spawning biomass for 2020, assuming fishing mortality equal to the recent 5-year average, was 756,100 t, 93% of the projected 2020 spawning biomass from the 2018 assessment of 810,158 t. The 2020 and 2021 ABCs using FABC=0.193 from this assessment model were lower than the 2018 ABC of 145,841 t; 128,060 t and 124,357 t. The 2020 and 2021 OFLs estimated in this assessment were 153,017 t and 148,597 t. The projected estimate of total biomass for 2020 was down by 3% from the 2018 assessment of 1,367,620 t, to 1,325,867 t. Despite the declines, the Arrowtooth Flounder stock in the Gulf of Alaska is not being subjected to overfishing and is not approaching a condition of being overfished.

For further information, contact Ingrid Spies (206) 526-4786

Kamchatka flounder - Bering Sea and Aleutian Islands - REFM
Before 2011, Kamchatka flounder and arrowtooth flounder were managed in aggregate as a single stock. Due to the emergence of a directed Kamchatka flounder fishery and concerns about overharvesting, the stocks were separated in 2011. The BSAI Kamchatka flounder assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 11,495 t and the maximum ABC is 9,708 t.

Northern rock sole - Bering Sea and Aleutian Islands - REFM
The vast majority of rock sole in the BSAI region is northern rock sole, and it is managed as a single stock. The stock is assessed biennially using an age-structured population dynamics model implemented in the software program AD Model Builder. No assessment was performed in 2019, the 2020 ABC and OFL values are 143,700 t and 147,500 t, respectively. Recommended ABCs correspond to the maximum permissible levels. This is a stable fishery that lightly exploits the stock because it is constrained by PSC limits and the BSAI optimum yield cap. Usually the average catch/biomass ratio is about 3-4 percent.

Northern and southern rock sole - Gulf of Alaska - REFM
Northern and southern rock sole in the GOA are managed as part of the shallow-water flatfish complex, which is discussed below.

Flathead sole - Bering Sea and Aleutian Islands - REFM
The BSAI flathead sole assessment is conducted in even years, with a partial update in odd years that includes revised harvest recommendations. For 2020, the OFL is 82,810 t and the maximum ABC is 68,134 t.

Flathead sole - Gulf of Alaska - REFM
This assessment is conducted using Stock Synthesis on a four-year schedule. 2019 was an off-year thus a partial assessment was presented. The projection model was run using updated catches. The 2019 spawning biomass estimate was above B40% and projected to increase through 2020. Biomass (age 3+) for 2019 was estimated to be 283,285 t and projected to slightly decrease in 2020. For 2019, the authors' recommendation was to use the maximum permissible ABC of 38,196 t from the updated projection. The FOFL is set at F35% (0.36) which corresponds to an OFL of 46,572 t.

For further information contact Carey McGilliard (206) 526-4696

Alaska plaice - Bering Sea and Aleutian Islands - REFM
Alaska plaice are assessed biennially using an age-structured population dynamics model implemented in the software program AD Model Builder. The 2019 assessment indicated that above average recruitment strength in 1998 and exceptionally strong recruitment in 2001 and 2002 have contributed to recent highs level of female spawning biomass. The Alaska plaice spawning stock biomass is projected to decline through 2023 while remaining above B35%. The recommended ABC for 2020 is 31,600 t based on an F40% = 0.125 harvest level, a 9% decrease from 2018. The 2020 overfishing level of 37,600 t is based on a F35% (0.15) harvest level.

Rex sole - Gulf of Alaska - REFM
This stock is on a four-year assessment cycle and a full assessment is due in 2021. In 2019 a partial

assessment was conducted, with the projection model run using updated catches. The model estimates of female spawning biomass and total biomass (3+) for the eastern area is stable and the western area appears to be increasing slightly. The recommendations for 2019 are an ABC of 14,878 t and an OFL of 18,127 t.

For further information contact Carey McGilliard (206) 526-4696

"Other flatfish" complex - Bering Sea and Aleutian Islands - REFM
The BSAI "Other flatfish" complex includes all flatfishes not managed individually, but the primary species by abundance are starry flounder, rex sole, longhead dab, Dover sole, and butter sole. This complex is on a 4-year assessment cycle and a full assessment is due in 2020. Harvest recommendations are made using Tier 5 methods (OFL = F * biomass, where F=M; ABC = 0.75 * OFL) and are not revised during off years. The ABC and OFL are calculated separately for rex sole, Dover sole, and a single group of all remaining species; these are then aggregated to produce a single set of recommendations for the complex. Survey data through 2018 indicate that the other flatfish species group is at a high level relative to the time series average and is lightly exploited. The resultant 2020 OFL and ABC are 21,824 t and 16,368 t, respectively.

For further information contact Meaghan Bryan (206) 526-4694

Shallow-water flatfish complex - Gulf of Alaska - REFM
The GOA shallow-water flatfish complex includes northern and southern rock sole, yellowfin sole, butter sole, starry flounder, English sole, sand sole, and Alaska plaice. Northern and southern rock soles are assessed using an age-structured model; for the remaining species harvest recommendations are made using Tier 5 methods (OFL = F * biomass, where F=M; ABC = 0.75 * OFL). The ABCs and OFLs for all groups are aggregated to produce recommendations for the complex. The complex has been moved to a 4-year assessment cycle. A full assessment was conducted in 2017 and will be repeated in 2021. For 2019 a partial assessment was done, and the projection model for northern and southern rock sole was re-run to generate new harvest recommendations. The resultant 2020 OFL and ABC are 68,010 t and 55,463 t, respectively. Area ABCs are apportioned based on random-effects model estimates of survey biomass.

For further information contact Carey McGilliard (206) 526-4696

Deep-water flatfish complex - Gulf of Alaska - REFM
The GOA deep-water flatfish complex includes Dover sole, Greenland turbot, and deepsea sole; Dover sole is the dominant species. Dover sole is assessed using Stock Synthesis, while Greenland turbot and deepsea sole recommendations are based on historical catch. The OFLs and ABCs for the individual species in the deepwater flatfish complex are determined and then summed for calculating a complex-level OFL and ABC. In 2019 a full assessment was conducted. Since Dover sole comprises approximately 98% of the deepwater flatfish complex they are considered the main component for determining the status of this stock complex. Catch levels for this complex remain well below the TAC and below levels where overfishing would be a concern. The 2020 OFL is 7,163 and 2020 ABC is 6,030 t, substantially lower than the previous full assessment.

N. Pacific halibut

1. Research

Halibut bycatch management in the North Pacific: A prospective model of fleet behavior - ESSR
There is a pressing need for conducting prospective analyses of fishing effort changes in response to management changes, including those designed to reduce bycatch. In June 2015, the North Pacific Fisheries Management Council (NPFMC) took action to reduce the prohibited species catch (PSC) limits for halibut in the Bering Sea and Aleutian Islands (BSAI) groundfish fisheries, and is currently exploring ways for tying future PSC limits to measures of halibut abundance. We are developing an empirical modeling approach for predicting the economic and ecological consequences of alternative halibut PSC management policies. Our model focuses on the dynamic decision making of vessels as they manage tradable quotas for target and bycatch species within a fishing season, and provides predictions of changes in the spatial and temporal distribution of fishing effort in response to management changes, including changes in catch limits and time/area closures. These predictions are then combined with estimated space/time distributions of species to predict the cumulative consequences for catch and quota balances, gross and net revenues, and the ecosystem resulting from alternative halibut PSC management measures.

Preliminary results suggest that the groundfish fleet is flexible in adjusting their fishing practices to reduce halibut bycatch to some degree; however, halibut bycatch reductions are costly, in terms of foregone groundfish revenue and operating costs, particularly at low levels of halibut PSC limits. Moreover, our results highlight behavioral margins that would not otherwise be predicted using models that do not account for the within-season dynamics of quota-based fisheries. While the application we pursue is specific to halibut PSC management in the BSAI groundfish fisheries, our methodological approach is capable of being applied to policy impacts in other quota-based multispecies fisheries. For further information contact Alan.Haynie@noaa.gov.

Movement of quota shares in the halibut and sablefish IFQ fisheries - ESSR
The North Pacific Fishery Management Council recently finalized the first comprehensive review of the Pacific Halibut and Sablefish IFQ Program. The review showed that QS holdings have moved between rural Alaska communities based on access to transportation, which is key to moving product to the increasingly fresh market for halibut. Based on findings from the review and subsequent discussion, the Council proposed that its IFQ Committee consider several specific issues with respect to the IFQ Program.

This study directly examines these issues by assessing the factors that underlie participants' decisions to both buy and sell quota shares in the Pacific halibut and sablefish IFQ fisheries. We are examining the probability of buying and selling quota shares as a factor of the characteristics of the participant, including attributes of their community of residence such as population, access to transportation, and availability of local halibut/sablefish buyers, as well as attributes of the quota shares. In addition, this study applies social network analysis to examine any trends in how participants buy and sell quota shares over time. This study is currently in progress and will contribute to managers' understanding of how quota share sales and access to the IFQ fisheries have changed over time. For further information, contact Marysia.Szymkowiak@noaa.gov.

O. Other Groundfish Species

Other groundfish stocks assessed by the AFSC - REFM

In addition to the assessments described above, the AFSC assesses and provides harvest recommendations for a sculpin (Cottoidea) complex and an octopus complex in both the BSAI and GOA. These are non-target species and exploitation rates are low. In addition, the AFSC produces status reports for several species groups included in the fishery management plan as "Ecosystem Components". These are stocks for which there are not active conservation concerns, but have ecosystem roles that warrant some level of monitoring. These groups currently include grenadiers, squids, and a diverse forage fish group (the osmerids capelin and eulachon, as well as Pacific sand lance, are the main species of interest).

Workshop on Unavoidable Survey Effort Reduction (WKUSER) – GAP and others

The International Council for the Exploration of the Sea Working Group on Improving Use of Survey Data for Assessment and Advice (WGISDAA) invited survey and stock assessment scientists to investigate challenges and responses to unavoidable reductions of survey effort scheduled for early January 2020. Most survey programs are at one time or another asked to make substantial short-term changes to survey operations due to budget .reductions, weather, and vessel breakdowns and unavailability. These short-term effort reductions typically compromise the long-term objectives of survey series in terms of accuracy, precision, and consistency of population estimation. Usually these reductions leave little time for planning and quantitative evaluation, so there is a real need to develop methods that provide a better understanding of the risks of different implementation options. Participants at this workshop will examine methods that can minimize the amount of information loss and seek appropriate methods for the survey design and objectives. These tools aim to assist survey scientists to make better decisions when unexpected events force changes, to facilitate better contingency planning, and to convey the likely consequences to assessment scientists and policy makers.

Participants were encouraged to contribute to the following topics:

- The current processes dealing with unavoidable reductions in survey effort and examining the existing coping strategies (e.g. spatial coverage, survey frequency, or sampling density) and their qualitative consequences.
- Develop key quality metrics that can be used to describe "total survey uncertainty" for common survey designs and indices of abundance.
- Define "changes to survey designs" that require inter-survey calibration and what changes can be resolved by a model-based approach to index generation.
- Develop methods that can provide quantitative decision-making tools describing impacts on the quality of survey deliverables and advisory products.

GAP and other AFSC scientists have been preparing several analyses for oral presentations on the following topics:

Stan Kotwicki	Challenges and priorities for WKUSER and beyond.
Michael Martin	An overview of NOAA Fisheries Surveys.
Anne Hollowed	SSC perspective on trade-offs among trawl survey schemes in federal waters off Alaska under varying funding scenarios.
Ned Laman	Effects of sampling density changes on biomass estimates from stratified random bottom trawl surveys in the Gulf of Alaska.

Jim Thorson	Measuring the impact of increased ageing effort: theory and case-study demonstration.
Stan Kotwicki	The effect of variable sampling efficiency on the reliability of observation error as a measure of uncertainty in abundance indices from scientific surveys.
Elaina Jorgensen	Systematic reduction in survey effort and the effect on variance of fish abundance.
Peter Munro	Comparing three estimators of change in trawl survey mean catch per unit effort (CPUE) the Mean Squared Error (MSE) of the estimate under different simulated scenarios.
Paul Spencer	Variance propagation from fishery-independent surveys to the stock assessment outputs.
Paul Von Szalay	A Comparison of Bottom Trawl Sampling Strategies in the Gulf of Alaska: Design vs. Model-Based Approaches.
Kresimir Williams	Cameras vs Catch: potential effects of implementing open codend tows for acoustic midwater fish surveys.
Jason Conner	Impact of reducing sample density on the accuracy and precision of design-based estimators of an abundance index for a bottom trawl survey in the eastern Bering Sea.
Meaghan Bryan	The Impact of survey frequency and intensity on detecting environmental anomalies and shifts in abundance.
Lauren Rogers	Evaluation of a survey with an adaptive sampling domain to capture climate-driven shifts in larval fish distributions.
Jon Richar	Considering changes in sampling density and survey frequency, and their effects on eastern Bering Sea crab population time series.
Cynthia Yeung	Survey Effort Reduction Impacts on the Assessment of the Thermal State of the Bering Sea Ecosystem.

For further information visit the ICES website at
https://www.ices.dk/community/groups/Pages/WKUSER.aspx

Or contact Stan Kotwicki (stan.kotwicki@noaa.gov) or Wayne Palsson (wayne.palsson@noaa.gov).

Joint Program Agreement with the Korean National Institute of Fisheries Bottom Trawl Survey Group – REFM, GAP

The National Institute of Fisheries Science of South Korea conduct systematic bottom trawl surveys of their territorial and adjacent waters. For the past several years, a cooperative agreement has led to working on survey design issues common to the Korean survey and bottom trawl surveys conducted by the AFSC. This work has included evaluating the herding effect, bottom tending and fishing configuration of research nets, and designing an expanded Korean survey. This work has led to specific research projects and exchanges of scientists between the countries. In March 2019, Wayne Palsson traveled to South Korea for a cruise on the *RV Tamgu 22 t*o execute a study examining footrope and bridle contact with the sea floor. During the summer, Mr. Donghoon Shin from NIFS participated in the AFSC's 2019 Gulf of Alaska Bottom Trawl Survey to learn and compare survey techniques. During the Autumn, Dr. Junghwa Choi visited the AFSC in Seattle to analyze recent data and plan for reporting the results of the study. AFSC's Jason Conner traveled to the NIFS laboratory to continue work in designing a simulation of their bottom trawl survey to evaluate expanded trawl survey designs.

Contact Peter Munro (peter.munro@noaa.gov) for more information.

CONSERVATION ENGINEERING (CE)

The Conservation Engineering (CE) group of the NMFS Alaska Fisheries Science Center (AFSC) (Noëlle Yochum, lead) conducts cooperative research with Alaska fishing groups and other scientists to better understand and mitigate bycatch, bycatch mortality, and fishing gear impacts to fish habitat. This is done through the evaluation of fish biology and behaviour, and gear design and use. In 2019, CE research focused on a project to, collaboratively with industry and science partners, develop and test a novel bycatch device (BRD) to reduce salmon bycatch (primarily chum, Oncorhynchus keta, and Chinook, O. tshawytscha) in the North Pacific walleye pollock ("pollock", Gadus chalcogrammus) trawl fisheries. In parallel with this project, we also continued to develop and evaluate camera technology to observe fish behavior in a trawl net without the use of visible light to illuminate the camera's field of view. In 2019, we continued to collaborate on an industry-led project to evaluate salmon excluders, and to host a workshop in support of industry-driven innovation in Alaska trawl fisheries.

Novel Salmon Excluder Design

Mitigating Pacific salmon (Oncorhynchus spp.) bycatch is a significant driver in the management of walleye pollock (Gadus chalcogrammus) pelagic trawl fisheries in the North Pacific. Various BRDs that permit salmon to escape from the trawl ('excluders') have been developed. High variability in escapement rates underscore a lack of understanding regarding mechanisms that promote escapement. In collaboration with Karsten Breddermann (Universität Rostoc, Chair of Marine Engineering), Mike Stone (retired fisherman, fishing net maker, and fleet manager), Barry Berejikian (NOAA NWFSC), David Irvine (commercial pollock captain), and John Gauvin (North Pacific Fisheries Research Foundation, NPFRF), we designed a novel funnel-style salmon excluder that manipulates water flow around the escapement area and provides a large surface area for escapement. We used computational fluid dynamics simulations to develop a model that was tested at a flume tank at the Fisheries and Marine Institute of Memorial University of Newfoundland in St. John's (Breddermann et al., 2020). Subsequent to the work done at the flume tank, a 'final' design was selected for construction at full scale and was tested in June 2019 during a research charter aboard the F/V Pacific Explorer, a catcher vessel trawler in the Bering Sea pollock fishery. During at-sea trials, we observed, using cameras, that the design provided easy and ample access to escapement areas, allowing salmon to both volitionally (swim) and passively (tumble out) escape, and salmon escapement rates were high (mean 0.58 ± 0.18). However, more comprehensive testing is needed over a breadth of fishing conditions and to evaluate the rate of escapement for the target species (pollock). Furthermore, additional research is needed to understand why salmon disproportionately escaped by swimming forward from aft of the excluder during haulback and turns.

Results from this study highlighted the importance of addressing key elements of salmon behaviour relative to excluder design, including: (i) salmon perception of the escapement area; (ii) salmon ability to access the escapement area; and (iii) salmon motivation to escape. Despite efforts to increase perceptibility of escapement areas and to provide sufficient access to them, salmon were retained. This emphasizes the importance of understanding and affecting the motivation of salmon to escape when designing a salmon excluder.

With respect to the technology used to observe salmon behaviour, cameras were used with both far red and white lights to illuminate the camera field of view. Those illuminated with far red light generated video where it was difficult to identify salmon. More work is therefore needed to address the need for inconspicuous technology to quantify and qualify fish behaviour.

Collaboration on Industry-Led Excluder Research
In August 2017, John Gauvin proposed an Exempted Fishing Permit (EFP) research project to develop and test salmon excluder designs for the different trawl vessel size classes fishing for Bering Sea pollock. The EFP includes three seasons of testing (winters of 2018, 2019, and 2020). The overall goal of this study is for the trials to culminate in an excluder design that effectively and reliably allows for salmon escapement, and, through the process, to gain a better understanding of what variables affect the efficacy of the design elements. The project is a collaborative effort with John Gruver of United Catcher Boats Association, Ed Richardson of At-Sea Processors Association, pollock fishermen and net designers, and the AFSC CE group. A different set of excluder designs were tested in 2018 and 2019. As a collaborator, CE has supported this research by being involved in the initial workshops to discuss excluder designs, and providing edits and feedback to the EFP proposal and the RFP for boat owners to bid on the opportunity to conduct the research on their vessel. CE also led the proposal review of the vessels that bid. Moreover, CE continues to support the research by being involved in the on-going sea trials, data analysis, evaluation of results, and planning.

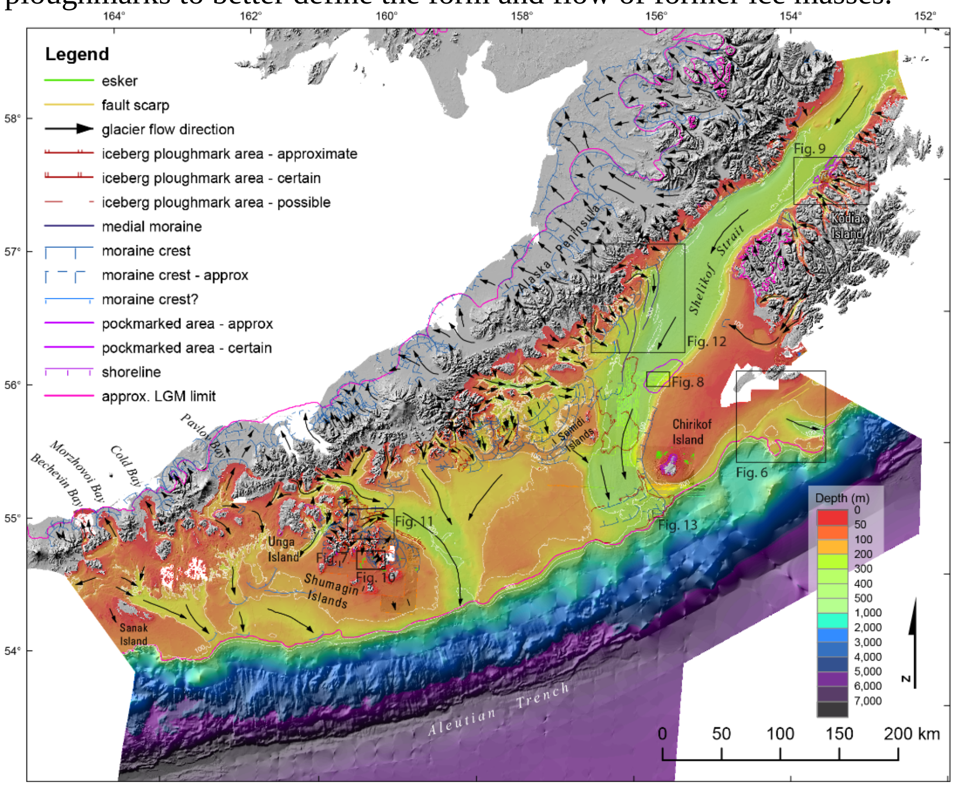
Support of Industry Innovation
In 2019 CE organized, with the help of a steering committee, the third Fisheries Innovation for Sustainable Harvest (F.I.S.H.) Workshop. Approximately 100 people participated from three NOAA Alaska Fisheries Science Center (AFSC) locations (Newport, OR; Seattle, WA; Kodiak, AK), connected through video conference. The overall goal of the workshop was to provide an opportunity for invited participants, including fishermen and those working on conservation engineering research or related technology development, to learn about and discuss current research related to innovation in North Pacific trawl fishing and tools that support that innovation. There were two workshop sessions, in addition to the presentations, one on prioritization of knowledge needs related to trawl gear performance and another evaluating excluders used in trawl gear. The success of the workshop was linked to the varied perspectives of the attendees, who work in different fisheries and ports, but all have aligned interests and commitment to innovation and sustainability.

Literature cited:
Breddermann, K., Stone, M., Yochum, N. 2020. Flow analysis of a funnel-style salmon excluder. In Proceedings of the Fourteenth International Workshop on Methods for the Development And Evaluation Of Maritime Technologies, İzmir, Turkey, November 5th - 7th, 2019, pp. 29-42.

For more information, contact MACE Program Manager (acting) Patrick Ressler (206) 526-4785.

Bathymetry and Geomorphology of Shelikof Strait and the Western Gulf of Alaska - RACE GAP
We defined the bathymetry of Shelikof Strait and the western Gulf of Alaska (WGOA) from the edges of the land masses down to about 7000 m deep in the Aleutian Trench. This map was produced by combining soundings from historical National Ocean Service (NOS) smooth sheets (2.7 million soundings); shallow multibeam and LIDAR (light detection and ranging) data sets from

the NOS and others (subsampled to 2.6 million soundings); and deep multibeam (subsampled to 3.3 million soundings), single-beam, and underway files from fisheries research cruises (9.1 million soundings). These legacy smooth sheet data, some over a century old, were the best descriptor of much of the shallower and inshore areas, but they are superseded by the newer multibeam and LIDAR, where available. Much of the offshore area is only mapped by non-hydrographic single-beam and underway files. We combined these disparate data sets by proofing them against their source files, where possible, in an attempt to preserve seafloor features for research purposes. We also attempted to minimize bathymetric data errors so that they would not create artificial seafloor features that might impact such analyses. The main result of the bathymetry compilation is that we observe abundant features related to glaciation of the shelf of Alaska during the Last Glacial Maximum including abundant end moraines, some medial moraines, glacial lineations, eskers, iceberg ploughmarks, and two types of pockmarks. We developed an integrated onshore–offshore geomorphic map of the region that includes glacial flow directions, moraines, and iceberg ploughmarks to better define the form and flow of former ice masses.



For further information, contact Mark.Zimmermann@noaa.gov

Zimmermann, M., Prescott, M.M, and Haeussler, P.J. 2019. Bathymetry and Geomorphology of Shelikof Strait and the Western Gulf of Alaska. Geosciences: Special Issue Geological Seafloor Mapping. 9(10), 409. https://doi.org/10.3390/geosciences9100409.

Research on surveying untrawlable habitats-RACE MACE & GAP

Bottom-trawl and acoustic surveys conducted by the AFSC have been the main source of fishery-independent data for assessing fish stocks in Alaska. But bottom trawls cannot sample in steep, rocky areas (“untrawlable” habitats) that are preferred by species such as Atka mackerel and rockfishes. Untrawlable areas make up to about 20% of the federally managed area where surveys have been attempted in the Gulf of Alaska and up to about 54% of the federally managed area in the Aleutian Islands. A number of commercially important rockfish species including dusky, northern, harlequin, and yelloweye rockfishes strongly prefer these untrawlable habitats. Many species of rockfishes are long-lived and reproduce late in life, making them particularly vulnerable to overfishing. Managers need accurate stock assessments to keep these fisheries sustainable. Unfortunately, assessments based on surveys of trawlable areas are highly uncertain for species that live mainly in untrawlable habitat.

The problem of assessing fish stocks in untrawlable habitat is not limited to Alaska. Developing new methods to sample in rock, reef, and other untrawlable habitats is a nationwide NOAA effort. NOAA's Untrawlable Habitat Strategic Initiative (UHSI), has been conducting several pilot projects for developing methodologies that can be used to sample untrawlable habitats. Many methods are being explored, and most involve acoustic or optical technologies (underwater cameras).

In Alaska, previous research has combined large-scale acoustics and optical sampling. A sampling plan for assessing fish in untrawlable habitats in the Gulf of Alaska is being developed for future implementation. In this planned survey bottom trawl samples will be replaced with high resolution photos from which fish species and sizes can be identified. Stereo cameras lowered from ships or moored near or on the seafloor will be used where each will be most effective. The Gulf of Alaska untrawlable survey design will be based on prior studies by the Alaska Fisheries Science Center and other researchers, including:

- Acoustic-optics studies
- Experiments with stationary triggered cameras
- Mapping and habitat classification efforts
- Remotely operated vehicle surveys
- Studies of fish response to camera equipment and movement
- A study of fish visual spectrum sensitivity
- Research into computer automated image analyses

Research on untrawlable habitats will continue to be important for producing the most accurate stock assessments possible for species such as rockfishes that prefer these inaccessible areas.

For more information contact: Kresimir Williams (Kresimir.williams@noaa.gov) or David Bryan (david.bryan@noaa.gov)

Developing Model-based Estimates for Bottom Trawl Survey Time Series—GAP

Some stock assessment authors are exploring models that utilize model-based bottom trawl survey biomass estimates. Members of the RACE GAP program are preparing to produce these estimates for stock assessment authors. Efforts in 2019 including developing standardized survey indices using the VAST model applied to selected species in the Eastern Bering Sea Shelf and the Gulf of Alaska and conducing preliminary runs and consultations with stock assessment authors from REFM and ABL. Analyses focusing on model parameters such as the number of knots, which base model to use, and which species to select were conducted in 2019. The aim is now to provide useful model-based results that can be compared to design-based estimates for the 2020 assessment cycle for key species in each survey area.

Contact Stan Kotwicki (stan.kotwicki@noaa.gov) or Jason Conner (Jason.conner@noaa.gov)

Trade-offs in covariate selection for species distribution models: a methodological comparison – GAP

Authors: Brodie, S.J., Thorson, J.T., Carroll, G., Hazen, E.L., Bograd, S., Haltuch, M.A., Holsman, K.K., Kotwicki, S., Samhouri, J.F., Willis-Norton, E. and Selden, R.L.

Species distribution models (SDMs) are a common approach to describing species' space-use and spatially-explicit abundance. With a myriad of model types, methods and parameterization options available, it is challenging to make informed decisions about how to build robust SDMs appropriate for a given purpose. One key component of SDM development is the appropriate parameterization of covariates, such as the inclusion of covariates that reflect underlying processes (e.g. abiotic and biotic covariates) and covariates that act as proxies for unobserved processes (e.g. space and time covariates). It is unclear how different SDMs apportion variance among a suite of covariates, and how parameterization decisions influence model accuracy and performance. To examine trade-offs in covariation parameterization in SDMs, we explore the attribution of spatiotemporal and environmental variation across a suite of SDMs. We first used simulated species distributions with known environmental preferences to compare three types of SDM: a machine learning model (boosted regression tree), a semi-parametric model (generalized additive model) and a spatiotemporal mixed-effects model (vector autoregressive spatiotemporal model, VAST). We then applied the same comparative framework to a case study with three fish species (arrowtooth flounder, Pacific cod and walleye pollock) in the eastern Bering Sea, USA. Model type and covariate parameterization both had significant effects on model accuracy and performance. We found that including either spatiotemporal or environmental covariates typically reproduced patterns of species distribution and abundance across the three models tested, but model accuracy and performance was maximized when including both spatiotemporal and environmental covariates in the same model framework. Our results reveal trade-offs in the current generation of SDM tools between accurately estimating species abundance, accurately estimating spatial patterns, and accurately quantifying underlying species–environment relationships. These comparisons between model types and parameterization options can help SDM users better understand sources of model bias and estimate error.

Spatio-temporal analyses of marine predator diets from data-rich and data-limited systems - GAP

Authors: Grüss, A., Thorson, J.T., Carroll, G., Ng, E.L., Holsman, K.K., Aydin, K., Kotwicki, S., Morzaria-Luna, H.N., Ainsworth, C.H. and Thompson, K.A

Accounting for variation in prey mortality and predator metabolic potential arising from spatial variation in consumption is an important task in ecology and resource management. However, there is no statistical method for processing stomach content data that accounts for fine-scale spatio-temporal structure while expanding individual stomach samples to population-level estimates of predation. Therefore, we developed an approach that fits a spatio-temporal model to both prey-biomass-per-predator-biomass data (i.e. the ratio of prey biomass in stomachs to predator weight) and predator biomass survey data, to predict "predator-expanded-stomach-contents" (PESCs). PESC estimates can be used to visualize either the annual landscape of PESCs (spatio-temporal variation), or can be aggregated across space to calculate annual variation in diet proportions (variation among prey items and among years). We demonstrated our approach in two contrasting scenarios: a data-rich situation involving eastern Bering Sea (EBS) large-size walleye pollock

(Gadus chalcogrammus, Gadidae) for 1992–2015; and a data-limited situation involving West Florida Shelf red grouper (Epinephelus morio, Epinephelidae) for 2011–2015. Large walleye pollock PESC was predicted to be higher in very warm years on the Middle Shelf of the EBS, where food is abundant. Red grouper PESC was variable in north-western Florida waters, presumably due to spatio-temporal variation in harmful algal bloom severity. Our approach can be employed to parameterize or validate diverse ecosystem models, and can serve to address many fundamental ecological questions, such as providing an improved understanding of how climate-driven changes in spatial overlap between predator and prey distributions might influence predation pressure.

Brodie, S.J., Thorson, J.T., Carroll, G., Hazen, E.L., Bograd, S., Haltuch, M.A., Holsman, K.K., Kotwicki, S., Samhouri, J.F., Willis-Norton, E. and Selden, R.L., 2020. Trade-offs in covariate selection for species distribution models: a methodological comparison. Ecography, 43(1), pp.11-24.

Grüss, A., Thorson, J.T., Carroll, G., Ng, E.L., Holsman, K.K., Aydin, K., Kotwicki, S., Morzaria-Luna, H.N., Ainsworth, C.H. and Thompson, K.A., Spatio-temporal analyses of marine predator diets from data-rich and data-limited systems. Fish and Fisheries.

Advancing Essential Fish Habitat (EFH) Species Distribution Modeling (SDM) Descriptions and Methods for North Pacific Fishery Management Plan (FMP) Species --GAP, AKRO

This study will address the Alaska Essential Fish Habitat (EFH) Research Plan's (referred to hereafter as the Research Plan) Research Priority #1 – *Characterize habitat utilization and productivity* (Sigler et al., 2017) by using the best available science to accomplish Objective #1 – *Develop EFH Level 1 information (distribution) for life stages and areas where missing* and Objective #2 – *Raise EFH level from 1 or 2 (habitat-related densities) to Level 3 (habitat-related growth, reproduction, or survival rates)*. We will characterize habitat utilization and productivity by generating spatial predictions of EFH from habitat-based species distribution models (SDMs) of North Pacific Fishery Management Plan (FMP) species' life stages where additional data sources (e.g., presence, presence-absence, and abundance data, updated life history schedules, and updated habitat covariate rasters) and advances in EFH information levels (e.g., availability of additional species response data and habitat-related vital rates) meet the two Research Plan objectives above. For Objective #1, we will develop EFH maps for FMP species' life stages that were not described in the 2015 EFH review because there were insufficient or no data to support modeling efforts at that time, but for which sufficient data currently exist and new data sources have been identified (e.g., small mesh trawl surveys). For Objective #2, we will raise EFH information Level 1 (L1) or Level 2 (L2) to Level 3 (L3) by integrating habitat-related vital rates generated from field and laboratory studies into updated, model-based EFH maps for those species. In addition to meeting these Research Plan objectives, we will introduce alternative SDM approaches for describing EFH both to incorporate new data sources and to optimize our modeling approaches through skill testing and simulation.

Ned Laman (RACE Division, AFSC, Seattle, WA), Jodi Pirtle (Alaska Regional Office, Juneau, AK), Chris Rooper (DFO Canada, Nanaimo, B.C.), Tom Hurst (FBEP, AFSC, Newport, OR)

At-Sea Backdeck Electronic Data Entry--GAP

The RACE groundfish group has been working on an effort to digitally record their survey data as it is collect on the back deck of survey vessels. This new method will eventually replace the original method of recording biological sampling data on paper forms (which then needed to be transcribed to a digital format at a later time). This effort has involved the development of in-house Android applications. These applications are deployed on off-the-shelf Android tablets.

The first application developed was a length recording app, which replaced the obsolete and unsustainable "polycorder" devices already in use. The "Length App" is now used on all groundfish surveys. A specimen collection app was deployed in 2017 and is now used on all survey vessels in 2019. A new "At Sea" editing application will be deployed in 2021.

Future plans include establishing two-way communication between the tablets and a wheelhouse database computer, so all collected biological data can be fully integrated real-time into a centralized database. This effort aims to allow us to collect more, and more accurate, biological data, in a more efficient way.

For further information contact Heather Kenney, (206) 526-4215 (heather.kenney@noaa.gov) or Alison Vijgen (206) 526-4186 (Alison.vijgen@noaa.gov).

Systematics Program - RACE GAP

Several projects on the systematics of fishes of the North Pacific have been completed or were underway during 2019. Orr and Wildes are continuing their work on sandlances by including Atlantic species in a global analysis and conducting more detailed population-level studies in the eastern and western Pacific. Similarly, they are collaborating on a study of Pacific Capelin and in particular on the taxonomic status of the Gulf of Alaska populations. Continuing progress has been made in examining morphological variation related to recently revealed genetic heterogeneity in rockfishes (*Sebastes crameri*; Orr, with NWFSC) and flatfishes (*Hippoglossoides*; Orr, Spies, Paquin, Raring, and Kai of Kyoto University); in a systematic revision of the agonid genus *Pallasina* (Stevenson, Orr, and Kai); and in a study of the population structure and demographic history of the pelagic Smooth Lumpsucker (Okazaki, Stevenson, Kai, and others at Kyoto Univ.). Work on the molecular phylogenetics and selected morphology of snailfishes was published (Orr et al., 2019a, with Spies, Stevenson, Kai, and the NWFSC, and University of Washington), as well as new records of skates for Alaska and British Columbia (Orr et al., 2019b, with Stevenson, Spies, Hoff, and the Royal BC Museum). The description and naming of a new snailfish, masquerading in Alaska under the name of *Careproctus melanurus* (the Blacktail Snailfish) is in review (Orr, Stevenson, Spies, and UW), and the descriptions of at least six new species of snailfishes, based on morphology and genetics, from the Arctic, Alaska, and Canada (Orr), are also underway.

Also, with AFSC geneticists, we are examining population-level genetic diversity, using NextGen sequencing techniques, in the Alaska Skate, *Bathyraja parmifera*, especially as related to its nursery areas, with NPRB support (Hoff, Stevenson, Spies, and Orr). Orr and Stevenson, with Spies, will also be examining the population genetics of nine species of Alaska's flatfishes, using the same NextGen sequencing techniques. Orr, in collaboration with the UW, UCLA, and the University of Western Alabama, will be exploring the use of genomics in the population dynamics and ageing of rockfishes. Stevenson is also collaborating with Spies and NWFSC and UW authors on a genetic documentation of the northward range expansion in the eastern Bering Sea stock of Pacific cod (Spies et al., in prep), and will be collaborating with Spies on a total genomic analysis of Walleye Pollock (along with post-doc Ellie Bors). Molecular and morphological studies on *Bathyraja interrupta* (Stevenson, Orr, Hoff, and Spies) are also continuing. In addition to systematic publications and projects, RACE systematists have been involved in works on summaries and zoogeography of North Pacific fishes, including collaborations with the University of Washington on a comprehensive book of the fishes of the Salish Sea with all species fully illustrated in color (Pietsch and Orr, 2019), and the biology of freshwater flatfishes (Orr, in press). Stevenson recently completed a study documenting recent northward shifts in the distribution of several marine species in the Bering Sea (Stevenson and Lauth, 2019), as well as an investigation documenting interactions between commercial fisheries and skate nursery areas (Stevenson, Hoff, Orr, and others, 2019). Stevenson and Orr recently concluded a collaboration with Hoff, Spies, Chris Rooper and others to develop a predictive model for skate nursery habitat in the eastern Bering Sea (Rooper et al., 2019), and Stevenson is continuing a collaboration with UW graduate student Kayla Hall on the early development of skate embryos.

2019 Publications:

Orr, J. W., I. B. Spies, D. E. Stevenson, G. C. Longo, Y. Kai, S. Ghods, and M. Hollowed. 2019a. Molecular phylogenetics of snailfishes (Cottiformes: Liparidae) based on MtDNA and RADseq genomic analyses, with comments on selected morphological characters. *Zootaxa* 4642:1–79. https://www.mapress.com/j/zt/article/view/zootaxa.4642.1.1/28865

Orr, J. W., D. E. Stevenson, G. Hanke, I. B. Spies, James A. Boutillier, and G. R Hoff. 2019b. Range extensions and new records from Alaska and British Columbia for two skates, *Bathyraja spinosissima* and *B. microtrachys*. *Northwestern Naturalist* 100(1):37–47. https://bioone.org/journals/Northwestern-Naturalist/volume-100/issue-1/NWN18-21/Range-Extensions-and-New-Records-from-Alaska-and-British-Columbia/10.1898/NWN18-21.short

Pietsch, T. W., and J. W. Orr. 2019. *Fishes of the Salish Sea: Puget Sound and the Straits of Georgia and Juan de Fuca.* University of Washington Press, Seattle, 1048 p. + 350 figs in 3 volumes. https://uwapress.uw.edu/book/9780295743745/fishes-of-the-salish-sea/

Rooper, C. N., G. R. Hoff, D. E. Stevenson, J. W. Orr, and I. B. Spies. 2019. Skate egg nursery habitat in the eastern Bering Sea: a predictive model. *Marine Ecology Progress Series* 609:163–178. https://repository.library.noaa.gov/view/noaa/21083

Stevenson, D. E., G. R. Hoff, J. W. Orr, I. Spies, and C. N. Rooper. 2019. Interactions between fisheries and early life stages of skates in nursery areas of the eastern Bering Sea. Fishery Bulletin 117:8–14. https://spo.nmfs.noaa.gov/sites/default/files/pdf-content/fish-bull/stevenson.pdf

Stevenson, D. E., and R. R. Lauth. 2019. Bottom trawl surveys indicate recent shifts in the distribution of marine species. Polar Biology 42:407–421. https://link.springer.com/article/10.1007/s00300-018-2431-1

V. Ecosystem Studies

Ecosystem Socioeconomic Profile (ESP) – AFSC

Ecosystem-based science is an important component of effective marine conservation and resource management; however, the proverbial gap remains between conducting ecosystem research and integrating with stock assessments. A main issue involves the general lack of a consistent approach to deciding when to incorporate ecosystem and socio-economic information into a stock assessment and how to test the reliability of this information for identifying future change. Our current national system needs an efficient testing ground and communication tool in order to effectively merge the ecosystem and stock assessment disciplines.

Over the past several years, we have developed a new standardized framework based on nationally collected data that facilitates the integration of ecosystem and socioeconomic factors within the stock assessment process (Shotwell et al., 2018). This Ecosystem and Socioeconomic Profile or ESP can be considered a type of research template that serves as a proving ground for testing ecosystem linkages before operational use in quota setting. The ESPs serve as a corollary stock-specific process to the large-scale ecosystem status reports, effectively creating a two-pronged system for ecosystem-based fisheries management at the AFSC.

The initial ESP process begins with a data evaluation of the stock to assess the priority for conducting an ESP and set tangible research priorities for the stock. Once it is established to conduct an ESP, a set of metrics are graded to determine vulnerabilities throughout the life history of the stock and assist with indicator development. Following metric grading, a sequential multi-stage testing phase ensues depending on the data availability of the stock to determine the relevant ecosystem and socioeconomic indicators for continued monitoring. The final stage of the ESP process is to produce full and executive summary standard reports to effectively and efficiently communicate the results of the ESP process to a wide variety of user groups (Shotwell et al., *In Review*).

Two of the three annual workshops planned to fine-tune the ESP framework to the needs of the AFSC have recently been completed. The first data workshop summarized the available data for use in an ESP from a large variety of programs both within and external to the AFSC. This workshop was conducted in May 2019 and results were presented at the Preview of Ecosystem and Economic Considerations (PEEC) meeting in June 2019 and at the Joint Crab and Groundfish September Plan Team 2019. The second model workshop was recently conducted in March 2020 through two small in-person host sites and large remote participation due to current events regarding COVID-19. The workshop presentations reviewed current progress on the ESPs as well as modeling applications to create value-added metrics or indicators for the ESPs and models to evaluate indicators for use in the ESPs and the operational stock assessments. A one-day discussion session is planned prior to the crab and groundfish September Plan Teams 2020 to provide a short review of the presentations and engage in-group discussions that were truncated due to the largely remote participation of the workshop.

A methods manuscript detailing the four-step ESP framework, along with technical memorandums of the workshops are planned for 2020. Additional web applications and data repository are also in development to provide access to the data and model output for use in the ESPs. These products will improve communication of the ESP framework and allow timely and consistent access to regional or stock-specific ecosystem and socio-economic indicators for use in the ESPs. Altogether, the workshops and reports will pave a clear path toward building next generation stock assessments and increase communication and collaboration across the ecosystem, economic, and stock assessment communities at the AFSC.

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

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Shotwell, S.K. 2018. Update on the Ecosystem and Socio-economic Profile (ESP). NPFMC Report. 11 p. See link below and select "ESP_Update_PT-0918_Shotwell.pdf" http://legistar2.granicus.com/npfmc/meetings/2018/9/984_A_Groundfish_Plan_Team_18-09-18_Meeting_Agenda.pdf?id=a1ffa673-eac1-44cb-89eb-1d46b7af71b1

Shotwell, S.K., K., Blackhart, D., Hanselman, C. Cunningham, K., Aydin, M., Doyle, B., Fissel, P., Lynch, P., Spencer, S., Zador. *In Review*. Creating a proving ground for operational use of ecosystem and socioeconomic considerations within next generation stock assessments.

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Shotwell, S.K., M. Dorn, A.L. Deary, B. Fissel, L. Rogers, and S. Zador. 2019. Ecosystem and Socioeconomic Profile of the Walleye Pollock stock in the Gulf of Alaska. Appendix 1A *In* Dorn, M., A.L. Deary, B.E. Fissel, D.T. Jones, N.E. Lauffenburger, W.A. Palsson, L.A. Rogers, S.A. Shotwell, K.A. Spalinger, and S.G. Zador. 2019. Assessment of the Walleye Pollock Stock in the Gulf of Alaska. Stock assessment and fishery evaluation report for the groundfish resources of the Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. 161 pp. Available online at: https://archive.afsc.noaa.gov/refm/docs/2019/GOApollock.pdf

2019 Crab ESPs:

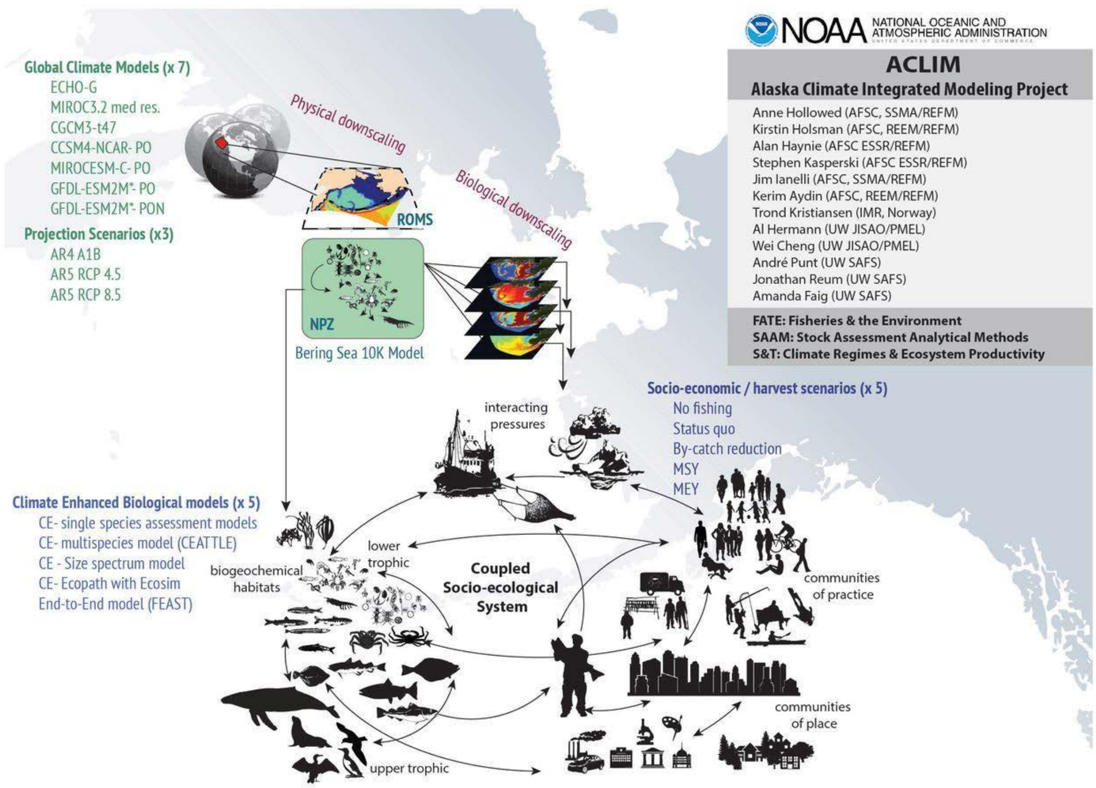
Fedewa, E., B. Garber-Yonts, K. Shotwell, and K. Palof. 2019. Ecosystem and Socioeconomic Profile of the Saint Matthew Blue King Crab stock in the Bering Sea. Appendix E *In* Palof, K., J. Zheng, and J. Ianelli. 2019. Saint Matthew Island Blue King Crab Stock Assessment 2019. Stock assessment and fishery evaluation report for the crab resources of the Bering Sea. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. 120 pp. Available online at: https://meetings.npfmc.org/CommentReview/DownloadFile?p=6ffde3ce-67be-4139-b165-cbff9062da06.pdf&fileName=C4%206%20SMBKC%20SAFE%202019.pdf

For more information, contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

Alaska Climate Integrated Modeling Project - REFM

The Alaska Climate Integrated Modeling project represents a comprehensive effort by NOAA Fisheries and partners to describe and project responses of the Bering Sea ecosystem – both the physical environment and human communities -- to varying climate conditions. Scientists are focusing on five key species where changes in productivity have been linked to climate variability:

walleye “Alaska” pollock, Pacific cod, Arrowtooth flounder, Northern rock sole and snow crab. A subset of scientists in ACLIM are also looking at impacts on other species in the food web and the broader ecosystem. To evaluate a range of possible future conditions, scientists are evaluating the effectiveness of existing fishery management actions under 11 different climate scenarios (spanning high and low CO2 futures expected to lead to different degrees of warming). They will also look at how human fishing fleets and communities can adapt to climate change through climate-informed management. Information from these integrated models is being used to make predictions at local scales. Output from these models will help decision-makers choose management measures that promote fisheries resilience, lessen climate impacts on species and communities, and take advantage of potential novel opportunities under climate change. For more information visit https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-climate-integrated-modeling-project.



The energy contribution of fish eggs to the marine food web in spring - RPP
Jens M. Nielsen*, Lauren A. Rogers, David G. Kimmel, Alison L. Deary, Janet T. Duffy-Anderson

Many fishes aggregate and spawn in high densities and release large amounts of energy and nutrients to the ambient environment in the form of eggs. These spawning events can provide important dietary resources for a range of predators. Despite the likely significance of fish eggs as an energy resource for other animals, there are very few studies that have quantified their importance for marine food webs. Here we assess the magnitude and timing of egg energy from Walleye Pollock (*Gadus chalcogrammus*) and their contribution to a highly productive ecosystem in Shelikof Strait, Gulf of Alaska. Our results show that aggregate spawning events of Walleye Pollock contribute considerably to the energy and nutritional fluxes of this coastal food web in spring. Walleye Pollock egg energy constituted on average 18.9% of April and 5.8% of May copepod production in the Shelikof Strait marine food web (Fig 1). In addition, the energy contributions from eggs appear one to three weeks earlier than the spring peak rates of zooplankton production and thus occur at a time when resources are still limited for many predators. Our analysis suggests that energy pulses from spawning events provide important energetic and nutritional fluxes in marine ecosystems.

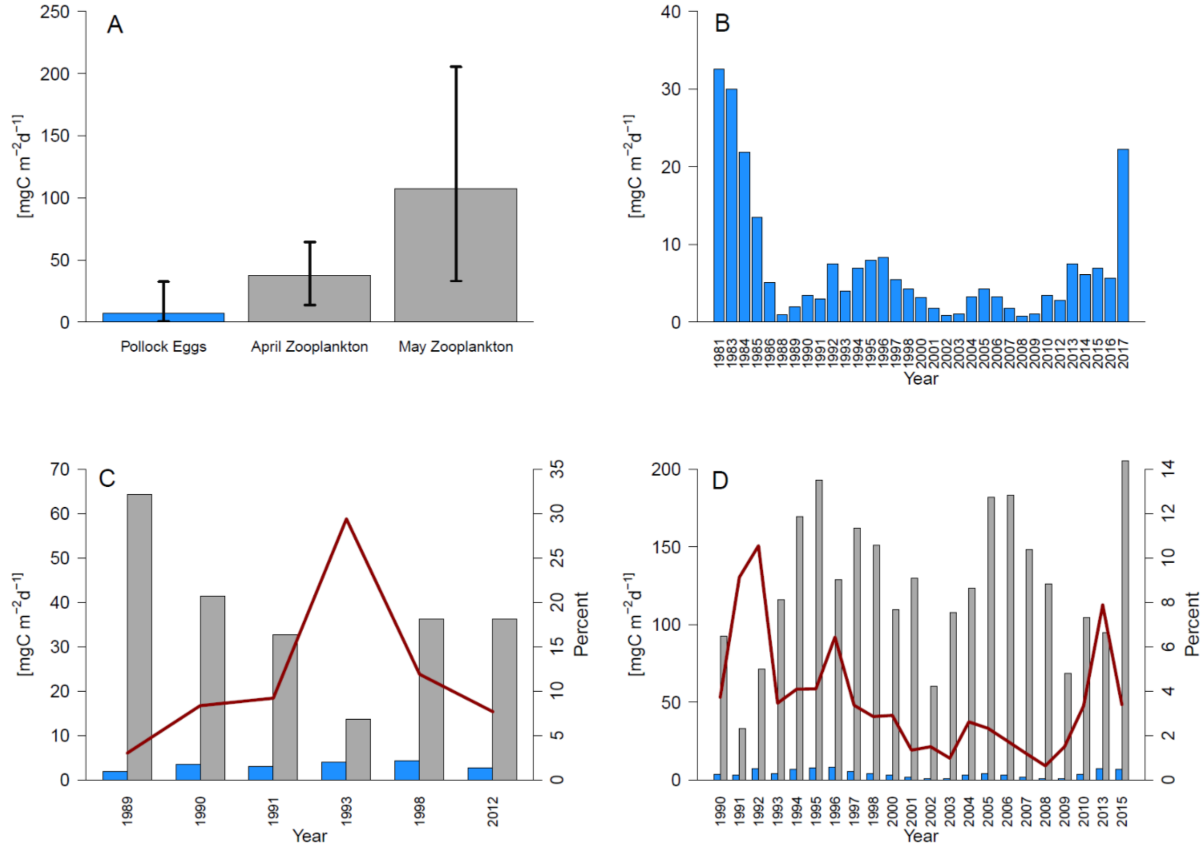


Fig 1: Estimates of, **A**) average production [mgC m^{-2} m^{-1}] of Walleye Pollock eggs deposited as energy, April and May zooplankton, **B**) annual egg production, and comparison of yearly Walleye Pollock egg production (blue) with **C**) April zooplankton (grey) and **D**) May (grey) zooplankton production. The red lines in **C** and **D** denote the relative proportion of egg production compared to total April or May zooplankton production.

Auke Bay Laboratories (ABL)

Pre- and Post-Winter Temperature Change Index and the Recruitment of Bering Sea Pollock

Description of indicators: The temperature change (TC) index is a composite index for the pre- and post-winter thermal conditions experienced by walleye pollock (*Gadus chalcogrammus*) from age-0 to age-1 in the eastern Bering Sea (Martinson et al., 2012). The TC index (year t) is calculated as the difference in the average monthly sea surface temperature in June (t) and August (t-1) (Figure 1) in an area of the southern region of the eastern Bering Sea (56.2°N to 58.1°N latitude by 166.9°W to 161.2°W longitude). Time series of average monthly sea surface temperatures were obtained from the NOAA Earth System Research Laboratory Physical Sciences Division website. Sea surface temperatures were based on NCEP/NCAR gridded reanalysis data (Kalnay et al., 1996, data obtained from http://www.esrl.noaa.gov/psd/cgi-bin/data/timeseries/timeseries1.pl). Less negative values represent a cool late summer during the age-0 phase followed by a warm spring during the age-1 phase for pollock.

Status and trends: The 2019 TC index value is -1.96, higher than the 2018 TC index value of -4.1, indicating improved conditions for pollock survival from age-0 and age-1 from 2018 to 2019, respectively. The increase in expected survival is due to the smaller difference in sea temperature from late summer (average) to the following spring (warmer). The late summer sea surface temperature (10.2 °C) in 2018 was near the longer term average (9.8 °C) and spring sea temperatures (8.2 °C) in 2018 were warmer than the long-term average of 5.3 °C in spring since 1949.

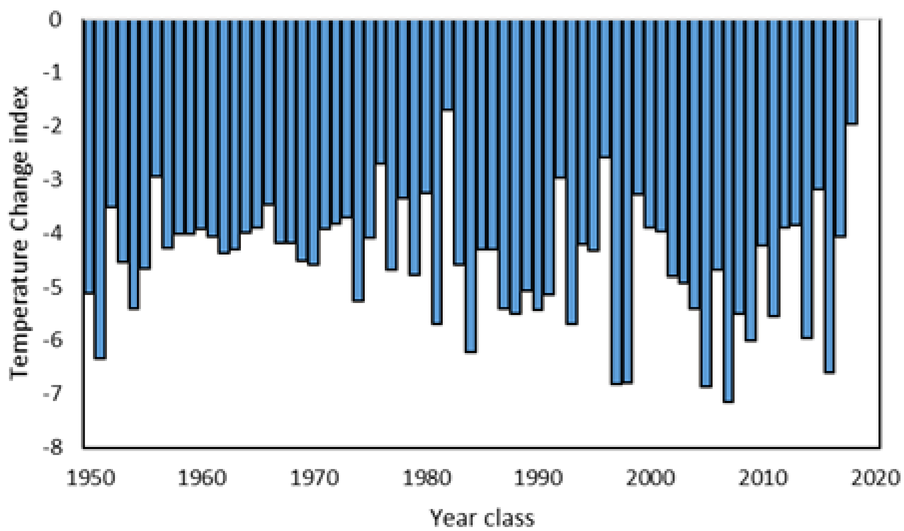


Figure 1: The Temperature Change index values from 1950 to 2019. Values represent the differences in sea temperatures on the south eastern Bering Sea shelf experienced by the 1949-2018 year classes of pollock. Less favorable conditions (more negative values) represent a warm summer during the age-0 life stage followed by a relatively cool spring during the age-1 life stage. More favorable conditions (less negative values) represent a cool summer during the age-0 life stage followed by a relatively warm spring during the age-1 life stage.

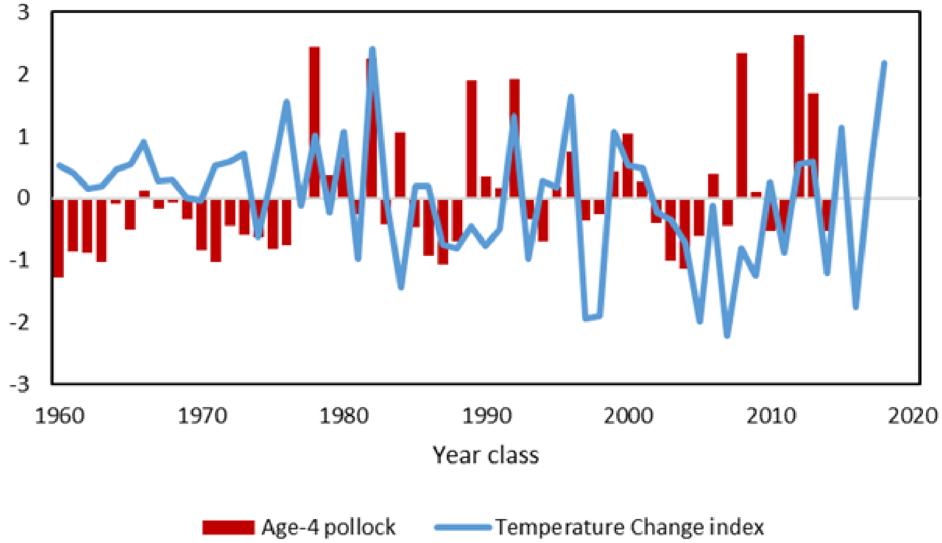


Figure 2: Normalized time series values of the temperature change index indicating conditions experienced by the 1960-2018 year classes of pollock during the summer age-0 and spring age-1 life stages. Normalized values of the estimated abundance of age-4 walleye pollock in the eastern Bering Sea from 1964-2018 for the 1960-2014 year classes. Age-4 walleye pollock estimates are from Table 28 in Ianelli et al. 2018. The TC index indicate above average conditions for the 2017 and 2018 year classes of pollock.

Factors causing observed trends: According to the original Oscillating Control Hypothesis (OCH), warmer spring temperatures and earlier ice retreat led to a later oceanic and pelagic phytoplankton bloom and more food in the pelagic waters at an optimal time for use by pelagic species (Hunt et al., 2002). The revised OCH indicated that age-0 pollock were more energy-rich and have higher over wintering survival to age-1 in a year with a cooler late summer (Coyle et al., 2011; Heintz et al., 2013). Therefore, the colder later summers during the age-0 phase followed by warmer spring temperatures during the age-1 phase are assumed favorable for the survival of pollock from age-0 to age-1. The 2018 year class of pollock experienced average summer temperatures during the age-0 stage and a warm spring in 2019 during the age-1 stage indicating slightly above average conditions for over wintering survival from age-0 to age-1.

Implications: The 2019 TC index value of -1.96 was above the long-term average of -4.56, therefore we expect above average recruitment of pollock to age-4 in 2022 from the 2018 year class (Figure 2).

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For further information contact Ellen Yasumiishi with questions, ellen.yasumiishi@noaa.gov.

Resource Ecology and Ecosystem Modeling Program (REEM)

Multispecies, foodweb, and ecosystem modeling and research are ongoing. Documents, symposia and workshop presentations, and a detailed program overview are available on the Alaska Fisheries Science Center (AFSC) web site at: http://www.afsc.noaa.gov/REFM/REEM/Default.php.

Ecosystem Considerations 2019: The Status of Alaska's Marine Ecosystems (REFM)
The status of Alaska's marine ecosystems is presented annually to the North Pacific Fishery Management Council as part of the Stock Assessment and Fishery Evaluation (SAFE) report. There are separate reports for each of four ecosystems: the eastern Bering Sea, Aleutian Islands, Gulf of Alaska, and the Arctic. Comprehensive environmental data are gathered from a variety of sources. The goal of these Ecosystem Considerations reports is to provide the Council and other readers with an overview of marine ecosystems in Alaska through ecosystem assessments and by tracking time series of ecosystem indicators. This information provides ecosystem context to the fisheries managers' deliberations. The reports are now available online at the Ecosystem Considerations website at: http://access.afsc.noaa.gov/reem/ecoweb/index.php.

Groundfish Stomach Sample Collection and Analysis - REFM
The REEM Program continued regular collection of food habits information on key fish predators in Alaska's marine environment. During 2019, samples were collected during the eastern Bering

Sea, northern Bering Sea, and Gulf of Alaska bottom trawl surveys. Analysis of samples was conducted aboard vessels and in the laboratory.

Online sources for REEM data on food habits and fish ecology

- Accessibility and visualization of the predator-prey data through the web can be found at http://www.afsc.noaa.gov/REFM/REEM/data/default.htm.
- The predator fish species for which we have available stomach contents data can be found at http://access.afsc.noaa.gov/REEM/WebDietData/Table1.php.
- Diet composition tables have been compiled for many predators and can be accessed, along with sampling location maps at http://access.afsc.noaa.gov/REEM/WebDietData/DietTableIntro.php.
- The geographic distribution and relative consumption of major prey types for Pacific cod, walleye pollock, and arrowtooth flounder sampled during summer resource surveys can be found at http://www.afsc.noaa.gov/REFM/REEM/DietData/DietMap.html.
- REEM also compiles life history information for many species of fish in Alaskan waters, and this information can be located at http://access.afsc.noaa.gov/reem/lhweb/index.php.

Economics and Social Sciences Research (ESSR)

Annual economic SAFE report - ESSR

The ESSR program annually produces an economic counterpart to the stock assessment and fishery evaluation reports (SAFE) published by the North Pacific Fishery Management Council (NPFMC). Published as an appendix to the omnibus NPFMC SAFE document, the Economic Status Report presents summary statistics on catch, discards, prohibited species catch, ex-vessel and first-wholesale production and value, participation by small entities, and effort in these fisheries.

Developing better understanding of fisheries markets-REFM/ESSR

This is an ongoing project to improve our understanding and characterization of the status and trends of seafood markets for a broad range of products and species. AFSC economists have met with a number of seafood industry members along the supply chain, from fish harvesters to those who process the final products available at local retailer stores and restaurants. This project will be a culmination of the information obtained regarding seafood markets and sources of information industry relies upon for some of their business decisions. The report includes figures, tables, and text illustrating the current and historical status of seafood markets relevant to the North Pacific. The scope of the analysis includes global, international, regional, and domestic wholesale markets to the extent they are relevant for a given product. An extract of the market profiles was included in *Status Report for the Groundfish Fisheries Off Alaska, 2017*. A standalone dossier titled *Alaska Fisheries Wholesale Market Profiles* contains the complete detailed set of market profiles (Wholesale_Market_Profiles_for_Alaskan_Groundfish_and_Crab_Fisheries.pdf). An updated version of the *Alaska Fisheries Wholesale Market Profiles* report is forthcoming with an expected publication date of June 2019. For more information, contact ben.fissel@noaa.gov.

Economic data reporting in groundfish catch share programs-REFM/ESSR

The 2006 reauthorization of the Magnuson-Stevens Fishery Management and Conservation Act (MSA) includes heightened requirements for the analysis of socioeconomic impacts and the collection of economic and social data. These changes eliminate the previous restrictions on collecting economic data, clarify and expand the economic and social information that is required, and make explicit that NOAA Fisheries has both the authority and responsibility to collect the economic and social information necessary to meet requirements of the MSA. Beginning in 2005 with the BSAI Crab Rationalization (CR) Program, NMFS has implemented detailed annual mandatory economic data reporting requirements for selected catch share fisheries in Alaska, under the guidance of the NPFMC, and overseen by AFSC economists. In 2008, the Amendment 80 (A80) Non-AFA Catcher-Processor Economic Data Report (EDR) program was implemented concurrent with the A80 program, and in 2012 the Amendment 91 (A91) EDR collection went into effect for vessels and quota share holding entities in the American Fisheries Act (AFA) pollock fishery. In advance of rationalization or new bycatch management measures in the Gulf of Alaska (GOA) trawl groundfish fishery currently in development by the NPFMC, EDR data collection began in 2016 to gather baseline data on costs, earnings, and employment for vessels and processors participating in GOA groundfish fisheries. For further information, contact Brian.Garber-Yonts@NOAA.gov

FishSET: a spatial economics toolbox - REFM/ESSR
Since the 1980s, fisheries economists have modeled the factors that influence fishers' spatial and participation choices in order to understand the trade-offs of fishing in different locations. This knowledge can improve predictions of how fishers will respond to area closures, changes in market conditions, or to management actions such as the implementation of catch share programs. NOAA Fisheries and partners are developing the Spatial Economics Toolbox for Fisheries (FishSET). The aim of FishSET is to join the best scientific data and tools to evaluate the trade-offs that are central to fisheries management. FishSET will improve the information available for NOAA Fisheries' core initiatives such as coastal and marine spatial planning and integrated ecosystem assessments and allow research from this well-developed field of fisheries economics to be incorporated directly into the fisheries management process. For further information, contact Alan.Haynie@NOAA.gov

Defining the economic scope for ecosystem-based fishery management -ESSR
The emergence of ecosystem-based fisheries management (EBFM) has broadened the policy scope of fisheries management by accounting for the biological and ecological connectivity of fisheries. Less attention, however, has been given to the economic connectivity of fisheries. If fishers consider multiple fisheries when deciding where, when, and how much to fish, then management changes in one fishery can generate spillover impacts in other fisheries. Catch share programs are a popular fisheries management framework that may be particularly prone to generating spillovers given that decreasing over-capitalization is often a primary objective. We use data from Alaska fisheries to examine spillovers from each of the main catch share programs in Alaska. We evaluate changes in participation—a traditional indicator in fisheries economics—in both the catch share and non-catch share fisheries. Using network analysis, we also investigate whether catch-share programs change the economic connectivity of fisheries, which can have implications for the socioeconomic resilience and robustness of the ecosystem, and empirically identify the set of fisheries impacted by each Alaska catch share program. We find that cross-fishery participation spillovers and changes in economic connectivity coincide with some, but not all, catch share programs. Our findings suggest that economic connectivity and the potential for cross-fishery spillovers deserves serious consideration, especially when designing and evaluating EBFM policies. Reference: Kroetz et al (2019) *Proceedings of the National Academy of Sciences* 116(10): 4188-4193. For further information contact Dan.Lew@noaa.gov.

Empirical models of fisheries production: Conflating technology with incentives? - ESSR

Conventional empirical models of fisheries production inadequately capture the primary margins of behavior along which fishermen act, rendering them ineffective for ex ante policy evaluation. We estimate a conventional production model for a fishery undergoing a transition to rights-based management and show that ex ante production data alone arrives at misleading conclusions regarding post-rationalization production possibilities— even though the technologies available to fishermen before and after rationalization were effectively unchanged. Our results emphasize the difficulty of assessing the potential impacts of a policy change on the basis of ex ante data alone. Since such data are generated under a different incentive structure than the prospective system, a purely empirical approach imposed upon a flexible functional form is likely to reflect far more about the incentives under status-quo management than the actual technological possibilities under a new policy regime. Reference: Reimer et al (2019) *Marine Resource Economics* 32(2): 169 - 190. For further information contact Alan.Haynie@noaa.gov.

Forecast effects of ocean acidification on Alaska crab and groundfish fisheries - ESSR
Coastal regions around Alaska are experiencing the most rapid and extensive onset of ocean acidification (OA) compared to anywhere else in the United States (Mathis et al. 2015). Assessing future effects of OA is inherently a multi-disciplinary problem that requires models to combine methods from oceanography and fisheries science with the necessary linkages to assess socio-economic impacts. NOAA's Alaska Fisheries Science Center (AFSC) and Pacific Marine Environmental Laboratory (PMEL) collaborate to form the Alaska Ocean Acidification Enterprise. This collaboration combines the scientific disciplines of chemical and biological oceanography, fish and crab physiology, and population and bioeconomic modeling. By integrating observational data with species response studies, OA forecast models, and human impact assessments, it has been determined that Alaska coastal communities and the vast fisheries that support them have varying degrees of vulnerability to OA, ranging from moderate to severe. The AFSC ocean acidification research plan for 2018-20 is currently available. The AFSC workplan for 2018-20 includes a project that will reconfigure and link existing crab bioeconomic models by developing a new multispecies bioeconomic model to simultaneously evaluate the combined cumulative impacts of OA on the crab fisheries off the coast of Alaska. In addition, a new single-species bioeconomic model with population dynamics for northern rock sole in the eastern Bering Sea and Gulf of Alaska will be developed. For further information, contact Michael.Dalton@noaa.gov.

Economic analysis of ecosystem tradeoffs - ESSR
Principle 4 in the NOAA Fisheries Ecosystem Based Fisheries Management (EBFM) Roadmap is to explore and address tradeoffs within an ecosystem. This project analyzes ecosystem tradeoffs that are represented by bioeconomic reference points. Maximum sustainable yield (MSY) is the most important biological reference point in single-species fisheries management. However, tradeoffs exist in achieving MSY with predator-prey relationships and other ecological factors. In this project, the definition of multi-species MSY is based on the production possibility frontier (PPF) in economics which is the classical graphical representation of tradeoffs between two (or more) goods because these show how production of one good can be increased only by diverting resources from and foregoing some of the other good. This project will derive PPFs based on predator-prey relationships in the Aleutian Islands from a bioenergetic food web model and from the classical Lotka-Volterra model applied to a 3-species system with Pacific cod, arrowtooth flounder, and walleye pollock in the Bering Sea. Results from this project will be available for consideration as part of the Bering Sea Fishery Ecosystem Plan process. For further information, contact Michael.Dalton@noaa.gov.

Optimal growth of Alaska's groundfish economy and optimum yield limits in the Bering Sea and Gulf of Alaska - ESSR
This project is joining the Ramsey optimal growth model from macroeconomics, calibrated to data from the Alaska Social Accounting Matrix (AKSAM), with harvest production functions and stock dynamics of the Schaefer model, based on Mueter and Megrey's (2006) multi-species surplus production models for groundfish complexes in the Bering Sea and Gulf of Alaska. Optimal growth represents an extension of benefits of fish consumption to the whole economy, compared to maximum economic yield (MEY), in the traditional Gordon-Schaefer bioeconomic model, which is based solely on fish sector profits and is not a true welfare measure. Since MEY ignores costs and benefits in the macroeconomy, optimal growth is generally superior to MEY in terms of social welfare. The new economic growth model currently estimates steady state optimal growth of Alaska's economy is achieved with an optimum yield limit of 1.8 million metric tons in the Bering Sea/Aleutian Islands, and 294 thousand metric tons in the Gulf of Alaska. Mueter and Megrey's estimates for effects on surplus production of the Pacific Decadal Oscillation (PDO) in the Bering Sea/Aleutian Islands, and sea bottom temperatures at the oceanographic station GAK1 in the Gulf of Alaska, are included to measure impacts of Pacific climate variability on Alaska's economy. For further information, contact Michael.Dalton@noaa.gov.

Regional and community size distribution of fishing revenues in the North Pacific - ESSR
The North Pacific fisheries generate over $4 billion in first wholesale revenues annually. However, the analysis supporting management plans focuses on describing the flow of these monies through each fishery, rather than across the individual cities and states in which harvesters live and spend their fishing returns. This study contributes by providing a regional overview of the benefits from North Pacific fishing, looking beyond the changes in any particular community or any particular fishery. It seeks to describe the regions to which revenues from North Pacific fisheries are accruing, whether that distribution has changed significantly over the last decade, and how any changes might be caused or affected by management. This is important because managers or stakeholders may have preferences over the distribution of benefits within their jurisdiction, and while the movement of fishing activity out of communities is frequently the focus of academic and policy research, research focusing on single communities often does not follow where those benefits go. Of particular interest is whether movement of North Pacific fishery revenues is dominated by movement within coastal Alaska, or primarily shifts away from coastal communities to other regions outside of Alaska. A manuscript describing this project is currently under AFSC review. For further information, contact Ron.Felthoven@noaa.gov.

Tools to explore Alaska fishing communities - ESSR
Community profiles have been produced for fishing communities throughout the state of Alaska in order to meet the requirements of National Standard 8 of the Magnuson-Stevens Act and provide a necessary component of the social impact assessment process for fisheries management actions. A total of 196 communities from around Alaska were profiled as part of this effort. Social scientists in the AFSC Economic and Social Science Research Program have developed two web-based tools, which are updated as new data become available. All of this information is available at: https://www.afsc.noaa.gov/REFM/Socioeconomics/Projects/communities/profiles.php.

VI - AFSC GROUNDFISH-RELATED PUBLICATIONS AND DOCUMENTS

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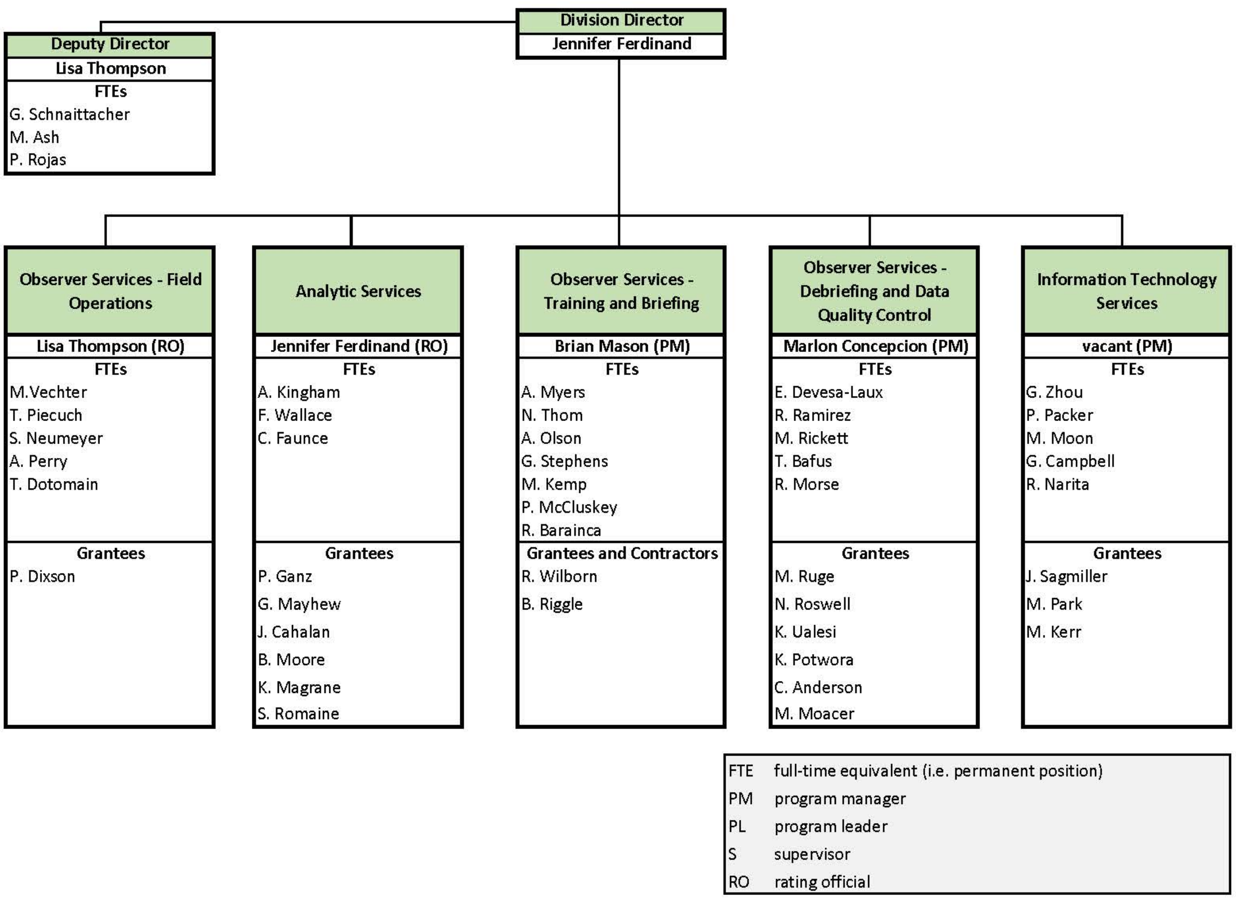
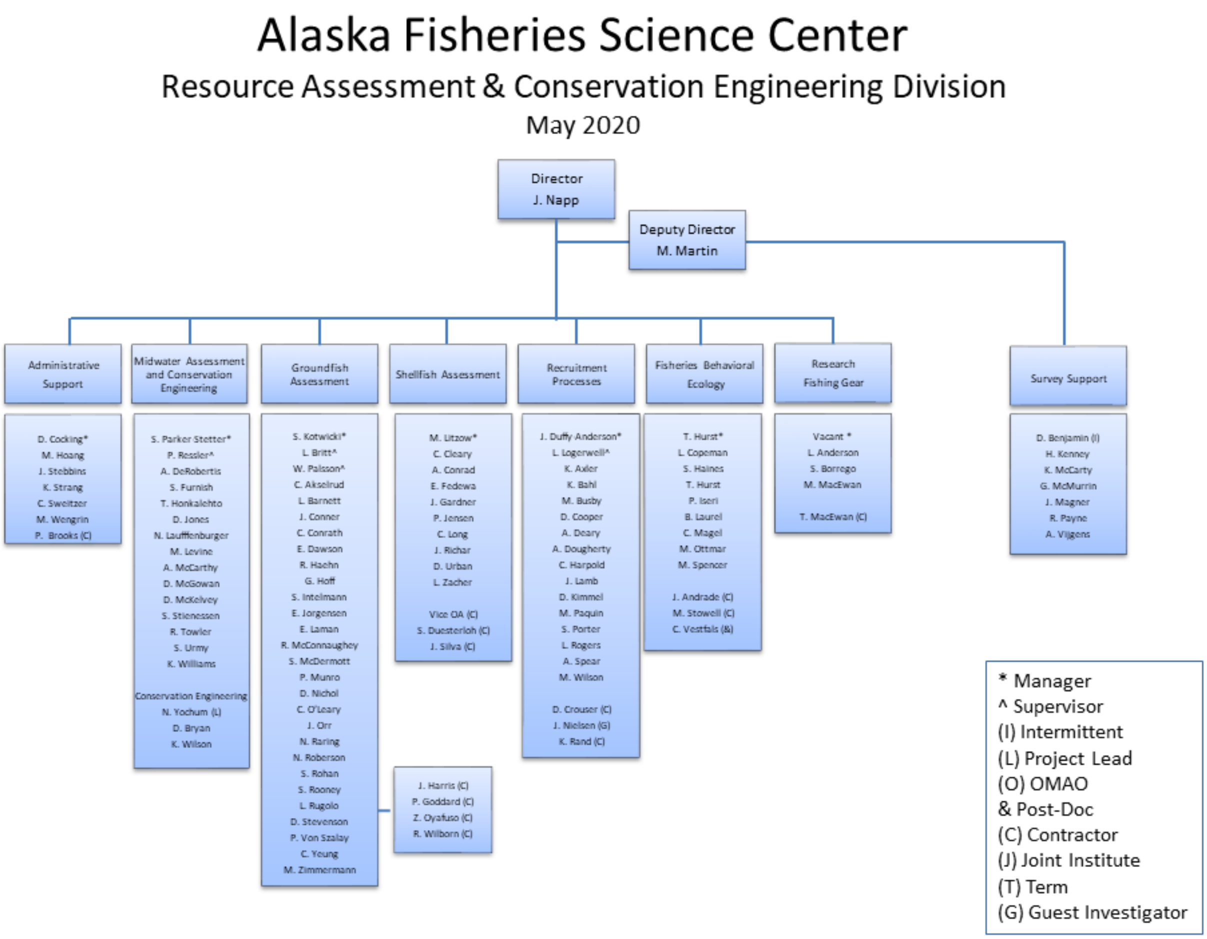
APPENDIX IV FMA



APPENDIX I. RACE ORGANIZATION CHART



APPENDIX II. REFM ORGANIZATION CHART

Division Director
Ron Felthoven

Deputy Director
Stephani Zador

Status of Stocks and Multispecies Assessment (SSMA)

Anne Hollowed (PM)

FTEs
A Hollowed (S/RO)
J Ianelli
M Dorn
G Thompson
S Barbeaux
P Spencer
W Stockhausen
C Szuwalski
S Lowe (S/RO)
M Bryan
O Ormseth
I Spies
C McGilliard
C Monnahan
K Shotwell

Contractors, postdocs, etc
A Havron
C Tarpay
E Bors
M Olmos
M Veron

Resource Ecology and Ecosystems Modeling (REEM)

Kerim Aydin (PM)

FTEs
K Aydin (S/RO)
J Reum
S Fitzgerald
K Holsman
G Lang
M Yang
B Ferriss

Contractors, postdocs, etc
R Hibpshman
K Kearny
I Ortiz
A Whitehouse
G Carroll
K Dill
K Gunther
S Wang

Economics and Social Science Research (ESSR)

Stephen Kasperski (PM)

FTEs
S Kasperski (S/RO)
M Dalton
B Fissel
B Garber-Yonts
A Haynie
D Lew
C Seung
S Wise
M Szymkowiak

Contractors, postdocs, etc
B Huang
S Devereaux
A Faig
M Harsh
J Lee
K Sparks
B McManus
M Rhodes-Reese

Age and Growth Program (AG)

Thomas Helser (PM)

FTEs
T Helser (S/RO)
I Benson
B Matta
C Kastelle
J Short
T TenBrink
S Neidetcher
E. Goldstein
Anderl (S/RO)
C Hutchinson
J Pearce
K Stone
J Brogan
C Gburski
C Piston
D Nadjkovic

Contractors, postdocs, etc
B Groom
M Arrington
J Healy

Admin (supports RACE and REFM)

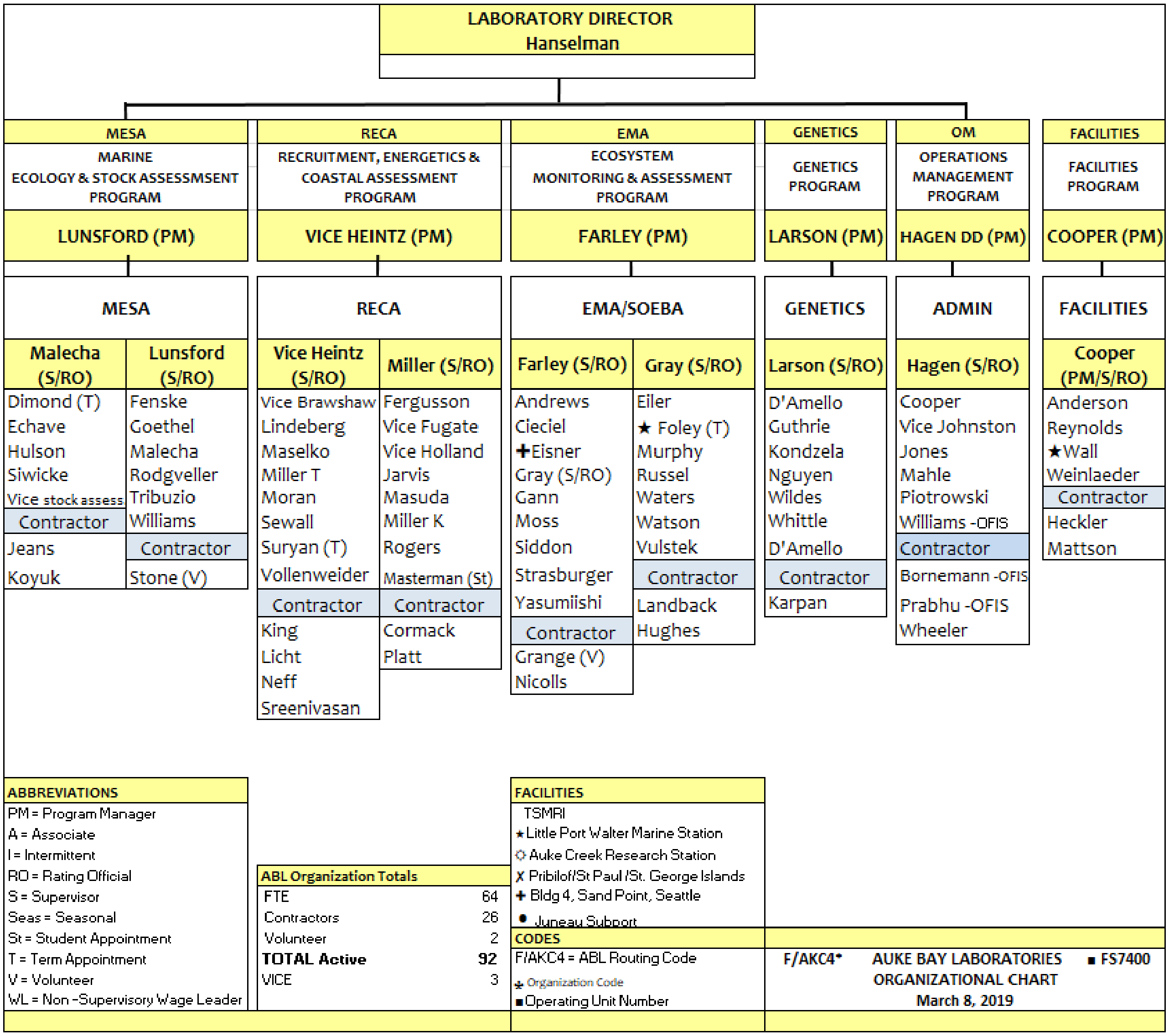
Dona Cocking (S/PM)

FTEs
M Hoang
K Strang
J Stebins
C Sweitzer
M Wengrin

Contractors, etc
P Brooks

FTE	full-time equivalent (i.e. permanent position)
PM	program manager
PL	program leader
S	supervisor
RO	rating official
vice	vacant position

APPENDIX III – AUKE BAY LABORATORY ORGANIZATIONAL CHART



APPENDIX IV – FMA ORGANIZATIONAL CHART

CANADA

British Columbia Groundfish Fisheries and Their Investigations in 2019

April 2020

Prepared for the
Technical Sub-Committee of the Canada-United States Groundfish Committee

Compiled by
M. Cornthwaite, L. Granum, and D. Haggarty
Fisheries and Oceans Canada
Science Branch, Pacific Biological Station,
Nanaimo, British Columbia V9T 6N7

Table of Contents

I. Agency Overview

Fisheries and Oceans Canada (DFO) has its regional headquarters office (RHQ) for the Pacific Region (British Columbia and Yukon) in Vancouver, British Columbia, with area offices and science facilities at various locations throughout the Region. Groundfish fishery management is conducted by the Groundfish Management Unit within the Fisheries Management Branch at RHQ, while Groundfish stock assessment and research is conducted by Science Branch at the Pacific Biological Station (PBS) in Nanaimo, and at the Institute of Ocean Sciences (IOS) in Sidney. Within Science Branch, a variety of programs are responsible for delivering groundfish stock assessments and research and for providing science advice to fishery managers, species at risk coordinators, marine spatial planners, etc. Directors, division managers, and section heads are as follows:

Fisheries and Oceans Canada Minister: The Honourable Bernadette Jordan

Regional Headquarters Office (RHQ)

Regional Director General: Rebecca Reid

Fisheries and Aquaculture Management Branch

Regional Director of Fisheries Management: Andrew Thomson
Regional Director of Resource Management: Neil Davis
Regional Manager of Groundfish: Adam Keizer

Science Branch

Regional Director of Science: Carmel Lowe

Strategic Science Initiatives Division (SSID): Brenda McCorquodale
- Centre for Science Advice – Pacific: Al Magnan
- Strategic Partnerships and Programs: March Klaver

Stock Assessment and Research Division (StAR): John Holmes
- Groundfish Section: Greg Workman
- Quantitative Assessment Methods Section: Chris Rooper
- Fisheries and Assessment Data Section: Shelee Hamilton
- Marine Invertebrates Section: Ken Fong
- Salmon Assessment: Antonio Velez-Espino
- Salmon Coordinator: Diana Dobson

Aquatic Diagnostics, Genomics & Technology Division (ADGT): Lesley MacDougall
- Applied Technology: Henrik Kreiberg
- Genetics: John Candy
- Aquatic Animal Health: Mark Higgins

Ocean Science Division (OSD): Kim Houston
- Ecology and Biogeochemistry: Andrew Ross
- Modelling & Prediction: Jon Chamberlain

- State of the Ocean: Charles Hannah

Ecosystem Science Division (ESD): Eddy Kennedy

- Marine Spatial Ecology & Analysis: Miriam O
- Aquatic Ecosystem & Marine Mammals: Sean MacConnachie
- Freshwater Ecosystems: Jeffery Lemieux
- Nearshore Ecosystems: Cher LaCoste
- Regional Ecosystem Effects on Fish & Fisheries: Kim Hyatt

Canadian Hydrographic Service (CHS): Mark LeBlanc

Groundfish research and stock assessment work is conducted amongst the Groundfish, Fisheries and Assessment Data, and Quantitative Methods Sections within StAR. Groundfish specimen ageing and genetics are conducted in the Applied Technologies and Genetics Sections in ADGT. Acoustic fisheries research and surveys are led by the Ecology and Biogeochemistry Section in OSD. Ecosystem studies, marine protected areas research and planning, and habitat research is undertaken in collaboration with staff in the Ecosystems Science Division (ESD).

Fishery Managers and other clients receive science advice from StAR through the Canadian Centre for Scientific Advice Pacific (CSAP) review committee. Groundfish subject matter experts meet periodically throughout the year to provide scientific peer review of stock assessment working papers and develop scientific advice; every peer review process involves both internal (DFO) and external reviewers. The resulting Science Advisory Report summarizes the advice to Fishery Managers, with the full stock assessment becoming a Research Document. Both documents can be viewed on the Canadian Stock Assessment Secretariat website: http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm. The frequency of review meetings and production of stock assessment advice for fisheries managers varies depending on departmental, branch and regional priorities.

The Canadian Coast Guard operates DFO research vessels. These research vessels include the J.P. Tully, Vector, and Neocaligus. The principal vessel used for groundfish research for the last three decades, the W.E. Ricker, was officially decommissioned in October of 2017. The replacement vessel for the W.E. Ricker, the Sir John Franklin, is currently undergoing preparations for deployment for her inaugural field season, anticipated for 2020. In the interim period, at sea operations for groundfish surveys requiring a large vessel have been conducted aboard chartered commercial fishing vessels.

The Groundfish Trawl, Sablefish, Rockfish, Lingcod, North Pacific Spiny Dogfish, and Halibut fishery sectors continue to be managed as an integrated fishery with Individual Vessel Quotas (IVQs). IVQs can be for specific areas or coastwide. Within the general IVQ context, managers also use a suite of management tactics including time and area specific closures and bycatch limits. The 2019 Groundfish Integrated Fisheries Management Plan (IFMP) is available from the Federal Science Library: https://waves-vagues.dfo-mpo.gc.ca/Library/40804343.pdf.

Allocations of fish for financing scientific and management activities are identified in the Groundfish IFMP. Collaborative Agreements were developed for 2019-20 between Fisheries and Oceans Canada and several partner organizations to support groundfish science activities through the allocation of fish to finance the activities. These agreements will be updated for 2020-21.

II. Surveys

A. Databases and Data Acquisition Software

GFBioField is a data acquisition software application created in-house by DFO staff in the Groundfish Surveys Program at the Pacific Biological Station in Nanaimo British Columbia. GFBioField was designed for real-time data capture and data entry during at-sea surveys but can also be used for dockside sampling and office-based data entry. Modified versions have been developed by Groundfish Surveys staff for use by other programs such as the Marine Invertebrates Section within the StAR Division, and the Aquatic Ecosystems and Marine Mammals Section and Regional Ecosystem Effects on Fish and Fisheries Section in the Ecosystem Science Division.

GFBioField uses a client-server architecture employing Microsoft SQL Server 2016 for the back-end data storage and business logic. Previous versions used a Microsoft Access 2007 project for the user interface. However, in 2018, DFO adopted Microsoft Office 2016 as the standard for all new workstations, and it was felt that continuing to maintain and support obsolete versions of the software would become increasingly difficult. Therefore, the GFBioField user interface was completely rebuilt as a Microsoft Access 2016 front-end. The new version was successfully deployed for the 2019 field season.

GFBio is an oracle database developed in-house by DFO staff in the 1990s, which houses groundfish research survey and commercial biological data collected in British Columbia from the 1940s to the present. GFBio now includes approximately 29 thousand trips and approximately 11.6 million individual fish specimens. In 2019, data entry activities concentrated on input of recent and historic groundfish research cruises and current-year commercial biological data from at-sea and dockside observers, as well as some non-groundfish survey data from other DFO surveys.

B. Commercial Fishery Monitoring and Biological Sampling

Groundfish commercial fisheries in British Columbia are subject to 100% catch monitoring, either by the at-sea observer program (ASOP) or by electronic monitoring, with all bottom trawl trips outside the Strait of Georgia accompanied by an at-sea observer, and all line trips subject to video monitoring. A dockside monitoring program (DMP) validates all commercial landings. Commercial fishery data from observer logs, fisher logs, and DMP are captured electronically in the groundfish modules of the Fishery Operations System (FOS) database, maintained by the Fisheries and Aquaculture Management Branch of DFO. Groundfish Science maintains GFFOS, which contains the groundfish FOS data, reformatted to be useful for scientific purposes.

In addition to monitoring catches at sea, the ASOP also provides biological samples of halibut, salmonids, and a variety of important commercial groundfish species from the observed trawl fishery. Biological samples are also collected from the hake fishery as part of the DMP. Additional commercial biological samples may also be collected by DFO staff at the dockside from sablefish trips or other trips that would not otherwise be sampled. Biological samples are uploaded to GFBio on a quarterly basis. In 2019, samples were collected from 323 commercial trips, resulting in approximately 24 thousand specimen records.

C. Research Surveys

The Fisheries and Oceans, Canada (DFO) Groundfish section of the Stock Assessment and Research Division conducts a suite of fishing surveys using bottom trawl, longline hook, and longline trap gear that, in aggregate, provide comprehensive coverage for all offshore waters of Canada's Pacific Coast. The randomized surveys include the Multispecies Synoptic Bottom Trawl, Hard Bottom Longline Hook, and Sablefish Longline Trap surveys (Figure 1). All the surveys follow similar random depth-stratified designs and have in common full enumeration of the catches (all catch sorted to the lowest taxon possible), size composition sampling for most species, and more detailed biological sampling of selected species. Most of the surveys are conducted in collaboration with the commercial fishing industry under the authorities of various Collaborative Agreements. In addition to these randomized surveys, a fixed-station longline hook survey targeting North Pacific Spiny Dogfish in the Strait of Georgia is completed every three years. The Groundfish section also routinely participates in the Canadian portion of the Joint Canada US Hake Acoustic Survey, collects groundfish information from a DFO Small-Mesh Bottom Trawl Survey, and funds an additional technician during the International Pacific Halibut Commission (IPHC) Setline Survey (Figure 2).

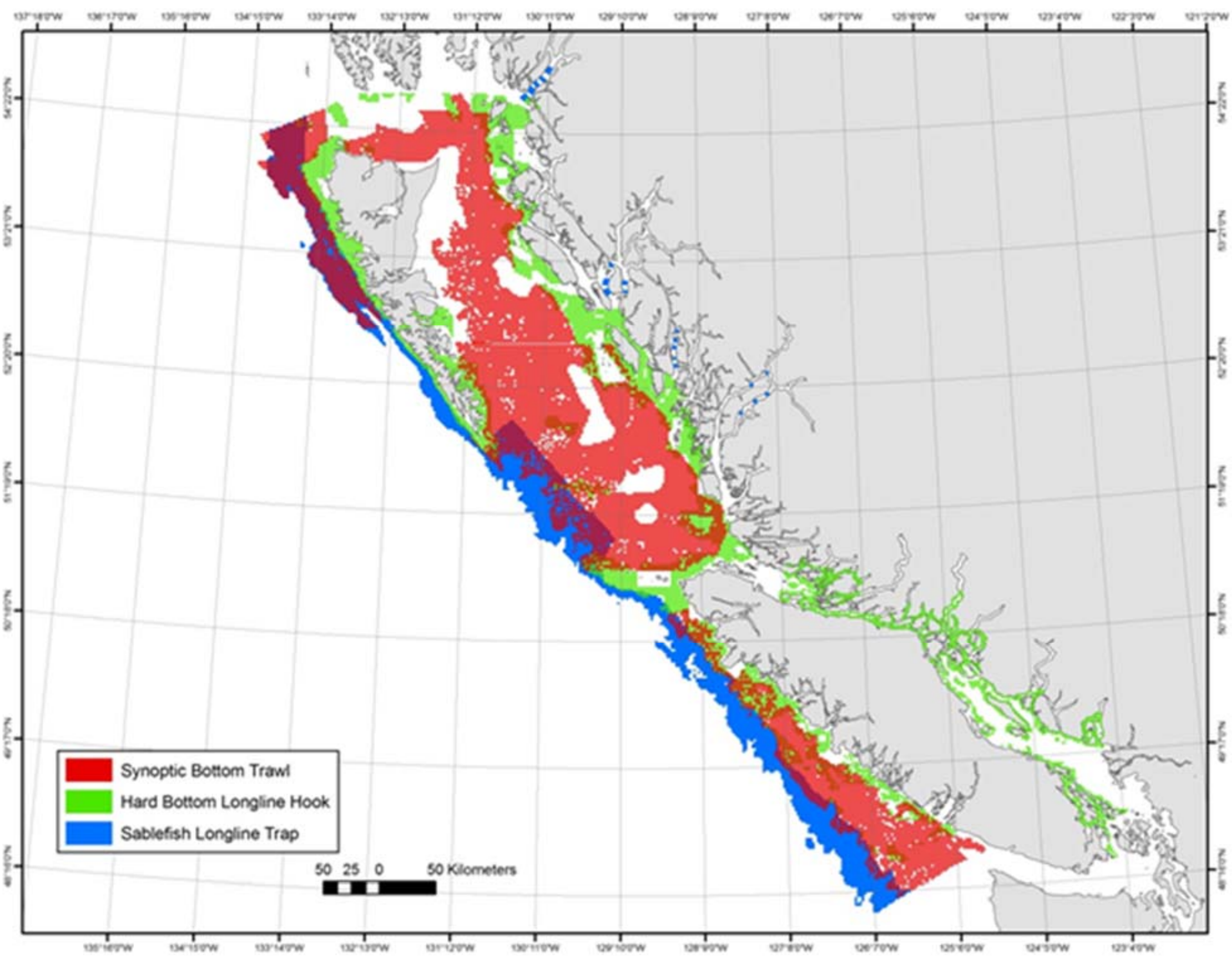


Figure 1. Random depth-stratified survey coverage.

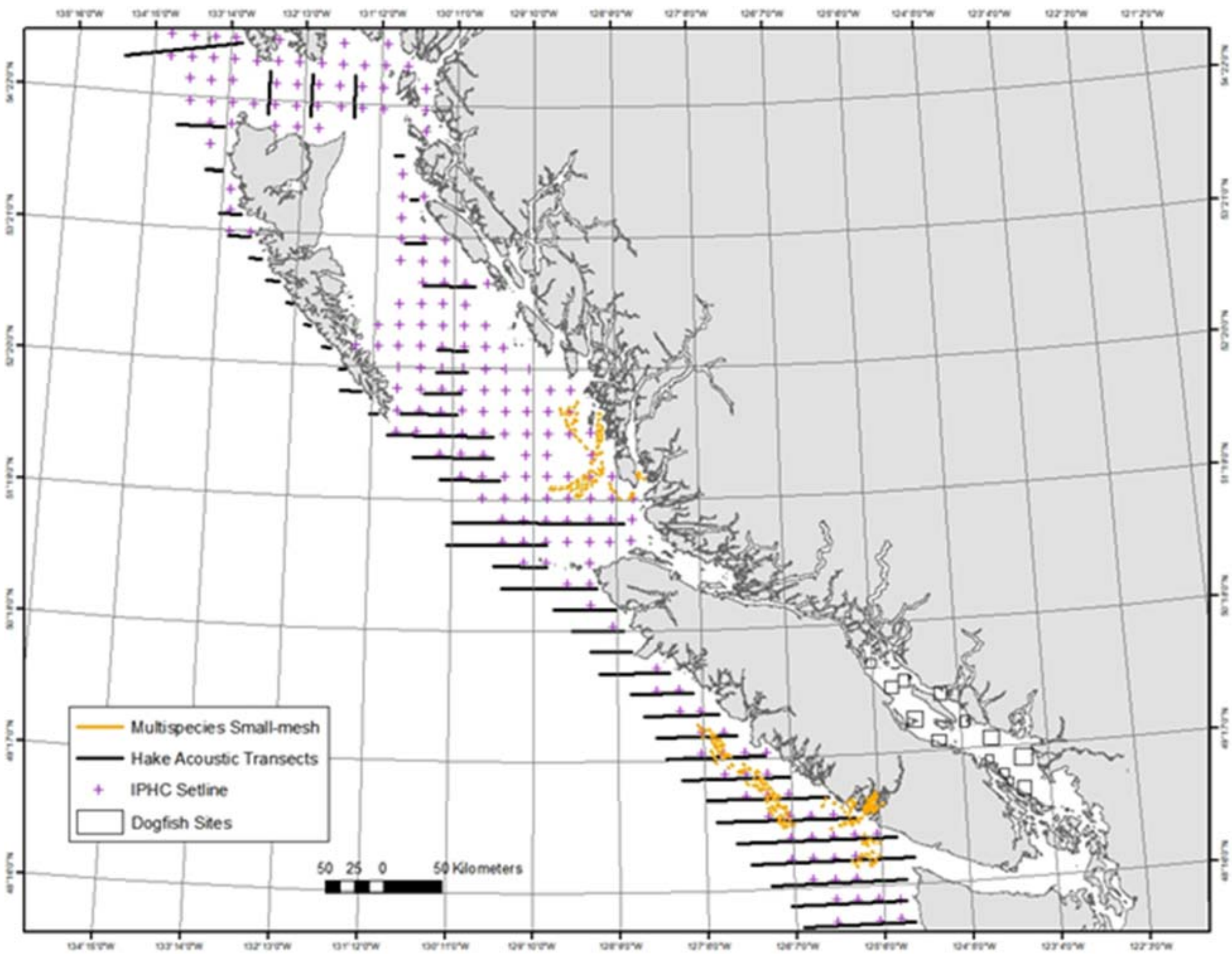


Figure 2. Non-random depth-stratified surveys that form part of the Groundfish surveys program including the Multi-species Small-mesh Bottom Trawl Survey, the Pacific Hake Acoustic Survey, the International Pacific Halibut Commission (IPHC) Setline Survey and the Strait of Georgia Dogfish Longline Hook Survey.

The **Multispecies Synoptic Bottom Trawl Surveys** are conducted in four areas of the BC coast with two areas surveyed each year, such that the whole coast is surveyed over a two-year period. Typically, the West Coast of Vancouver Island (WCVI) and West Coast of Haida Gwaii (WCHG) are surveyed in even-numbered years, while Hecate Strait (HS) and Queen Charlotte Sound (QCS) are surveyed in odd-numbered years (Figure 3). An additional synoptic bottom trawl survey has been conducted twice in the Strait of Georgia (SOG), but vessel availability and staffing constraints have precluded establishing a regular schedule for this survey.

These surveys are conducted under a collaborative agreement with the Canadian Groundfish Research and Conservation Society (CGRCS) and, in typical years, one survey occurs on a Canadian Coast Guard Vessel and one survey occurs on a chartered commercial fishing vessel. In aggregate, the surveys provide coast-wide coverage of most of the trawlable habitat between 50 and 500 meters depth.

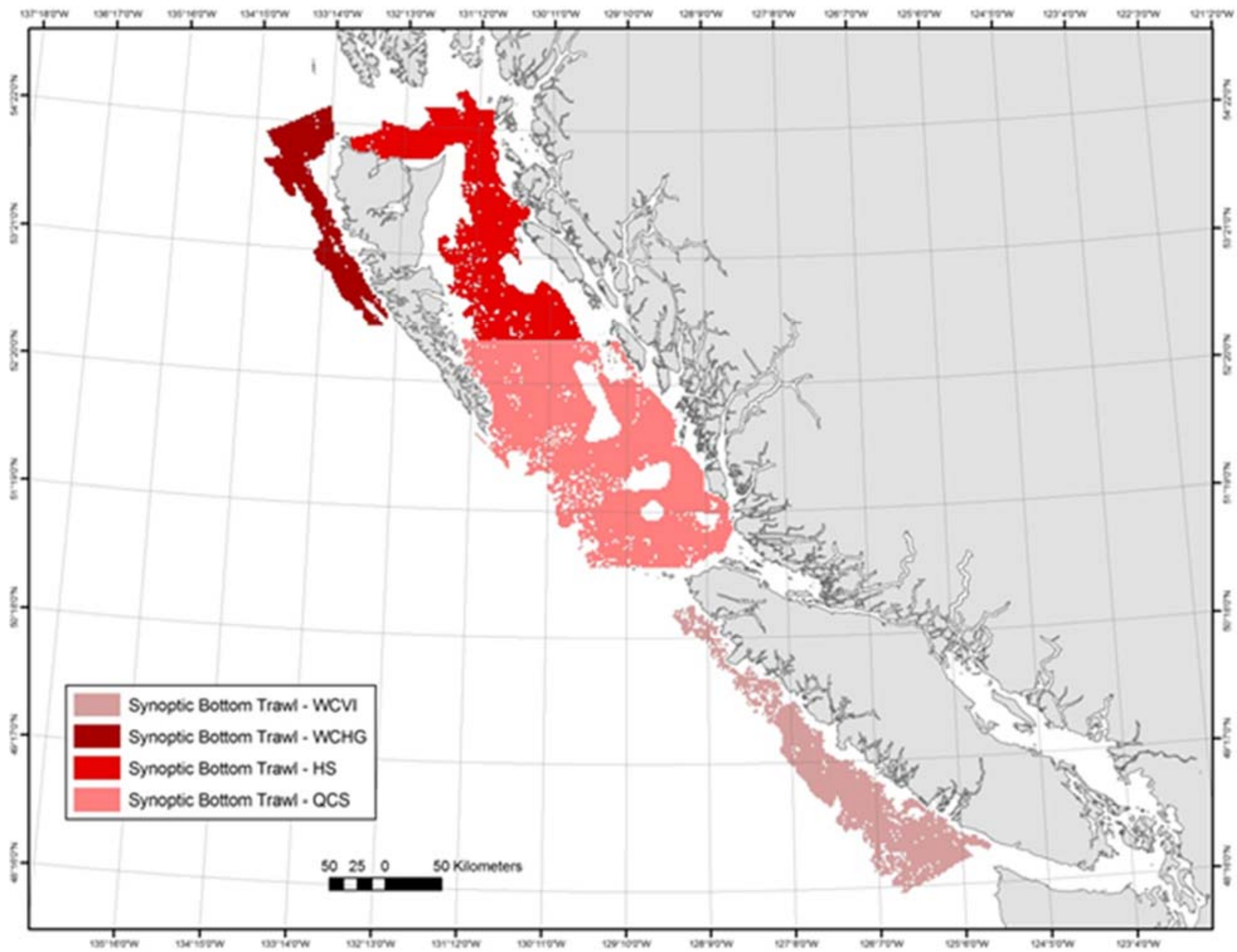


Figure 3. Multi-species Synoptic Bottom Trawl Survey coverage.

In 2019, the HS and QCS surveys were conducted on the chartered commercial vessel the F/V Nordic Pearl. The HS survey was completed from mid-May to mid-June while the QCS survey was completed from mid-July to early August. One hundred and thirty-six (136) and 242 successful tows were completed in the HS and QCS areas, respectively (Figure 4). In Hecate Strait, the dominant species in the catch were Spotted Ratfish (*Hydrolagus colliei*), Arrowtooth Flounder (*Atheresthes stomias*), and Rex Sole (*Glyptocephalus zachirus*). In Queen Charlotte Sound, the dominant species in the catch were Sablefish (*Anoplopoma fimbria*), Pacific Ocean Perch, (*Sebastes alutus*), and Arrowtooth Flounder (*Atheresthes stomias*).

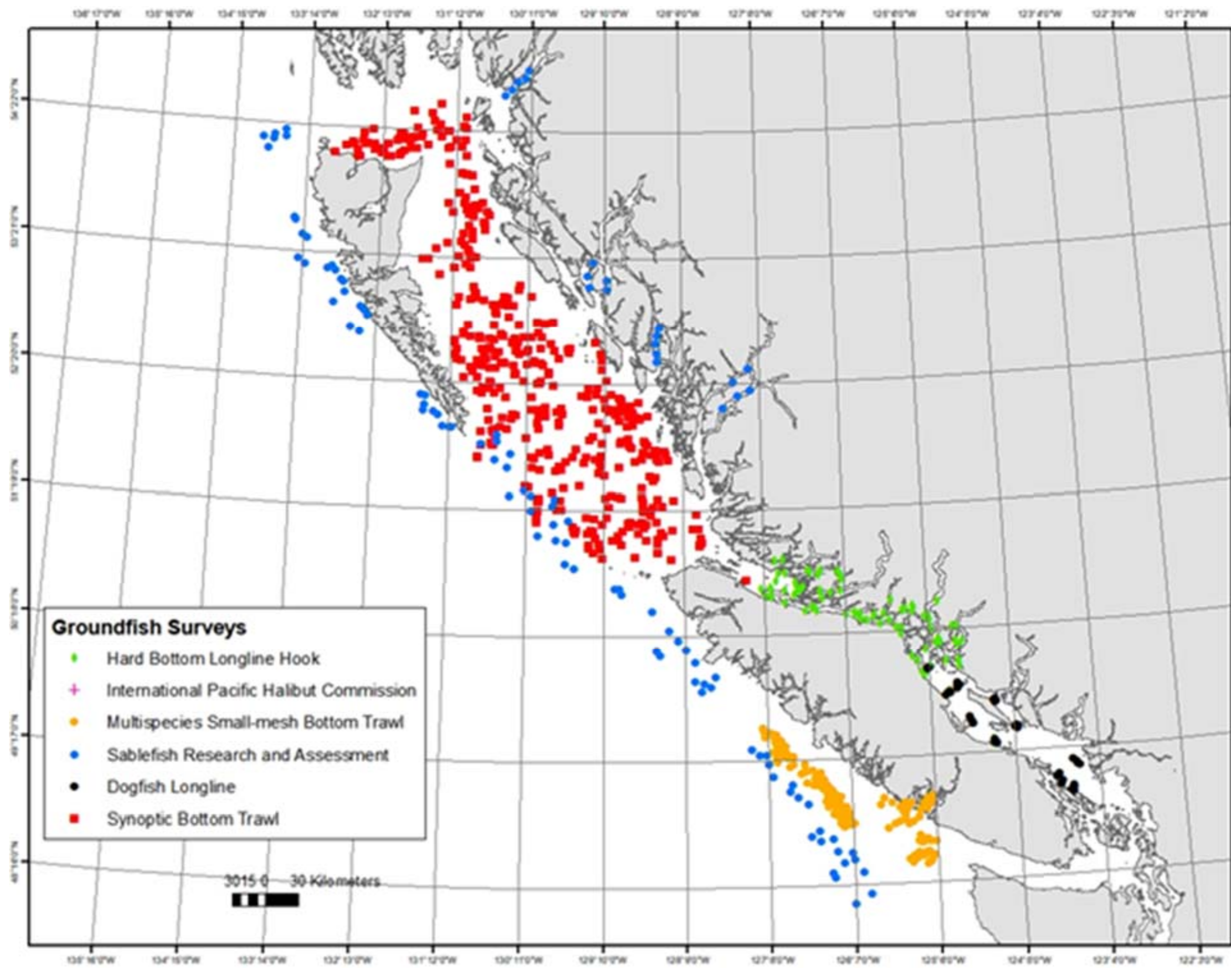


Figure 4. Fishing locations of the 2019 Groundfish surveys. The HBLL outside and IPHC FISS survey data were not available at the time of writing so have not been included.

The **Hard Bottom Longline Hook (HBLL) Surveys** are conducted annually in "outside" waters (not between Vancouver Island and the mainland) and "inside" waters (between Vancouver Island and the mainland). Both the "outside" and "inside" areas are divided into northern and southern regions, and surveys annually alternate between the regions, such that the whole coast is surveyed over a two-year period. The outside surveys are conducted under a collaborative agreement with the Pacific Halibut Management Association (PHMA) and occur on chartered commercial vessels, while the inside surveys are conducted by DFO and occur on a Canadian Coastguard vessel. In aggregate, the HBLL surveys provide coast-wide coverage of most of the untrawlable habitat between 20 and 220 meters depth.

In 2019 the northern region of the outside area and both the northern and a small part of the southern region of the inside area were surveyed (Figure 4). The outside HBLL survey was conducted on the chartered commercial longline vessels Banker II, Western Sunset, and Borealis 1 during August. A total of 197 sets were completed. Further details of the outside survey have not been included in this report because they were not available at the time of writing. The inside HBLL survey was conducted on the Canadian Coast Guard vessel Neocaligus from late July to late August. A total of 80 sets were completed including 71 in the northern region and 9 in the southern region. The 9 sets in the southern region were sites that were omitted from the 2018 survey due to time constraints. In addition, 19 sets were completed at historic Strait of Georgia Dogfish Longline sites as part of a pilot study to compare the different gears, baits, depths and timing of the two surveys.

The **Sablefish Research and Assessment Survey** is an annual longline trap survey targeting sablefish. This survey releases tagged Sablefish at randomly selected fishing locations in offshore waters, as well as at fixed stations in four mainland inlets. The survey also provides catch rates and biological data for use in stock assessments. The survey is conducted under collaborative agreement with the Canadian Sablefish Association and occurs on a chartered commercial vessel. This survey covers the depth range of 150 m to 1500 m for the entire outer BC coast as well as a number of central coast inlets.

In 2019, the survey was conducted on the F/V Pacific Viking from early October to late November. A total of 89 and 20 sets were completed in the offshore and inlet areas, respectively (Figure 4). The most abundant fish species encountered by weight were Sablefish (*Anoplopoma fimbria*), followed by Pacific Halibut (*Hippoglossus stenolepis*), Lingcod (*Ophiodon elongatus*), North Pacific Spiny Dogfish (*Squalus suckleyi*), and the Rougheye/ Blackspotted Rockfish Complex (*Sebastes aleutianus/ melanostictus*).

The **Strait of Georgia Dogfish Longline Hook Survey** is a triennial fixed-station survey targeting North Pacific Spiny Dogfish. The survey, which visits 10 to 12 sites spread throughout the central Strait of Georgia, was first conducted in the late 1980s and then resurrected in 2004 with a study to explore a change from J to circle hooks and followed up with a survey using circle hooks in 2005. In 2019, the survey was conducted on board the Canadian Coast Guard vessel Neocaligus during the first two weeks of October. A total of 39 sets were completed at the 10 core sites (Figure 4). There is a hope that the Dogfish catch rate indices from the Hard Bottom Longline Hook (HBLL) Surveys could be used in place of this directed single-species survey.

The **Small-mesh Bottom Trawl Survey** is an annual fixed-station survey of commercially important shrimp grounds off the West Coast of Vancouver Island that was initiated in 1973. Catch rate indices generated by the survey have been used to track the abundances of several groundfish stocks. Groundfish staff provide assistance in catch sorting and species identification and also collect biological samples from selected fish species. The 2019 survey was conducted on the F/V Nordic Pearl from late April to mid-May and a total of 112 usable tows were completed. The most abundant fish species encountered were North Pacific Spiny Dogfish (*Squalus suckleyi*), Rex Sole (*Glyptocephalus zachirus*), Dover Sole (*Microstomus pacificus*), Slender Sole (*Lyopsetta exilis*), and Flathead Sole (*Hippoglossoides elassodon*).

The IPHC provides DFO an opportunity to deploy an additional technician during the International Pacific Halibut Commission's (IPHC) Fishery-independent Setline Survey (FISS). The technician is funded as part of a collaborative agreement with the Pacific Halibut Management Association (PHMA) and identifies the catch to species level on a hook-by-hook basis and collects biological samples from rockfish. This information has been collected every year since 2003 except for a one-year hiatus in 2013. At the time of writing, DFO has received the 2019 IPHC survey data, but they have not yet been added to GFBio so they are not included in this report.

Details of each survey are included in Appendix I.

III. Reserves

Canada has surpassed its marine conservation target commitment of protecting 10 percent of coastal and marine areas through effectively managed networks of protected areas and other effective area-based conservation measures by 2020, a commitment made under the United Nations Convention on Biological Diversity (UN CBD) Aichi Target 11. Approximately 14% of Canada's EEZ are now protected. One marine conservation target initiative is to put a network of Marine Protected Areas (MPAs) in BC's Northern Shelf Bioregion (NSB). A draft MPA network scenario was released for comment by stakeholders on the advisory committee on February 28, 2019, and consultation on this plan is ongoing. In 2020, the partners will continue to work through outstanding questions including scope and level of detail for the action plan, approach to phased implementation, and principles that will guide future governance and implementation. The Marine Protected Area Technical Team (MPATT) will consider all spatial advice received and work towards a revised network scenario and a socio-economic analysis will be completed on a revised scenario. A revised draft scenario will be shared with stakeholders, local governments and the public for review and comment in 2021.

The Hecate Strait/Queen Charlotte Sound Glass Sponge Reefs MPA that was designated under Canada's Oceans Act in February 2017 to protect glass sponge reefs in Hecate Strait and Queen Charlotte Sound will be part of the NSB MPA network, as will the Gwaii Haanas National Marine Conservation Area Reserve (NMCAR) and Haida Heritage Site. The Scott Islands marine National Wildlife Area (NWA), an area that conserves a vital marine area for millions of seabirds on the Pacific coast, will also be part of the NSB MPA. Fishing activity is currently not prohibited in the NWA.

Parks Canada and the Archipelago Management Board have introduced new zoning to the Gwaii Haanas NMCA which includes multiple use zones (IUCN protection level IV-VI) as well as high protection zones (IUCN Ib-III) and two small restricted access zones that are intertidal/terrestrial. These zones came into effect on May 1, 2019 (Figure X MCT Map). The two RCAs that were formerly within the GHNMCA boundaries have been rescinded and replaced with the new zoning. Parks Canada is also still working to establish an NMCAR in the Salish Sea.

Another major initiative is the designation of the Offshore Pacific Seamounts and Vents Closure. The Area of Interest (AOI) was designated in 2017 and an offshore groundfish fishing closure was put into place to protect seamount and vent communities (Figure 5). The Endeavour Hydrothermal Vents MPA, designated under Canada's Ocean Act in 2003, is within the Offshore AOI. The Endeavour MPA was designated to ensure the protection of hydrothermal vents, and the unique ecosystems associated with them. The regulation to establish the MPA prohibits the removal, disturbance, damage or destruction of the venting structures or the marine organisms associated with them while allowing for scientific research that will contribute to the understanding of the hydrothermal vent ecosystem.

The SGaan Kinghlass-Bowie Seamount MPA, which was designated in 2008, protects communities living on Bowie Seamount which rises from depths to 3000 m to within 24 m of the surface, as well as two other seamounts and adjacent areas (https://dfo-mpo.gc.ca/oceans/mpa-zpm/bowie-eng.html).

The other 162 Rockfish Conservation Areas (RCAs) designated as fishery closures between 2004-2007 (Yamanaka and Logan 2010), remain in place. The Glass Sponge Reef Conservation Areas are closed to all commercial and recreational bottom contact fishing activities for prawn, shrimp, crab and groundfish (including halibut) in order to protect the Strait of Georgia and Howe Sound Glass Sponge Reefs (http://www.dfo-mpo.gc.ca/oceans/ceccsr-cerceef/closures-fermetures-eng.html).

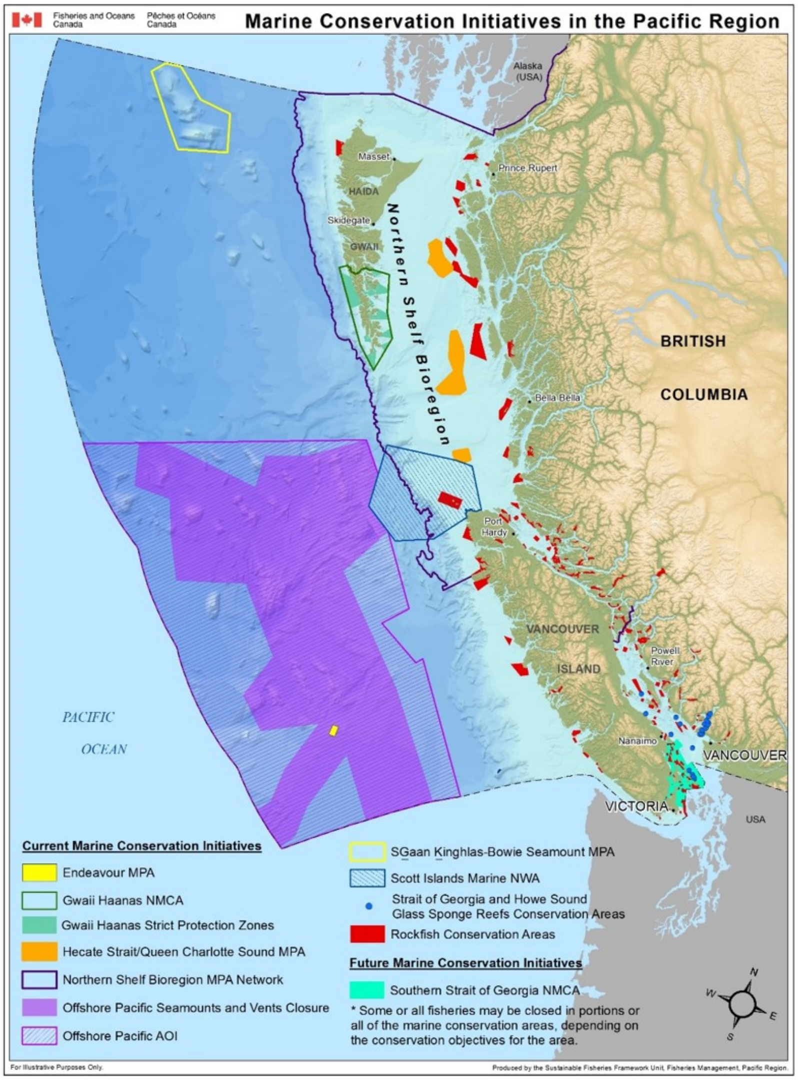


Figure 5. Marine Conservation Initiatives in the Pacific Region (Map by F. Yu).

IV. Review of Agency Groundfish Research, Assessment and Management

A. Hagfish

1. Research

No new research in 2019.

2. Assessment

Nothing to report.

3. Management

There is currently no fishery for Hagfish in BC, although there continues to be interest in redeveloping the fishery. One proponent has submitted a proposal that has been reviewed by DFO, but no decision has been made.

B. Dogfish and other sharks

1. Research

i) North Pacific Spiny Dogfish

Data collection continued in 2019 through the annual groundfish multi-species trawl and longline surveys, dedicated dogfish surveys, and at-sea observer sampling of the trawl fishery. North Pacific Spiny Dogfish are routinely sampled in both surveys and by observers, and in 2019 over 13,000 pieces were sampled.

Following the August 2019 inside Hard Bottom Longline Hook (HBLL) Survey, a gear comparison experiment was made between the HBLL gear and bait (size 14/0 circle hooks and squid bait) and the Dogfish Longline Hook Survey (size 14 circle hooks and 6 inch herring pieces) to compare catch rates of dogfish and rockfish on each gear type. Both types of gear were set at three dogfish sites. The purpose of the gear comparison was to begin to collect data which will be used to determine the feasibility of using a summer index to replace the index from the triennial October survey. Data have not yet been analyzed. The Dogfish Longline Hook Survey was then completed using the normal dogfish survey specifications in October (see Appendix 1).

ii) Other Shark Species

Other species of shark are sampled opportunistically during annual groundfish multi-species trawl and longline surveys and at-sea observer sampling of the trawl fishery. In 2019, samples included Bluntnose Sixgill Shark, Salmon Shark, Brown Cat Shark, Tope Shark, Blue Shark, and Pacific Sleeper Shark. In addition, anecdotal information on encounters with other shark species is also collected through the Shark Sightings Network (https://www.dfo-mpo.gc.ca/species-especes/sharks/info/sightings-eng.html).

2. Assessment

i) North Pacific Spiny Dogfish

North Pacific Spiny Dogfish were last assessed in 2010. No new assessment is currently scheduled.

In 2011, the Committee on the Status of Wildlife in Canada (COSEWC) assessed the conservation status of North Pacific Spiny Dogfish as Special Concern, citing low fecundity, long generation time (51 years), uncertainty regarding trends in abundance of mature individuals, reduction in size composition, and demonstrated vulnerability to overfishing as the causes for concern. Nevertheless, COSEWIC acknowledged that the population remains relatively abundant, and overfishing is currently unlikely.

COSEWC status reports are available at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports.html.

ii) Other Shark Species

As no directed commercial fisheries for sharks other than North Pacific Spiny Dogfish exist in British Columbia, there have been no requests for any stock assessments.

The Committee on the Status of Wildlife in Canada (COSEWC) has assessed the conservation status of a number of British Columbia shark species, and three species are listed under the Canadian Species at Risk Act (SARA):

- Basking Shark: Designated Endangered in 2007. Status re-examined and confirmed in 2018. Listed under SARA.
- Bluntnose Sixgill Shark: Designated Special Concern in 2007. Currently being re-examined. Listed under SARA.
- Tope Shark: Designated Special Concern in 2007. Currently being re-examined. Listed under SARA.

Blue Shark (North Pacific population) was examined by COSEWIC in 2016 and designated Not at Risk. White Shark and Brown Cat Shark were considered in 2006 and 2007 and placed in the Data Deficient category.

COSEWC status reports are available at https://www.canada.ca/en/environment-climate-change/services/species-risk-public-registry/cosewic-assessments-status-reports.html.

3. Management

i) North Pacific Spiny Dogfish

North Pacific Spiny Dogfish are managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP), and are permitted to be retained in the recreational fishery. There is currently no targeted fishing for Dogfish as markets have essentially collapsed, with the directed dogfish fleet harvesting 0% of its TAC in 2019 and the trawl fleet intercepting only 4.3% of its TAC. All fishery induced mortality at this time is as bycatch in directed fisheries for other species, with little to none of the catch being retained or landed. The hook and line fleet in aggregate has taken about 0.5% of their dogfish quota. Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

ii) Other Shark Species

Currently, there is no directed commercial fishery for other shark in Canadian Pacific waters; only Salmon Shark are permitted to be retained in the recreational fishery. Species at Risk Act prohibitions only apply to species listed as extirpated, endangered or threatened; thus, they do not apply to species of special concern. Nevertheless, commercial fisheries are no longer permitted to retain Species at Risk Act listed shark species − all bycatch for these species is to be released at sea with the least possible harm. Catch limits for the recreational fishery have been reduced to “no fishing” for all species listed under the Species at Risk Act, and “zero retention” (catch and release) for all other shark species except Salmon Shark. Codes of conduct have been developed for encounters with Basking Sharks (https://www.dfo-mpo.gc.ca/species-especes/publications/sharks/coc/coc-basking/index-eng.html) and other sharks (https://www.dfo-mpo.gc.ca/species-especes/publications/sharks/coc/coc-sharks/index-eng.html).

C. Skates

1. Research

Data collection continued in 2019 through trawl and longline surveys. Most individual skates encountered on groundfish research surveys are sampled (length, weight if feasible, sex) and released alive if possible. Species sampled in 2019 were Longnose Skate (n=1029), Sandpaper Skate (n=235), Big Skate (n=218), Aleutian Skate (n=10), Roughtail Skate (n=1), and Alaska Skate (n=1). No skates were sampled from commercial fisheries.

2. Assessment

Big Skates and Longnose Skate were assessed in 2013 (King et al 2015). No new assessment is currently planned. No other skate species in British Columbia are assessed.

Based on tagging results and fishery spatial patterns, Big Skate and Longnose Skate were assessed based on four Skate Management Areas: 3CD (Groundfish Major Areas 3C, 3D, and Minor Areas 19 and 20 of 4B); 5AB (Major Areas 5A, 5B, and Minor Area 12 of 4B); 5CDE (Major Areas 5C, 5D, and 5E); and 4B (Minor Areas 13-18, 28, and 29 of Major Area 4B).

3. Management

Big and Longnose skates are currently managed under sector and area TACs. For all other species of skate there are no management measures in place.

Big and Longnose skates are IVQ (individual vessel quota) species managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

Literature Cited:

King, J.R., Surry, A.M., Garcia, S., and Starr, P.J. 2015. Big Skate (*Raja binoculata*) and Longnose Skate (*R. rhina*) stock assessments for British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/070. ix + 329 p. https://waves-vagues.dfo-mpo.gc.ca/Library/362171.pdf

D. Pacific Cod

1. Research

Data collection continued in 2019 through trawl and longline surveys and at-sea observer sampling of the trawl fishery.

2. Assessment

Pacific Cod was assessed in 2018 but the research document is still awaiting translation before appearing on the CSAS website. The Science Advisory Report (SAR 2019/008) is available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2019/2019_008-eng.html.

Four stocks are defined for management purposes in BC: Strait of Georgia (4B); West Coast Vancouver Island (3CD); Queen Charlotte Sound (5AB); and Hecate Strait (5CD). Historically each area has been assessed separately; however, for the 2018 assessment, data from Areas 5AB and 5CD were combined into a single stock assessment, due to the lack of biological evidence for separate stocks and improved fits to the combined data compared to data from area 5AB alone. Area 3CD was assessed separately. Area 4B was not assessed as there is no directed commercial fishery there.

3. Management

Pacific Cod is an IVQ (individual vessel quota) species, managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

E. Walleye Pollock

1. Research

Data collection continued in 2019 through trawl and longline surveys and at-sea observer sampling of the trawl fishery.

2. Assessment

Walleye Pollock was assessed in 2017 but the research document is still awaiting translation before appearing on the CSAS website. The Science Advisory Report (SAR 2018/020) is available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2018/2018_020-eng.html.

Walleye Pollock was assessed as two stocks based on differences in observed mean weights between northern British Columbia (~1kg/fish) and southern British Columbia (~0.5 kg/fish). The BC North stock encompasses Major areas 5C, 5D, and 5E, while the BC South stock encompasses Major Areas 3C, 3D, 5A, 5B, plus minor areas 12 & 20 in 4B. The Strait of Georgia (i.e. “Gulf” - Major Area 4B not including minor areas 12 & 20) was not assessed.

3. Management

Walleye Pollock is an IVQ (individual vessel quota) species, managed as part of the integrated mixed species multi-gear groundfish fishery under the Integrated Fisheries Management Plan (IFMP). Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

F. Pacific Whiting (Hake)

1. Research

There are two commercially harvested and managed stocks of Pacific hake. The offshore stock is the principal target of the commercial fishery comprising the bulk of landings year over year. A smaller and discrete stock residing within the Strait of Georgia is targeted episodically when market demand is sufficient, and the available fish are large enough for processing. Biological data on Pacific Hake (age samples and length-sex frequency data) are collected from the commercial fishery through the at-sea observer and dockside monitoring programs.

Triennial (until 2001), then biennial acoustic surveys, covering the known extent of the Pacific hake stock have been run since 1995. An acoustic survey, ranging from California to northern British Columbia is currently run in odd-numbered years, to continue the biennial time series. The biomass estimate generated from the 2019 survey was 1.723 million t. In addition, there has been a biennial acoustic survey for Pacific hake in the Strait of Georgia since 2011. Methods are currently being developed to calculate a biomass estimate for the Strait of Georgia surveys, which will then be used as the primary index of abundance for a Strait of Georgia stock assessment. There was no survey in the Strait of Georgia in 2018 – 2020 due to restrictions in chartering as a result of the decommissioning of the W.E. Ricker in 2016, but there is a plan to continue the time series in 2021 with the new Offshore Fisheries Science Vessel CCGS Sir John Franklin.

2. Assessment

As in previous years, and as required by the Agreement Between the Government of Canada and the Government of the United States of America on Pacific hake/Whiting (the Pacific Whiting treaty), the 2019 harvest advice was prepared jointly by Canadian and U.S. scientists working together, collectively called the Joint Technical Committee (JTC) as stated in the treaty. The assessment model used was Stock Synthesis 3 (SS3). The 2019 model had almost the same model structure used in 2018, with updates to catch and age compositions. Standard sensitivities requested by the Scientific Review Group showed little difference when compared with the base model. The largest cohort caught in the fishery was age-4's, followed by age 2's. The three cohorts currently sustaining the fishery were born in 2010, 2014, and 2016. There has not been an assessment of Pacific hake in the Strait of Georgia.

3. Management

The coastwide TAC for 2019 was set at 597,500 t with Canada receiving 26.12% and the US receiving 73.88% as agreed upon in the hake treaty. Canadian commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

G. Grenadiers

1. Research

There is no directed work conducted on Grenadiers. Opportunistic sampling occurs on groundfish trawl surveys, but no Grenadiers were encountered in 2019.

2. Assessment

Grenadiers are not commercially harvested in BC and are rarely encountered during commercial fisheries. Consequently, there are no assessment activities planned for these species.

3. Management

There are no management objectives or tactics established for these species. These species are caught incidentally in the deep-water rockfish (Rougheye/Shortraker/Thornyhead) and Dover Sole fisheries and in the Sablefish trap fishery. 100% of the catch is discarded.

H. Rockfish

1. Research

Biological samples are collected on an ongoing basis from annual trawl, longline, and trap surveys, and from the commercial trawl fishery via the at-sea observer program.

i) Inshore Rockfish

Dr. Dana Haggarty is collaborating with Dr. Sarah Dudas and Dr. Stephanie Archer on a project funded by DFO's SPERA (Strategic Program for Ecosystem Based Research and Advice) to develop the novel method of passive acoustic monitoring (PAM) for fishes. Species of interest for this project include Pacific Herring and three rockfish species: Copper, Yelloweye, and Quillback Rockfishes. Most of the field work has now been done using paired visual (diver and drop camera) and audio surveys (soundtraps). They are testing the PAM methods by assessing temporal patterns in habitat use by deploying hydrophones in and adjacent to the Northumberland Channel RCA for one year. This project will also evaluate the impact of ship noise on the sensitivity of PAM. Although Dr. Archer has left DFO, she remains involved in the project and Dr. Philina English has been hired as a term research scientist to lead the project. Collaborators at the University of Victoria (UVic), Dr. Francis Juanes and graduate student Xavier Mouy have been making good progress in describing rockfish sounds and developing an automatic fish detector for the acoustic data to facilitate data processing. This project is due to be completed by the end of 2020-21.

Dr. Haggarty is also collaborating with colleagues at UVic and Ballstate University as well as industry (Angler's Atlas) to improve and monitor compliance in Rockfish Conservation Areas (RCAs) and Marine Protected Areas (MPAs). Angler's Atlas has already upgraded their smart phone App, MyCatch, to include the location of all RCAs and to provide users with warnings when they are in an RCA. The app works employs the cell phone's internal GPS and with downloaded maps, so users do not need to be on cell networks for it to function. There is also a function to collect data on the use of descending devices for rockfishes and an outreach program associated with this. This project was funded by the BC Salmon Restoration and Innovation Fund (BCSRIF) until the end of 2022-23.

ii) Offshore Rockfish

The Offshore Rockfish program has only one DFO person available; therefore, all efforts are devoted to stock assessment in collaboration with an industry-sponsored scientist. To facilitate stock assessment, the Offshore Rockfish program maintains a suite of PBS R software packages (https://github.com/pbs-software). The Groundfish Surveys program coordinates all sample collections (otoliths, genetic tissues, morphology measurements, etc.) and the Sclerochronology Lab researches ageing protocols and methods.

2. Assessment

i) Inshore Rockfish

British Columbia (BC) "Inside" stocks are generally those occurring in Area 4B (Queen Charlotte Strait, Strait of Georgia, and Strait of Juan de Fuca), while "Outside" stocks occur outside Area 4B (West Coast Vancouver Island, West Coast Haida Gwaii, Queen Charlotte Sound, Hecate Strait, Dixon Entrance).

Outside Yelloweye Rockfish

The Outside population of Yelloweye Rockfish was designated as Special Concern in 2008 by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC).

In 2019, DFO collaborated with Industry (the Pacific Halibut Management Association, PHMA) on a closed-loop simulation modelling to test performance of a set of candidate management procedures (MPs) against specific quantitative objectives. The outside stock was split into two different regions representing the North and Southern parts of the province. Alternative data scenarios produced a wide range of estimated stock status, as well as biological and management parameters, from which 4 representative OMs (using a 1960 or 1918 start year and alternative catch scenarios) were selected for simulation testing MPs. The 4 OMs ranged in current biomass from approximately 2,600 to 8,200 t in the North (groundfish management areas 5BCDE) and 1,900 to 4,400 t in the South (groundfish management areas 3CD5A). This range is considerably wider than the statistical uncertainty within any particular OM. No single factor clearly explains the range of biomasses because natural mortality, absolute catch levels, and historical recruitments all affect biomass and recruitment estimates either directly or indirectly. None of the 4 OMs indicate that either OYE stock area has been fished to less than 20% of the unfished level or below 40% of BMSY, as inferred in previous assessments. Model estimates of spawning biomass depletion relative to unfished levels range from 29-51% in the North, 21-43% in the South, and 27-48% coastwide. These correspond to 111-185% of BMSY in the North, 75-154% in the South, and 96-173% coastwide.

The candidate MPs evaluated included three different assessment methods: i) a catch-at-age (CAA) assessment model, a surplus production (SP) assessment model, and an empirical rule (IDX) using survey index trends. The three assessment methods were used in combination with different harvest control rules or implementation error scenarios to create a set of candidate MPs that were simulation tested for each of the 4 OMs for North and South areas independently. Performance statistics were evaluated using combined outputs across OMs via a 50%-16.67%-16.67%-16.67% weighting scheme. Simulations of MP performance for setting future OYE TACs generally showed robust, or potentially robust, performance to a wide range of OM scenarios. The CAA MPs were tuned to achieve a target fishing mortality rate that would provide relatively stable OYE biomass over the projection period and biomass in both the North and South responded accordingly. Management procedures based on SP models or survey index trends (IDX) produced a range of increases or stable trends in future OYE biomass. The IDX MPs were tuned to avoid biomass declines in the first 10 years, which produced long-term increases or stable trends in biomass with high inter-annual catch variability. Although the SP models generally led to biomass increases, they did so because of under-estimation biases and often showed erratic patterns in TACs. It is likely that undesirable properties of IDX and SP MPs could be improved via further tuning.

Cox, S.P., Doherty, B., Benson, A.J., Johnson, S.D., and Haggarty, D. 2020. Evaluation of potential rebuilding strategies for Outside Yelloweye Rockfish in British Columbia. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/041.

Inside Yelloweye Rockfish

The inside stock of Yelloweye Rockfish is a data-limited stock, occurring in Groundfish Management Area 4B (Queen Charlotte Strait, Strait of Georgia, and Strait of Juan de Fuca) in British Columbia (BC). The stock was designated as Special Concern by COSEWIC in 2008.

The stock was assessed as being below the LRP in 2010, resulting in a published rebuilding plan. DFO is currently working on an evaluation of the rebuilding plan using a closed-loop simulation model similar to the work that was done for Outside Yelloweye Rockfish. The working paper will be presented at CSAS in June 2020.

Quillback Rockfish

The Inside and Outside management units of Quillback Rockfish were last assessed in 2010 after the Committee On the Status of Endangered Wildlife In Canada (COSEWIC) designated them as threatened in November 2009. A Bayesian state space surplus production model was used in the stock assessment for the two management units. The model required fishery catch reconstructions to provide catch series from 1918 to 2010, as well as, abundance trends for the two management units. Reference Case model runs provided median biomass estimates for 2011 of 6,480 tonnes (CV 1.21) for the outside management unit and 2,668 tonnes (CV 0.60) for the inside management unit. B2010/Bmsy for the outside and inside is 0.736 (95%CI is 0.266 to 1.814) and 0.493 (95% CI is 0.252 to 0.945), respectively. The probability that the biomass of the outside Quillback Rockfish is above 0.4 Bmsy is 81.2 % and above 0.8 Bmsy is 45.6%. The probability that the biomass of the inside Quillback Rockfish is above 0.4 Bmsy is 70.2% and above 0.8 Bmsy is 11.5%. Stocks in both management areas appear to be within the cautious zone. Quillback is due to being reassessed in 2021 in advance of a COSEWIC reassessment..

Yamanaka, K.L., McAllister, M.K., Etienne, M.-P., and Flemming, R. 2011a. Stock assessment and recovery potential assessment for Quillback Rockfish (*Sebastes maliger*) on the Pacific coast of Canada. DFO Can. Sci. Advis. Sec. Res. Doc. 2011/135: vii + 151 p.

Other Inshore Rockfish Species (Copper, China, Tiger, Brown, Black, Deacon Rockfishes).

Inshore Rockfishes were assessed as a group in 2001, but none of these other inshore species have been assessed individually by DFO.

ii) Offshore Rockfish

Bocaccio

Bocaccio were designated as endangered by COSEWIC in 2013. However, a strong cohort was born in 2016, and subsequently starting appearing in increasing numbers in survey catches and commercial fisheries coastwide.

Bocaccio rockfish (BOR) along the BC coast was assessed in 2019 using an annual catch-at-age model tuned to six fishery-independent trawl survey series, a truncated bottom trawl CPUE series, annual estimates of commercial catch since 1935, and age composition data from survey series (31 years of data from four surveys) and the commercial fishery (12 years of data). The model started from an assumed equilibrium state in 1935, and the survey data covered the period 1967 to 2019 (although not all years were represented). Two fisheries were modelled: one a combined bottom and midwater trawl fishery and an ‘other’ fishery, which combined halibut longline, sablefish trap, salmon troll, rockfish hook and line, etc. The second fishery was a compromise that acknowledged other methods capturing this species while keeping the complexity to a minimum, given the lack of good information from these additional fisheries.

Three base runs using a two-sex model were implemented in a Bayesian framework (using the Markov Chain Monte Carlo procedure) under a scenario that fixed natural mortality to three levels (0.07, 0.08, 0.09) while estimating steepness of the stock-recruit function, catchability for the surveys and CPUE, and selectivity for four of the six surveys and the commercial trawl fleet. These three runs were combined into a composite base case which explored the major axis of parameter uncertainty in this stock assessment (Figure 6). Nine sensitivity analyses were performed to test the effect of alternative model assumptions (Figure 7).

The composite base case suggested that the BOR spawning population was in the Critical Zone (with a probability >0.99), as did the three component runs. This was in spite of the stock being moderately productive and exploitation rates being uniformly low. For instance, the median exploitation by the trawl fishery, which accounted for 95% of the catch, in the final year was estimated to be 0.025 (0.012-0.044) even at the very low biomass levels. A strong cohort, estimated at 44 times the long term average recruitment (range: 30-58), was born in 2016 and was projected to bring this stock out of the Critical Zone by the beginning of 2023 and would have a better than 50% probability of being in the Healthy Zone in that same year.

These predictions were entirely dependent on the assessed size of the 2016 year class, which was highly uncertain. However, there was evidence, beginning in 2017, that this cohort was large and dominated the available data. Three of the synoptic surveys, particularly the Queen Charlotte Sound survey in 2019, showed strong quantitative increases in abundance and in distribution. This cohort dominated the age and length frequencies in the commercial trawl, beginning in 2018. Similar strong recruitment (in 2010 and 2013) in the US BOR population, located south of Monterey, had lifted that stock out of an ‘overfished’ designation and was assessed in 2017 to be approaching 0.5B0. The BC authors suggested that the demonstrable capacity of the four active synoptic surveys plus the high quality monitoring of the trawl fishery catches and discards will verify the future progress of the strong 2016 cohort as it recruits to the fishery.

Starr, P. J. and Haigh, R. in press. Bocaccio (*Sebastes paucispinis*) stock assessment for British Columbia in 2019, including guidance for rebuilding plans. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/nnn: iii + xxx p.

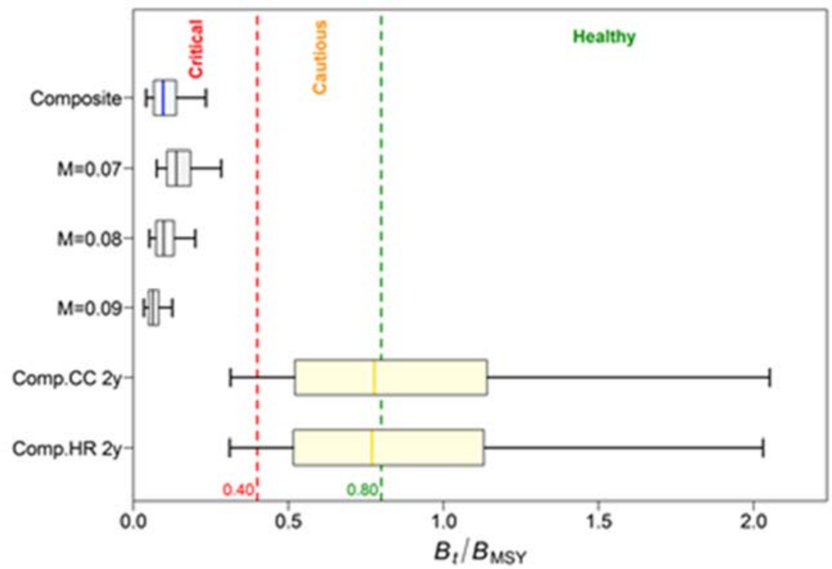


Figure 6. Status of the coastal BOR stock relative to the DFO PA provisional reference points of 0.4BMSY and 0.8BMSY for the t=2020 composite base case and the component base runs that are pooled to form the composite base case. Also shown are projected stock status for the composite base case at the beginning of 2022 after fishing at a constant catch=200 tonnes/year or a constant exploitation rate of 0.04/year. Model year 2022 is the second year that the 2016 cohort is assumed to contribute to the spawning population. Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior.

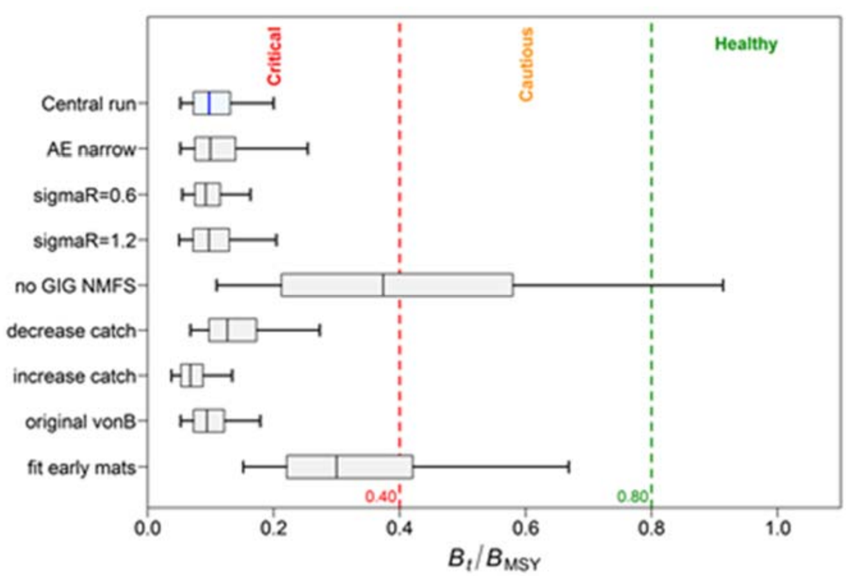


Figure 7. Stock status at beginning of 2020 of the BOR stock relative to the DFO PA provisional reference points of 0.4BMSY and 0.8BMSY for the central run of the composite base case and eight sensitivity runs (see y-axis notation and sensitivity descriptions in the main text). Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior. See CSAS research document for details of the sensitivity runs

Pacific Ocean Perch

The most recent stock assessment (2017) is publicly available on the CSAS website (Research Document 2018/031).

Redstripe Rockfish

The most recent stock assessment (2017) is still awaiting translation; however, a summary report is available (Science Advisory Report 2018/049).

Rougheye/Blackspotted Rockfish

The Rougheye/ Blackspotted (REBS) complex, called Rougheye Rockfish Type I and Type II by COSEWIC was designated as Special Concern in 2007. A COSEWIC re-assessment is anticipated, but has been postponed until after the next stock assessment is completed.

Preliminary stock assessment work was attempted in 2019 for the Rougheye/ Blackspotted (REBS) complex by a student at Simon Fraser University (SFU) but difficulties arose when the student transferred to the University of British Columbia (UBC). The Offshore Rockfish program has taken over the stock assessment for delivery in May 2020.

Widow Rockfish

Widow Rockfish (WWR) along the BC coast was assessed in 2019 using a catch-at-age model tuned to five fishery-independent trawl survey series, one bottom trawl CPUE series, annual estimates of commercial catch since 1940, and age composition data from survey series (five years of data from four surveys) and the commercial fishery (30 years of data). The model starts from an assumed equilibrium state in 1940, and the survey data cover the period 1967 to 2018 (although not all years are represented). Nine base runs using a two-sex model were implemented in a Bayesian framework (using the Markov Chain Monte Carlo procedure) under a scenario that fixed natural mortality to three levels (0.07, 0.08, 0.09) and set the accumulator age to three values (40, 45, 50 y) while estimating steepness of the stock-recruit function, catchability for surveys and CPUE, and selectivity for surveys and the commercial trawl fleet. These nine runs were combined into a composite base case which explored the major axes of uncertainty in this stock assessment (Figure 8). Twelve sensitivity analyses were performed to test the effect of alternative model assumptions (Figure 9).

The composite base case suggested that low exploitation in the early years, including that by foreign fleets, coupled with several strong recruitment events (in 1961 and 1990) have sustained the population to the present. Exploitation rates were high during a period of heavy fishing by the domestic fleet extending from the mid-1980s to the mid-1990s, causing the stock size to diminish. Exploitation rates dropped with the implementation of 100% observer coverage in 1996 and the introduction of catch limits coupled with IVQs in 1997.

The spawning biomass (mature females only) at the beginning of 2019 was estimated to be 0.37 (0.26, 0.54) of unfished biomass (median and 5th and 95th quantiles of the Bayesian posterior distribution). This biomass was estimated to be 1.51 (0.92, 2.61) of the spawning biomass at maximum sustainable yield, BMSY.

Advice to managers was presented as decision tables that provided probabilities of exceeding limit and upper stock reference points for five-year projections across a range of constant catches. The DFO provisional ‘Precautionary Approach compliant’ reference points were used, which specify a ‘limit reference point’ (LRP) of 0.4BMSY and an ‘upper stock reference point’ (USR) of 0.8BMSY. The estimated spawning biomass at the beginning of 2019 had a probability of 1 of being above the LRP, and a probability of 0.98 of being above the USR. Five-year projections using a constant catch of 2000 t/y indicated that, in 2024, the spawning biomass had probabilities of 0.99 of remaining above the LRP, and 0.91 of remaining above the USR. Catches greater than 2250 t/y will cause u2024 to exceed the uMSY reference point with a probability of greater than 0.5.

Starr, P. J. and Haigh, R. in press. Widow Rockfish (*Sebastes entomelas*) stock assessment for British Columbia in 2019. DFO Can. Sci. Advis. Sec. Res. Doc. 2019/nnn: iii + xxx p.

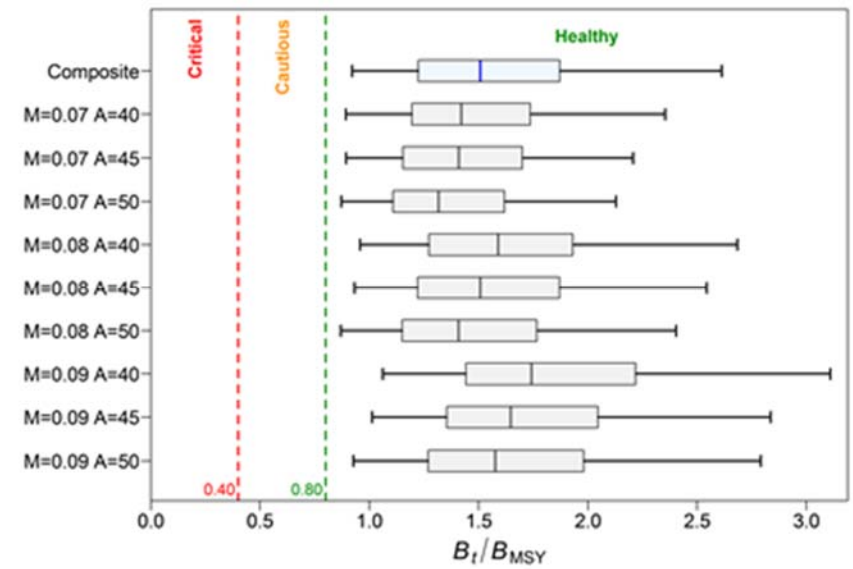


Figure 8. Status of the coastal WWR stock relative to the DFO PA provisional reference points of 0.4BMSY and 0.8BMSY for the t=2019 composite base case and the component base runs that are pooled to form the composite base case. Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior.

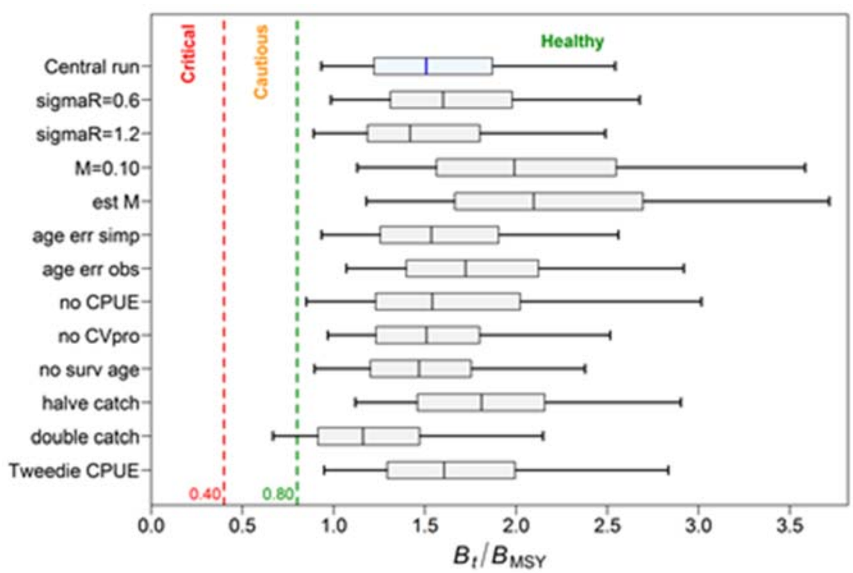


Figure 9. Stock status at beginning of 2019 of the WWR stock relative to the DFO PA provisional reference points of 0.4BMSY and 0.8BMSY for the central run of the composite base case and twelve sensitivity runs (see y-axis notation and sensitivity descriptions in the main text). Boxplots show the 0.05, 0.25, 0.5, 0.75 and 0.95 quantiles from the MCMC posterior. See CSAS research document for details of the sensitivity runs.

Yellowtail Rockfish

Yellowtail Rockfish were last assessed in 2014. The Science Advisory Report (SAR 2015/010) is available at https://waves-vagues.dfo-mpo.gc.ca/Library/364528.pdf.

Canary Rockfish

In 2007, Canary Rockfish along the Pacific coast of Canada was designated as Threatened by the Committee on the Status of Endangered Wildlife in Canada, with commercial fishing identified as the primary threat. This designation means that Fisheries and Oceans Canada, as the responsible jurisdiction under the Canadian Species at Risk Act, is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, threats to its survival and recovery, and the feasibility of its recovery.

The Canary Rockfish stock assessment was last updated in 2009. In 2017, DFO prepared a summary of available information on Canary Rockfish in preparation for a re-assessment by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC); the pre-COSEWIC assessment is awaiting translation before appearing on the CSAS website. A new full stock assessment by DFO is planned for 2021.

Silvergray Rockfish

Silvergray Rockfish were last assessed in 2014. The Research Document (2016/042) and Science Advisory Report (SAR 2014/028) are available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2016/2016_042-eng.html and https://waves-vagues.dfo-mpo.gc.ca/Library/364111.pdf.

Yellowmouth Rockfish

In 2010, Yellowmouth Rockfish along the Pacific coast of Canada was designated as Threatened by COSEWIC, with commercial fishing identified as the primary threat. This designation means that Fisheries and Oceans Canada, as the responsible jurisdiction under the Canadian Species at Risk Act, is required to undertake a number of actions. Many of these actions require scientific information on the current status of the species, threats to its survival and recovery, and the feasibility of its recovery.

In 2011 – 2012, DFO completed a Stock Assessment and Recovery Potential Assessment. The Research Document (2012/095) and Science Advisory Report (SAR 2011/060) are available at https://waves-vagues.dfo-mpo.gc.ca/Library/347270.pdf and https://waves-vagues.dfo-mpo.gc.ca/Library/345104.pdf.

The next assessment is planned for fall 2020.

Shortraker Rockfish

Shortraker Rockfish were last assessed in 1998. There is currently no new assessment planned.

Redbanded Rockfish

The last assessment for Redbanded Rockfish was attempted in 2014; however, no model was found that was able to produce reliable results, so researchers were unable to provide specific quantitative advice to fisheries management. The Research Document (2017/058) is available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_058-eng.html.

Darkblotched Rockfish

In 2009, Darkblotched Rockfish along the Pacific coast of Canada was designated as Special Concern by COSEWIC. There is currently no stock assessment planned.

3. Management

i) Inshore Rockfish

Inside and Outside Yelloweye Rockfish still fall under a rebuilding plan that is documented in Appendix 9 of the 2019 IFMP (https://waves-vagues.dfo-mpo.gc.ca/Library/40765167.pdf). Most inshore rockfish are managed with Total Allowable Catches under the Individual Transferable Quota system.

Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

Recreationally, the retention of Yelloweye Rockfish in inside and outside waters is prohibited. In outside waters, recreational fishers are limited to 3 rockfishes daily, only 1 of which may be a China, Tiger or Quillback Rockfish; possession limits are twice the daily limits, and the season runs from April 1 – November 15. In inside waters (4B), recreational fishers can take 1 rockfish daily, possession limits are twice the daily limit and the season runs from May 1 – October 1. A condition of the recreational license is that: “Anglers in vessels shall immediately return all rockfish that are not being retained to the water and to a similar depth from which they were caught by use of an inverted weighted barbless hook or other purpose-built descender device.”

ii) Offshore Rockfish

Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

I. Thornyheads

1. Research

Data collection continued in 2019 through trawl and longline surveys and at-sea observer sampling of the trawl fishery.

2. Assessment

Longspine Thornyhead was designated “Special Concern” by COSEWIC in 2007. An assessment has been requested but not yet scheduled.

Shortspine Thornyheads were assessed in 2015. The Research Document (2017/015) and Science Advisory Report (SAR 2016/016) are available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_015-eng.html and https://waves-vagues.dfo-mpo.gc.ca/Library/365535.pdf.

3. Management

Longspine and Shortspine Thornyhead are both IVQ species. Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

J. Sablefish

The Sablefish management system in British Columbia is an adaptive ecosystem-based approach in which three pillars of science – hypotheses, empirical data, and simulation - play a central role in defining management objectives and in assessing management performance relative to those objectives via Management Strategy Evaluation (MSE). Objectives relate to outcomes for three categories of ecosystem resources: target species, non-target species, and Sensitive Benthic Areas.

The MSE process is used to provide management advice each year that supplements the stock assessment process by providing a way to explicitly evaluate harvest strategies given a set of stock and fishery objectives and uncertainties/hypotheses about Sablefish fishery and resource dynamics. Fisheries and Oceans Canada (DFO) and Wild Canadian Sablefish Ltd. have collaborated for many years on fisheries management and scientific research with the aim of further supporting effective assessment and co-management of the Sablefish stock and the fishery in Canadian Pacific waters.

1. Research

In addition to the annual Sablefish Research and Assessment Survey (see Appendix 1 for details), research activities in 2019 included the continuation of an informal collaboration among Sablefish scientists from DFO, NOAA, ADFG and academia on range-wide Sablefish ecology and management. The overarching goal of the collaboration is to develop a range-wide, spatially explicit population dynamics model for Sablefish that can be used to explore questions of biological and management relevance across the eastern North Pacific. In 2019 primary research activities towards this goal included initiating a synthesis of life history characteristics across the Sablefish range, analyses to identify and develop range-wide indices of abundance and the evaluation of time- and size-varying movement within and among regions (e.g., Alaska, British Columbia and the US West Coast).

2. Assessment

Sablefish stock status is regularly evaluated via the MSE process. An operating model (i.e., representation of alternative hypotheses about 'true' Sablefish population dynamics) is used to simulate data for prospective testing of management procedure performance relative to stock and fishery objectives. The current Sablefish operating model (OM) was revised in 2015/16 to account for potential structural model misspecification and lack-of-fit to key observations recognized in previous models (DFO 2016). Specific modifications included: (i) changing from an age-/growth- group operating model to a two-sex/age-structured model to account for differences in growth, mortality, and maturation of male and female Sablefish, (ii) adjusting model age- proportions via an ageing error matrix, (iii) testing time-varying selectivity models, and (iv) revising the multivariate-logistic age composition likelihood to reduce model sensitivity to small age proportions. These structural revisions to the operating model improved fits to age-composition and at-sea release data that were not well-fit by the previous operating model. Accounting for ageing errors improved the time-series estimates of age-1 Sablefish recruitment by reducing the unrealistic auto-correlation present in the previous model results. The resulting estimates clearly indicate strong year classes of Sablefish that are similar in timing and magnitude to estimates for the Gulf of Alaska. Two unanticipated results were that (i) time-varying selectivity parameters were not estimable (or necessarily helpful) despite informative prior information from tagging and (ii) improved recruitment estimates helped to explain the scale and temporal pattern of at-sea release in the trawl fishery. The latter finding represents a major improvement in the ability to assess regulations (e.g., size limits) and incentives aimed at reducing at-sea releases in all fisheries.

The status of the Sablefish stock is judged on the scale of the OM which was last updated in 2019 (DFO 2019). Based on the 2019 assessment, the current point estimate of Sablefish spawning stock biomass in Canada is 16,300 t. This spawning biomass is at the transition from the Cautious to Healthy zones under the DFO FPA Framework (i.e., B2018/BMSY = 0.8). The updated stock status of Canadian Sablefish depended on the absolute size of the 2015-year class the raw estimate of this which was about eight times the historical average. This created the impression of the largest recorded recruitment from one of the lowest spawning biomasses ever observed in Canada. However, this estimated recruitment is highly uncertain, and both the timing and magnitude of the year-class size should be better estimated as several more years of fishery and survey data accumulate.

In 2019 the updated operating model was used to generate simulated data to test the current and alternative management procedures (MPs). The joint posterior distribution of spawning biomass and stock-recruitment steepness was used to generate five scenarios that captured a range of hypotheses related to current spawning biomass and productivity. These feedback simulations showed that the current MP (no limits on at-sea releases) meets biological objectives but ranked near the bottom in terms of catch performance and revenues compared to MPs with at-sea release management measures. A no size limit (i.e., full retention) MP performed best for both biological and fishery objectives, followed by MPs that included caps on sub-legal releases. These simulations also showed that the largest conservation risk is tuning the maximum target harvest rate in MPs assuming large 2015 recruitment, but then it fails to materialize.

The revised operating model continues to assume that the BC Sablefish stock is a closed population, despite evidence of movements among Sablefish stocks in Alaska and US waters south of BC (Hanselmen et al. 2014) and little genetic evidence of population structure across these management regions (Jasonowicz et al. 2017) . These movements may have implications for the assumptions made about Sablefish stock dynamics in BC (i.e., recruitment, productivity) that are not currently captured by the revised OM or reflected in MP performance evaluations. The collaboration between DFO, NOAA and ADFG identified above in the research section is working towards the development of a coastwide Sablefish OM to understand the potential consequences of the mismatch between Sablefish stock structure and management by simulation testing current, and potential future, MPs to quantify their performance against a range of conservation and fishery objectives.

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3. Management

The MP that is currently in place for the Canadian Sablefish fishery was last evaluated in 2019 through the Sablefish MSE (see Assessment section above). This MP is based on a surplus production model fit to time-series observations of total landed catch, and the fishery independent survey CPUE, to forecast Sablefish biomass for the coming year. The surplus production model outputs are then input to a harvest control rule to calculate the recommended catch of legal Sablefish in a given year. This MP includes a 3-year phased-in period to a new maximum target harvest rate of 5.5% in 2022.

Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

K. Lingcod

1. Research

Ongoing data collection continued in 2019 through surveys, port sampling, at-sea observer sampling, and recreational creel surveys. Additional biological samples (length, weight, sex, maturity and fins for ageing) were collected on the Inside HBLL N and the Outside HBLL N, and the Queen Charlotte Strait and Hecate Strait Synoptic Trawl Surveys.

2. Assessment

Inside, the waters within the Strait of Georgia, and Outside, the rest of the BC Coast, Lingcod populations are assessed and managed as separate units. Outside Lingcod were scheduled to be assessed in the spring of 2019; however, the assessment has been pushed back due to other program demands as well as the desire to have some age-data to inform the catchability of the longline surveys. Fins collected on the IPHC, trawl surveys and Outside HBLL surveys are currently being processed. Inside Lingcod were last assessed in 2014.

3. Management

Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

L. Atka Mackerel

The distribution of Atka mackerel does not extend into the Canadian zone.

M. Flatfish

1. Research

Ongoing data collection in support of the flatfish research program, inclusive of Arrowtooth Flounder, Petrale Sole, Southern Rock Sole, Dover Sole, and English Sole continued in 2019 through surveys and at-sea observer sampling.

2. Assessment

Arrowtooth Flounder

Arrowtooth Flounder was last assessed in 2016. The final assessment was finalized and published through the Canadian Science Advice Secretariat (CSAS) in 2017. The research document and science advisory report are available at http://www.dfo-mpo.gc.ca/csas-sccs/Publications/ResDocs-DocRech/2017/2017_025-eng.html and https://waves-vagues.dfo-mpo.gc.ca/Library/365131.pdf.

Concerns expressed by industry participants regarding localized depletion on several the historic fishing grounds have led to a request from fisheries management for an updated assessment. Efforts are underway to deliver that assessment by the fall of 2020.

Petrale Sole

Petrale sole was last assessed in 2007. In response to a request for updated harvest advice from fishery managers, aging of otoliths was completed in 2018. Planning is currently underway to deliver an updated assessment in 2020/21.

Southern Rock Sole

Southern Rock sole was last assessed in 2013. No request for updated advice has been received, but aging of otoliths was undertaken in 2019 in anticipation of an updated assessment sometime in 2021/22.

Dover Sole

Dover sole was last assessed in 1999. Aging of otoliths is currently underway in anticipation of an updated assessment in 2020.

English Sole

English sole was also last assessed in 2007. No request for updated advice has been received, but aging of otoliths was undertaken in 2019 in anticipation of an updated assessment sometime in 2020/21.

3. Management

Arrowtooth Flounder, Petrale Sole, Southern Rock Sole, Dover sole, and English Sole are all managed by annual coastwide or area specific TACs and harvested primarily by the IVQ multi-species bottom trawl fishery. Commercial TACs and landings for 2019 are provided in Appendix 2. To support groundfish research and account for unavoidable mortality incurred during the 2019 Groundfish surveys, research catches are allocated before defining the TAC. See Appendix 2 for details.

Pacific Halibut & IPHC Activities

Pacific halibut caught incidentally by Canadian groundfish trawlers are measured and assessed for condition prior to being released. Summaries of these length data are supplied annually to the IPHC. In addition, summaries of live and dead releases (based on condition) from both the trawl and line fisheries in British Columbia are provided.

Commercial TACs and landings for 2019 are provided in Appendix 2.

N. Other Groundfish Species

Nothing to report at this time.

V. Ecosystem Studies

A. Data-limited Species

The Fisheries and Oceans Canada (DFO) Sustainable Fisheries Framework (DFO 2009) lays the foundation for an ecosystem-based and precautionary approach to fisheries management that enables continued productivity of Canada’s fisheries.

In recent decades, DFO groundfish stock assessments have focused on data-rich species, resulting in a subset of stocks with full stock assessments, while many stocks with less informative data remain unassessed. Consequently, quotas assigned to rarely assessed or unassessed stocks may result in catch rates that are too high, may restrict harvesting opportunities to catch target species, or may result in failure for fisheries to meet seafood certification standards.

Starting in 2015, work was initiated to address this gap. Instead of a tiered approach as is used in other jurisdictions around the world, the approach eventually adopted for BC groundfish stocks considers data-richness on a continuous scale and focuses on simulation testing multiple management procedures on a stock-by-stock basis to choose an approach that best meets fisheries risk objectives.

Groundfish Data Synopsis

The first phase consisted of a groundfish data synopsis, as described in the 2019 TSC report. The synopsis provides a visual snapshot of temporal trends and spatial distributions of commercial catches and survey indices, growth and maturity characteristics, and data availability for over 100 BC groundfish stocks. The synopsis was peer reviewed through a Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR) process in 2018 and published in 2019 as a Research Document (Anderson et al. 2019). An article describing the approach will be featured in 2020 in the AFS Fisheries Magazine (Anderson et al. in press).

Management Procedure Framework

The second phase is the development of a framework for applying a management-procedure (MP) approach to data-limited groundfish stocks in British Columbia. (Data-limited stocks are defined here as those with insufficient data to reliably estimate stock status or estimate abundance or productivity with conventional stock assessment methods such as statistical catch-at-age models.) The MP framework will be reviewed through a CSAS RPR process in June 2020. Specifically, the MP framework tests the performance of a suite of data-limited management procedures against conservation and fishery objectives. This is done using an existing closed-loop simulation framework that includes building appropriate operating models, testing suites of management procedures, and determining management procedures that best meet conservation and fishery objectives for one or more case-study stocks. The framework uses the open source R package DLMtool (Carruthers and Hordyk 2018), developed at the University of British Columbia, in partial partnership with DFO.

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VI. Other related studies

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VII. Publications

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Appendix 1: Details of Fisheries and Oceans, Canada Pacific Region Groundfish Surveys in 2019

Overview

The Fisheries and Oceans, Canada (DFO) Groundfish section of the Stock Assessment and Research Division includes a surveys program. The program includes a suite of fishing surveys using bottom trawl, longline hook, and longline trap gear that, in aggregate, provide comprehensive coverage for all offshore waters of Canada's Pacific Coast (Figure 10). All the surveys follow random depth-stratified designs and have in common full enumeration of the catches (all catch sorted to the lowest taxon possible), size composition sampling for most species, and more detailed biological sampling of selected species. Most of the surveys are conducted in collaboration with the commercial fishing industry under the authorities of various Collaborative Agreements. In addition to these randomized surveys, a fixed-station longline hook survey targeting North Pacific Spiny Dogfish in the Strait of Georgia is completed every three years. The Groundfish section also routinely participates in the Canadian portion of the Joint Canada US Hake Acoustic Survey, collects groundfish information from a DFO Small-Mesh Bottom Trawl Survey, and funds an additional technician during the International Pacific Halibut Commission (IPHC) Setline Survey (Figure 11).

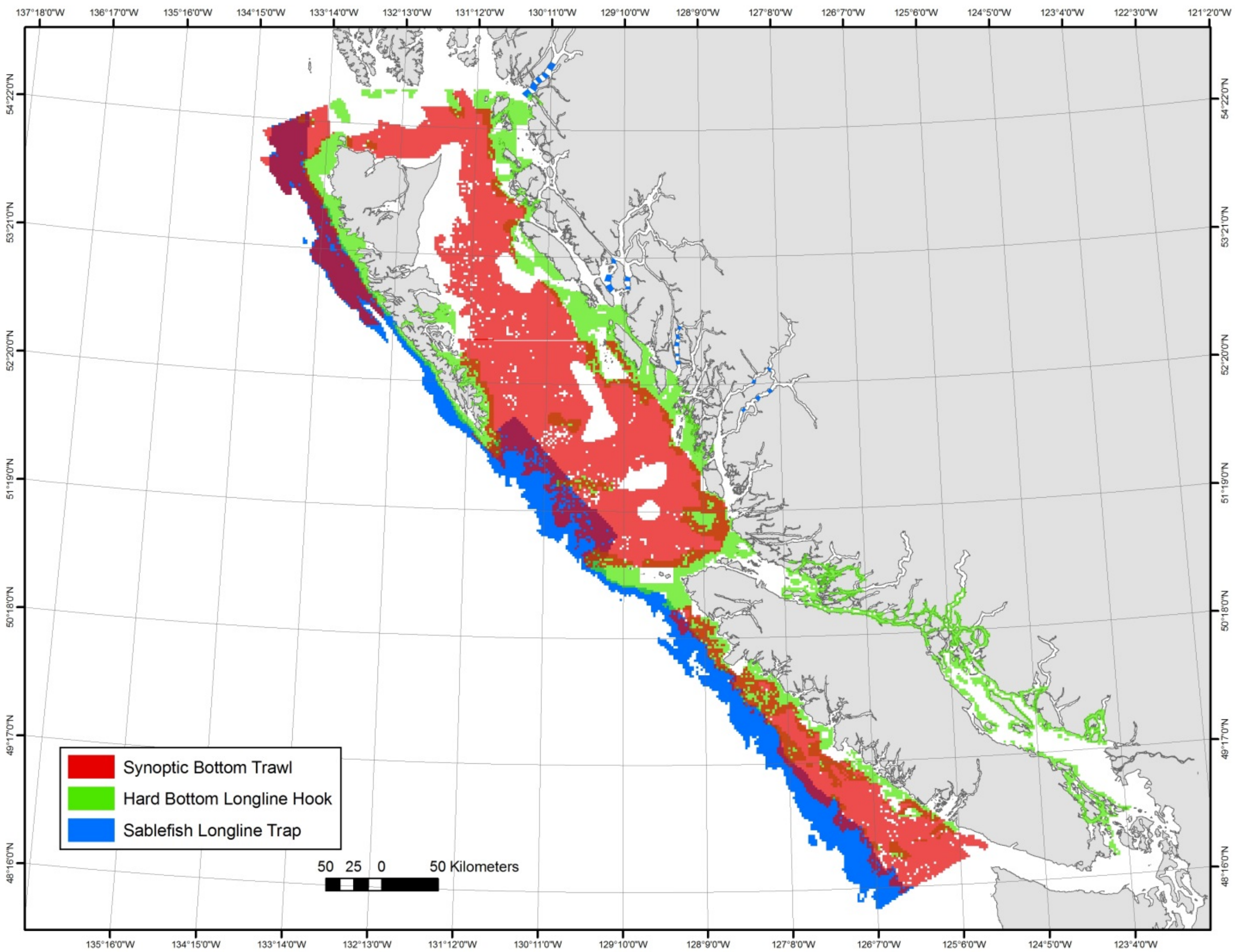


Figure 10. Random depth-stratified survey coverage.

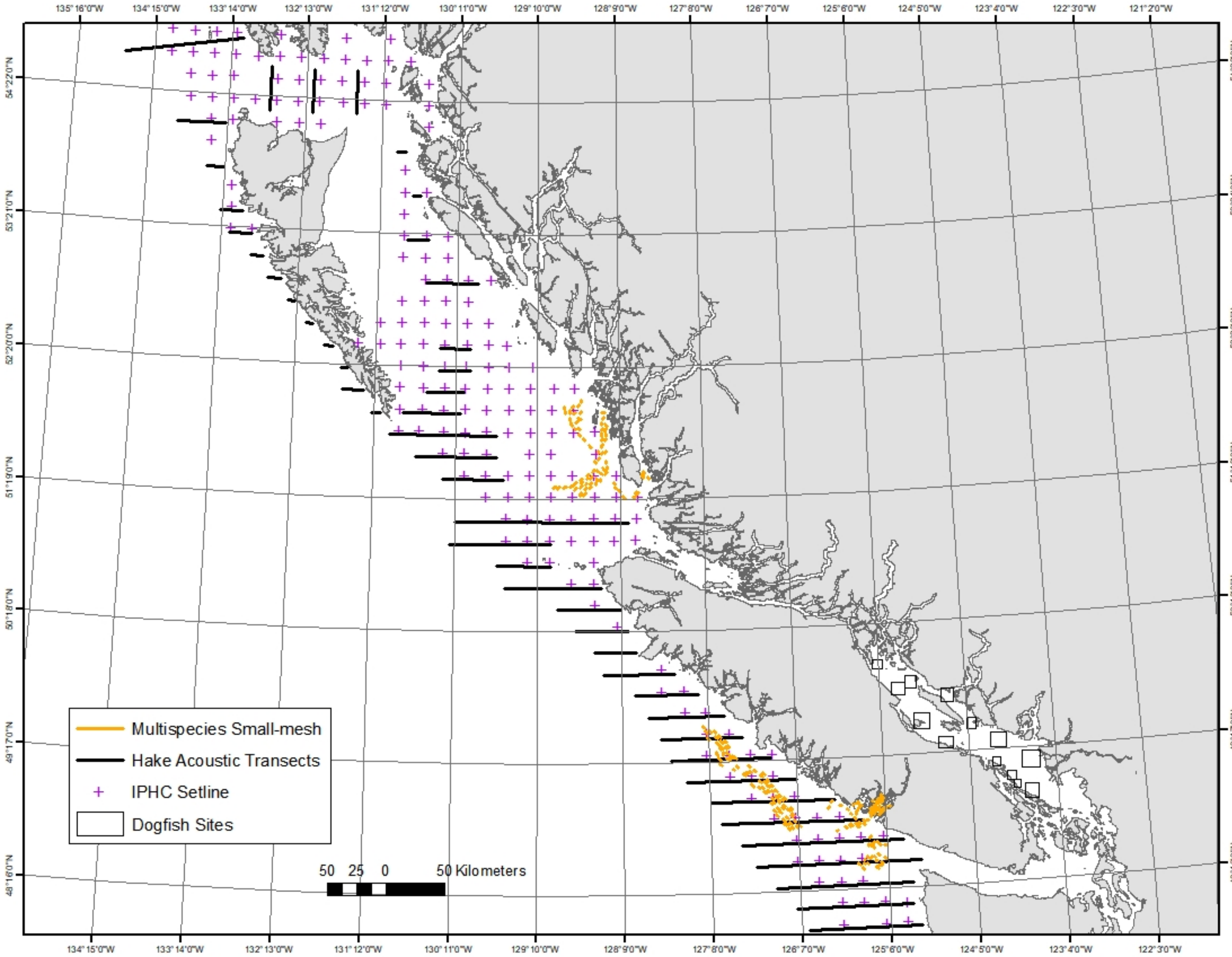


Figure 11. Non-random depth-stratified surveys that form part of the Groundfish surveys program including the Multi-species Small-mesh Bottom Trawl Survey, the Pacific Hake Acoustic Survey, and the International Pacific Halibut Commission (IPHC) Setline Survey.

Each year, two or three area-specific random depth-stratified bottom trawl surveys known as Multi-species Synoptic Bottom Trawl Surveys are conducted. The commercial trawl industry provides the vessel for one survey while the other survey is conducted onboard a Canadian Coast Guard research trawler. Surveys are conducted with a combination of DFO staff and industry-hired sea-going technicians. These bottom trawl surveys provide coast-wide coverage of most of the trawlable habitat between 50 and 500 meters depth.

Each year, in addition to the annual bottom trawl surveys, two area-specific random depth-stratified longline hook surveys known as Hard Bottom Longline Hook (HBLL) Surveys are conducted. The commercial longline hook industry contracts vessels and sea-going technicians for a survey of “outside” waters (not between Vancouver Island and the mainland) while a separate longline hook survey of “inside” waters (between Vancouver Island and the mainland) is conducted by DFO staff onboard a Canadian Coast Guard research vessel. These longline hook surveys provide coast-wide coverage of most of the non-trawlable habitat between 20 and 220 meters depth that is not covered by the bottom trawl surveys.

In addition to the bottom trawl and hook and line surveys, an annual, coast-wide longline trap survey targeting sablefish, known as the Sablefish Research and Assessment Survey, is also conducted. The commercial sablefish industry supplies the chartered commercial fishing vessel and the survey is conducted with a combination of DFO staff and industry-hired sea-going technicians. This survey covers the depth range of 150 m to 1500 m for the entire outer BC coast as well as a number of central coast inlets.

In addition to the bottom trawl, hook and line, and trap surveys, a longline hook survey targeting North Pacific Spiny Dogfish is conducted every three years and an annual Hake Acoustic Survey is conducted for Pacific Hake. The Strait of Georgia Dogfish Longline Hook Survey follows a fixed-station design and is intended to provide biological, catch, and effort data. The Hake Acoustic Survey is conducted as part of the Pacific Whiting Treaty and typically alternates year to year between research and assessment activities. Both of these surveys are conducted aboard the Canadian Coast Guard research vessels by DFO staff.

Each year, Groundfish section staff also participate in the Multi-species Small-mesh Bottom Trawl Survey onboard the Canadian Coast Guard research trawler. This survey follows a fixed-station design and visits commercially important shrimp grounds off the west coast of Vancouver Island and in eastern Queen Charlotte Sound. Groundfish program staff participate in the survey to provide assistance in enumerating the catch while also collecting biological samples from selected fish species.

During their annual survey, the International Pacific Halibut Commission (IPHC) only fully enumerates the catch for, and collects biological samples from, Pacific Halibut. In an effort to acquire more data on groundfish species intercepted by this survey, particularly rockfish, the commercial longline fishing industry provides an additional technician aboard each of the IPHC chartered survey vessels. The extra technician fully enumerates the catch of all species and collects biological samples from selected inshore species of rockfish as well as Lingcod.

This report summarizes all the 2019 surveys (Figure 12) including the Multi-species Synoptic Bottom Trawl surveys conducted in Hecate Strait and Queen Charlotte Sound, the Hard Bottom Longline Hook Survey conducted in the northern part of “outside” waters and both the northern and southern parts of “inside waters”, the coast-wide Sablefish Research and Assessment Survey, the Multi-species Small-mesh Bottom Trawl Survey off the west coast of Vancouver Island, and the IPHC setline survey. Unfortunately, at the time of writing, the data from the Hard Bottom Longline Hook Survey of “outside” waters and the IPHC setline survey are not yet finalized so have not been included. The results of the Pacific Hake Acoustic Survey are also not included in this report.

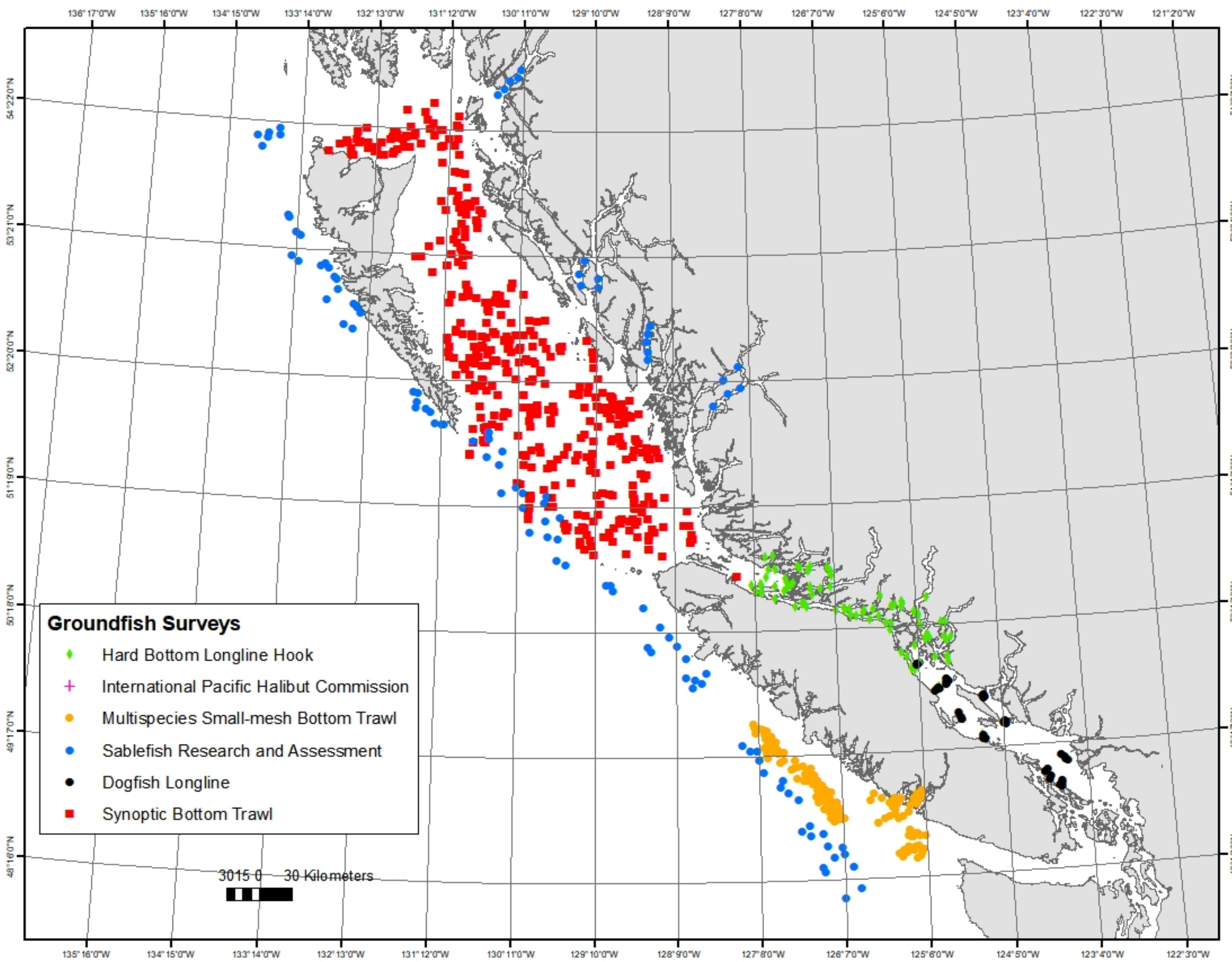


Figure 12. Fishing locations of the 2019 Groundfish surveys.

Multi-species Synoptic Bottom Trawl Surveys

Fisheries and Oceans, Canada (DFO) together with the Canadian Groundfish Research and Conservation Society (CGRCS) have implemented a comprehensive multi-species bottom trawl survey strategy that covers most of the BC coast. The objectives of these surveys are to provide fishery independent abundance indices of as many benthic and near-benthic fish species available to bottom trawling as is reasonable while obtaining supporting biological samples from selected species. The abundance indices and biological information are incorporated into stock assessments, status reports, and research publications.

All of the synoptic bottom trawl surveys along the British Columbia coast have followed the same random depth-stratified design. Each survey area is divided into 2 km by 2 km blocks and each block is assigned one of four depth strata based on the average bottom depth in the block. The four depth strata vary between areas. For each survey and in each year, blocks are randomly selected within each depth stratum. If a survey block is not fishable for any reason it will be abandoned and the vessel will proceed to the next block.

There are four core synoptic bottom trawl surveys, two of which are conducted each year. The Hecate Strait survey and the Queen Charlotte Sound survey are conducted in odd-numbered years while the West Coast Vancouver Island survey and the West Coast Haida Gwaii (formerly Queen Charlotte Islands) survey are conducted in even-numbered years (Figure 13).

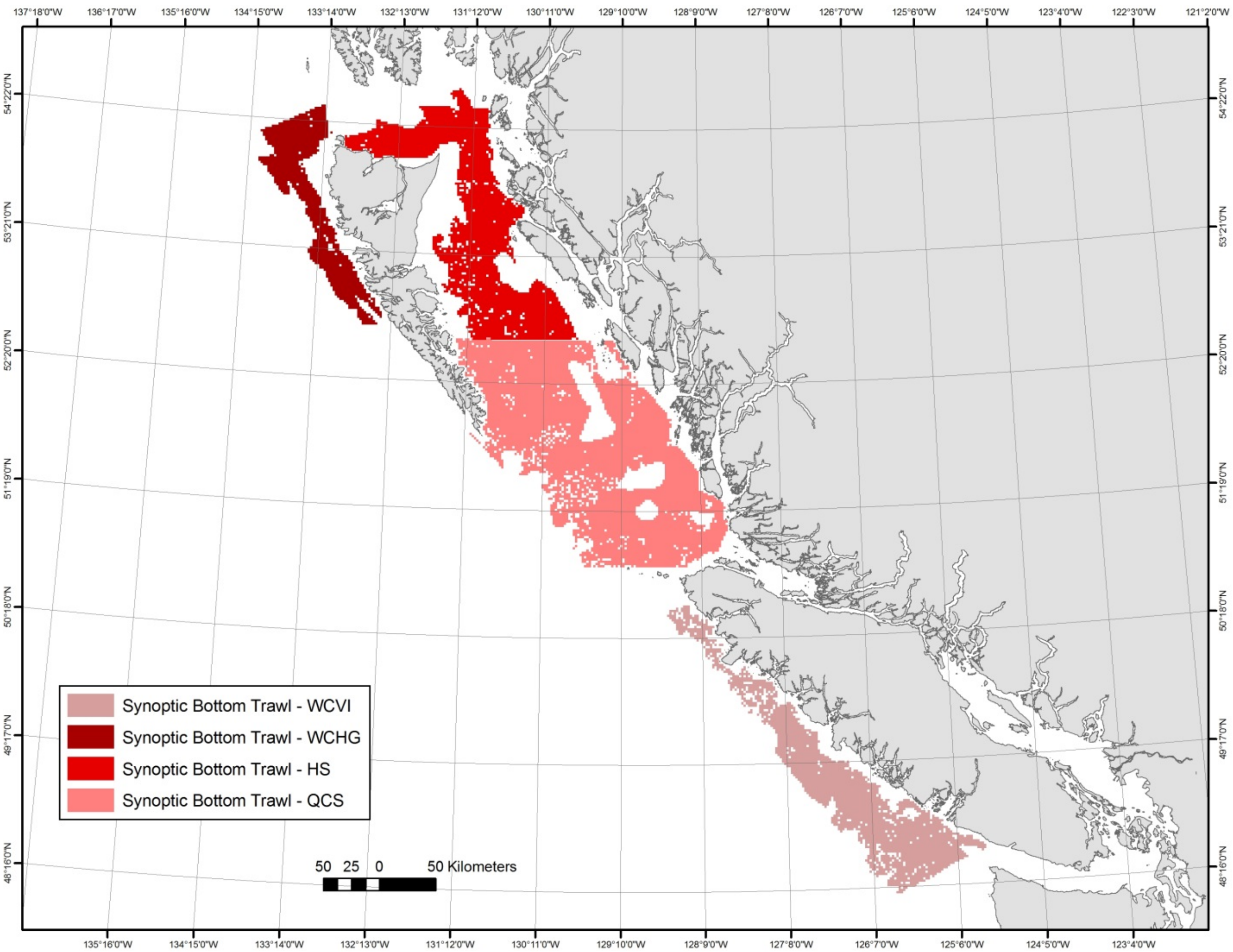


Figure 13. Multi-species Synoptic Bottom Trawl Survey coverage.

In addition to the four core surveys, a Strait of Georgia survey was initiated in 2012 with the intention of repeating the survey every 3 years. The first scheduled repeat of the survey was in 2015 but it was not possible to conduct the survey during March. Nonetheless, research vessel time was available during May and it appeared that the time period would remain available in future years. However, due to changes in department priorities, the May time period was actually not available in subsequent years. As such, the plan in 2017 was to revert back to the original time frame for the Strait of Georgia survey and complete a survey in March. The survey would continue biennially, in odd numbered years. Unfortunately, the research vessel was not operational in 2017 so no survey was completed and the survey is now on hiatus due to staffing constraints.

The synoptic bottom trawl surveys are conducted on both chartered commercial vessels and government research vessels. The Hecate Strait survey, the West Coast Vancouver Island survey, and the Strait of Georgia survey are all conducted on a Canadian Coast Guard research trawler while the Queen Charlotte Sound survey and the West Coast Haida Gwaii are conducted on chartered commercial fishing vessels.

The four core synoptic surveys (Hecate Strait, Queen Charlotte Sound, West Coast Vancouver Island, and West Coast Haida Gwaii) are all fished using an Atlantic Western IIA bottom trawl. In contrast, the Strait of Georgia survey is fished using a much smaller Yankee 36 bottom trawl. The decision to use the smaller trawl makes direct comparisons between the areas difficult but allowed us to cover the survey area in the available days. The use of the smaller trawl allows more blocks to be fished each day as the net is faster to deploy and retrieve and catches tend to be smaller.

In 2019 the Hecate Strait and Queen Charlotte Sound surveys were conducted. Both surveys were conducted on a chartered commercial vessel because the Canadian Coast Guard research trawler was not operational.

Hecate Strait Multi-species Synoptic Bottom Trawl Survey

The Hecate Strait Multi-species Synoptic Bottom Trawl Survey was conducted on the F/V Nordic Pearl between May 16 and June 12, 2019. We assessed a total of 196 blocks (Table 1, Figure 14). Of the 147 total tows conducted, one was a test tow that was completed outside of the survey area, 136 were successful survey tows, and 10 were failures due to hang ups or insufficient bottom time. Note that some blocks are only successfully fished following more than one attempt.

The total catch weight of all species was 49,992 kg. The mean catch per tow was 340 kg, averaging 22 different species of fish and invertebrates in each. The most abundant fish species encountered were Spotted Ratfish (*Hydrolagus colliei*), Arrowtooth Flounder (*Atheresthes stomias*), Rex Sole (*Glyptocephalus zachirus*), Dover Sole (*Microstomus pacificus*), and English Sole (*Parophrys vetulus*). The number of tows where the species was captured and total catch weight from usable tows as well as the estimated biomass and relative survey error for the 25 most abundant species are shown in Table 2. Biological data, including individual length, weight, sex, maturity, and age structure were collected from a total of 21,731 individual fish of 45 different species (Table 3).

Table 1. 2019 Hecate Strait Multi-species Synoptic Bottom Trawl Survey final block summary showing the number of blocks rejected based on fishing master's knowledge or by on-ground inspection, number of failed blocks (due to hang-ups or insufficient bottom time), number of successful tows, and number of un-fished blocks (due to other reasons such as tide, weather, or other vessels in the area) by stratum.

Depth Stratum (m)	Rejected Prior	Rejected Inspected	Failed	Success	Not Assessed	Total
10 to 70	4	32	3	41	0	83
70 to 130	0	6	1	44	0	51
130 to 220	0	7	1	37	0	45
220 to 500		3	0	14	0	17
Total	**4**	**48**	**5**	**136**	**0**	**196**

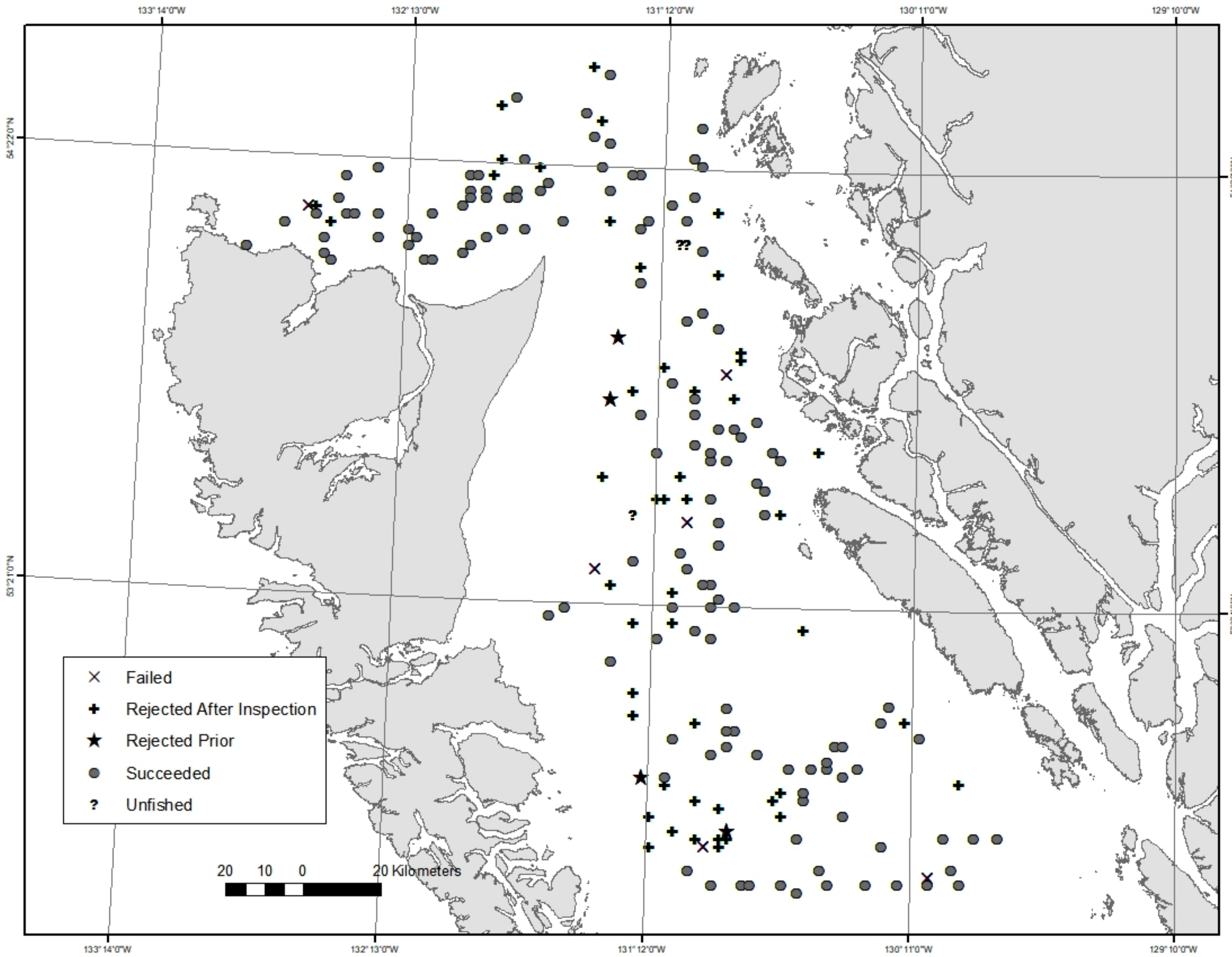


Figure 14. Final status of the allocated blocks for the 2019 Hecate Strait Multi-species Synoptic Bottom Trawl Survey.

Table 2. Number of catches and total catch weight from usable tows, estimated biomass, and relative survey error for the top 25 species (by weight) captured in the 2019 Hecate Strait Multi-species Synoptic Bottom Trawl Survey.

Species	Scientific Name	Number of Tows	Catch (kg)	Biomass (t)	Relative Error
Spotted Ratfish	*Hydrolagus colliei*	130	10004	8883	0.25
Arrowtooth Flounder	*Atheresthes stomias*	107	6684	4392	0.11
Rex Sole	*Glyptocephalus zachirus*	111	4752	3015	0.16
Dover Sole	*Microstomus pacificus*	97	4131	2801	0.26
English Sole	*Parophrys vetulus*	86	3033	3365	0.22
Pacific Ocean Perch	*Sebastes alutus*	49	2594	1512	0.45
Walleye Pollock	*Gadus chalcogrammus*	98	2534	1573	0.32
Pacific Cod	*Gadus macrocephalus*	102	1720	1752	0.37
Sablefish	*Anoplopoma fimbria*	77	1656	1056	0.36
Pacific Halibut	*Hippoglossus stenolepis*	84	1279	1298	0.15
Silvergray Rockfish	*Sebastes brevispinis*	40	1073	653	0.55
Southern Rock Sole	*Lepidopsetta bilineata*	56	1051	1544	0.22
Flathead Sole	*Hippoglossoides elassodon*	58	1045	650	0.25
North Pacific Spiny Dogfish	*Squalus suckleyi*	72	1036	725	0.59
Yellowtail Rockfish	*Sebastes flavidus*	31	642	385	0.48
Pacific Sanddab	*Citharichthys sordidus*	59	565	667	0.36
Big Skate	*Beringraja binoculata*	23	565	668	0.38
Petrale Sole	*Eopsetta jordani*	76	501	329	0.16
Redbanded Rockfish	*Sebastes babcocki*	33	344	242	0.19
Longnose Skate	*Raja rhina*	45	296	226	0.19
Shortspine Thornyhead	*Sebastolobus alascanus*	30	265	224	0.24
Lingcod	*Ophiodon elongatus*	38	245	240	0.38
Quillback Rockfish	*Sebastes maliger*	35	243	227	0.31
Starry Flounder	*Platichthys stellatus*	11	221	312	0.64
Copper Rockfish	*Sebastes caurinus*	14	202	341	0.57

Table 3. Number of fish sampled for biological data during the 2019 Hecate Strait Multi-species Synoptic Bottom Trawl Survey showing the number of lengths, age structures, and DNA tissue samples that were collected by species.

Species	Scientific Name	Lengths Collected	Age Structures Collected	DNA Tissue Collected
Aleutian Skate	*Bathyraja aleutica*	10	0	0
Arrowtooth Flounder	*Atheresthes stomias*	2095	685	0
Big Skate	*Beringraja binoculata*	53	0	0
Bocaccio	*Sebastes paucispinis*	58	56	54
Butter Sole	*Isopsetta isolepis*	194	0	0
Canary Rockfish	*Sebastes pinniger*	127	88	0
Copper Rockfish	*Sebastes caurinus*	114	84	0
Curlfin Sole	*Pleuronichthys decurrens*	121	105	0
Dover Sole	*Microstomus pacificus*	1437	831	0
English Sole	*Parophrys vetulus*	1671	912	0
Eulachon	*Thaleichthys pacificus*	459	0	70
Flathead Sole	*Hippoglossoides elassodon*	752	0	0
Greenstriped Rockfish	*Sebastes elongatus*	74	52	0
Kelp Greenling	*Hexagrammos decagrammus*	51	0	0
Lingcod	*Ophiodon elongatus*	94	57	0
Longnose Skate	*Raja rhina*	82	0	0
North Pacific Spiny Dogfish	*Squalus suckleyi*	101	0	0
Pacific Cod	*Gadus macrocephalus*	889	671	0
Pacific Hake	*Merluccius productus*	26	0	0
Pacific Halibut	*Hippoglossus stenolepis*	319	0	0
Pacific Ocean Perch	*Sebastes alutus*	660	426	0
Pacific Sanddab	*Citharichthys sordidus*	1077	0	0
Pacific Tomcod	*Microgadus proximus*	479	0	0
Petrale Sole	*Eopsetta jordani*	609	405	0
Puget Sound Rockfish	*Sebastes emphaeus*	11	0	0
Pygmy Rockfish	*Sebastes wilsoni*	55	0	0
Quillback Rockfish	*Sebastes maliger*	261	244	0
Redbanded Rockfish	*Sebastes babcocki*	176	172	0
Redstripe Rockfish	*Sebastes proriger*	70	54	0
Rex Sole	*Glyptocephalus zachirus*	2469	936	0
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus* complex	46	46	46
Sablefish	*Anoplopoma fimbria*	542	228	0
Sand Sole	*Psettichthys melanostictus*	209	0	0
Sandpaper Skate	*Bathyraja interrupta*	23	0	0
Sharpchin Rockfish	*Sebastes zacentrus*	67	0	0
Shortspine Thornyhead	*Sebastolobus alascanus*	341	136	0
Silvergray Rockfish	*Sebastes brevispinis*	218	161	0
Slender Sole	*Lyopsetta exilis*	546	0	0
Southern Rock Sole	*Lepidopsetta bilineata*	1142	589	0
Spotted Ratfish	*Hydrolagus colliei*	2485	0	0
Starry Flounder	*Platichthys stellatus*	62	0	0
Walleye Pollock	*Gadus chalcogrammus*	1218	0	0
Yelloweye Rockfish	*Sebastes ruberrimus*	1	1	1
Yellowmouth Rockfish	*Sebastes reedi*	40	38	0
Yellowtail Rockfish	*Sebastes flavidus*	197	118	0

Queen Charlotte Sound Multi-species Synoptic Bottom Trawl Survey

The Queen Charlotte Sound Multi-species Synoptic Bottom Trawl Survey was conducted on the F/V Nordic Pearl between July 16 and August 13, 2018. We assessed a total of 290 blocks (Table 4, Figure 15). Four of the randomly selected blocks fell within the Gwaii Haanas National Marine Conservation Area and at the time of the survey, no decisions had been made as to whether or not research trawl surveys will be permitted to continue in the reserve. As such, we decided to treat these blocks as temporarily unfishable and they were left unassessed at the end of the survey. Of the 274 total tows conducted, 242 were successful and 32 were failures due to hang ups or insufficient bottom time. Note that some blocks are only successfully fished following more than one attempt.

The total catch weight of all species was 154,899 kg. The mean catch per tow was 567 kg, averaging 24 different species of fish and invertebrates in each. The most abundant fish species encountered were Sablefish (*Anoplopoma fimbria*), Pacific Ocean Perch, (*Sebastes alutus*), Arrowtooth Flounder (*Atheresthes stomias*), Silvergray Rockfish (*Sebastes brevispinis*), Pacific Hake (*Merluccius productus*), Yellowmouth Rockfish (*Sebastes reedi*), and North Pacific Spiny Dogfish (*Squalus suckleyi*). The number of tows where the species was captured and total catch weight from usable tows as well as the estimated biomass and relative survey error for the 25 most abundant species are shown in Table 5. Biological data, including individual length, weight, sex, maturity, and age structure were collected from a total of 40,109 individual fish of 48 different species (Table 6). Oceanographic data, including water temperature, depth, salinity, and dissolved oxygen were also recorded for most tows.

Table 4. 2019 Queen Charlotte Sound Multi-species Synoptic Bottom Trawl Survey final block summary showing the number of blocks rejected based on fishing master's knowledge or by on-ground inspection, number of failed blocks (due to hang-ups or insufficient bottom time), number of successful tows, and number of un-fished blocks (due to other reasons such as tide, weather, or other vessels in the area) by stratum.

Depth Stratum (m)	**Rejected Prior**	**Rejected Inspected**	**Failed**	**Success**	**Not Assessed**	**Total**
South 50 to 125 m	1	1	2	35	0	39
South 125 to 200 m	0	6	5	62	0	73
South 200 to 330 m	0	5	2	26	0	33
South 330 to 500 m	0	1	0	9	0	10
North 50 to 125 m	0	4	1	15	1	21
North 125 to 200 m	0	5	3	52	2	62
North 200 to 330 m	4	4	4	35	1	48
North 330 to 500 m	0	0	0	8	0	8
Total	**5**	**26**	**17**	**242**	**4**	**294**

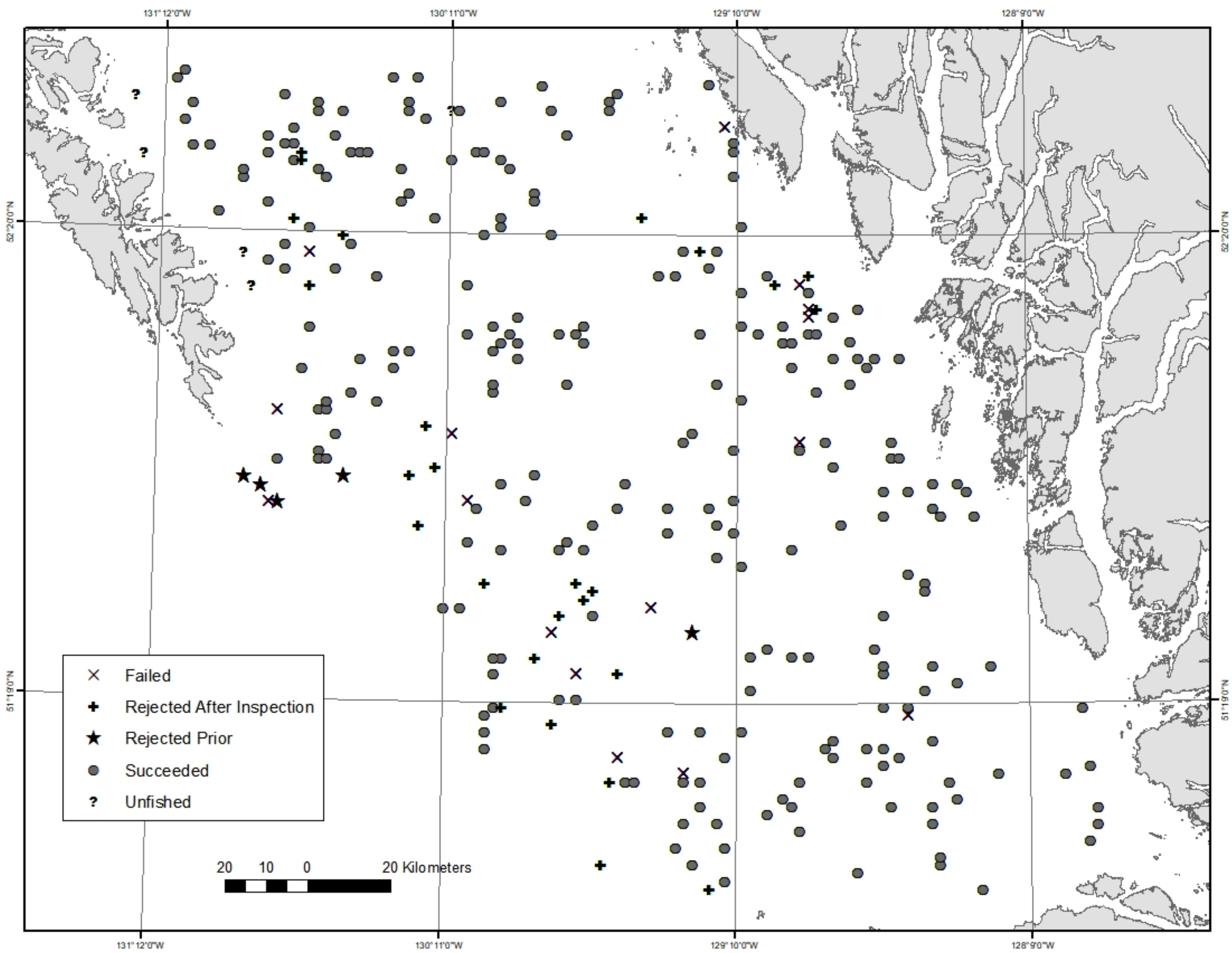


Figure 15. Final status of the allocated blocks for the 2019 Queen Charlotte Sound Multi-species Synoptic Bottom Trawl Survey.

Table 5. Number of catches and total catch weight from usable tows, estimated biomass, and relative survey error for the top 25 species (by weight) captured in the 2019 Queen Charlotte Sound Multi-species Synoptic Bottom Trawl Survey.

Species	**Scientific Name**	**Number of Tows**	**Catch (kg)**	**Biomass (t)**	**Relative Error**
Sablefish	*Anoplopoma fimbria*	178	20610	15233	0.28
Pacific Ocean Perch	*Sebastes alutus*	163	18949	15111	0.16
Arrowtooth Flounder	*Atheresthes stomias*	215	16018	12167	0.15
Silvergray Rockfish	*Sebastes brevispinis*	166	12877	10192	0.18
Pacific Hake	*Merluccius productus*	124	11761	9264	0.22
Yellowmouth Rockfish	*Sebastes reedi*	62	7146	5401	0.69
North Pacific Spiny Dogfish	*Squalus suckleyi*	99	7122	12167	0.91
Redstripe Rockfish	*Sebastes proriger*	68	4828	3482	0.23
Splitnose Rockfish	*Sebastes diploproa*	44	4524	3376	0.46
Rex Sole	*Glyptocephalus zachirus*	219	4430	3494	0.1
Canary Rockfish	*Sebastes pinniger*	52	3784	2924	0.53
Walleye Pollock	*Gadus chalcogrammus*	156	3610	2959	0.26
Yellowtail Rockfish	*Sebastes flavidus*	67	3471	2407	0.38
Redbanded Rockfish	*Sebastes babcocki*	113	3206	2531	0.48
Dover Sole	*Microstomus pacificus*	201	2843	2188	0.12
Bocaccio	*Sebastes paucispinis*	107	2412	1671	0.4
English Sole	*Parophrys vetulus*	117	2288	2306	0.2
Flathead Sole	*Hippoglossoides elassodon*	136	2137	1737	0.16
Shortspine Thornyhead	*Sebastolobus alascanus*	75	1606	1250	0.12
Spotted Ratfish	*Hydrolagus colliei*	229	1556	1352	0.12
Petrale Sole	*Eopsetta jordani*	134	1306	1082	0.14
Pacific Cod	*Gadus macrocephalus*	113	1300	1004	0.13
Lingcod	*Ophiodon elongatus*	126	1298	1128	0.15
Shortbelly Rockfish	*Sebastes jordani*	42	1220	1315	0.53
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus* complex	64	1160	733	0.24

Table 6. Number of fish sampled for biological data during the 2019 Queen Charlotte Sound Multi-species Synoptic Bottom Trawl Survey showing the number of lengths and age structures that were collected by species.

Species	**Scientific Name**	**Lengths Collected**	**Age Structures Collected**	**DNA Tissue Collected**
Alaska Skate	*Bathyraja parmifera*	1	0	0
Arrowtooth Flounder	*Atheresthes stomias*	3991	657	0
Big Skate	*Beringraja binoculata*	33	0	0
Bocaccio	*Sebastes paucispinis*	830	720	270
Brown Cat Shark	*Apristurus brunneus*	8	0	0
Canary Rockfish	*Sebastes pinniger*	492	313	0
Curlfin Sole	*Pleuronichthys decurrens*	190	160	0
Darkblotched Rockfish	*Sebastes crameri*	157	0	0
Dover Sole	*Microstomus pacificus*	2073	527	0
English Sole	*Parophrys vetulus*	1289	550	0
Eulachon	*Thaleichthys pacificus*	415	0	75
Flathead Sole	*Hippoglossoides elassodon*	1675	0	0
Greenstriped Rockfish	*Sebastes elongatus*	525	196	0
Lingcod	*Ophiodon elongatus*	603	445	0
Longnose Skate	*Raja rhina*	154	0	0
Longspine Thornyhead	*Sebastolobus altivelis*	144	109	0
North Pacific Spiny Dogfish	*Squalus suckleyi*	210	0	0
Pacific Cod	*Gadus macrocephalus*	943	639	0
Pacific Hake	*Merluccius productus*	1748	464	0
Pacific Halibut	*Hippoglossus stenolepis*	209	0	0
Pacific Ocean Perch	*Sebastes alutus*	3176	1236	0
Pacific Sanddab	*Citharichthys sordidus*	1069	0	0
Pacific Tomcod	*Microgadus proximus*	99	0	0
Petrale Sole	*Eopsetta jordani*	1145	638	0
Pygmy Rockfish	*Sebastes wilsoni*	24	0	0
Quillback Rockfish	*Sebastes maliger*	177	99	0
Redbanded Rockfish	*Sebastes babcocki*	790	583	0
Redstripe Rockfish	*Sebastes proriger*	1475	545	0
Rex Sole	*Glyptocephalus zachirus*	4067	158	0
Rosethorn Rockfish	*Sebastes helvomaculatus*	165	0	0
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus* complex	565	565	556
Roughtail Skate	*Bathyraja trachura*	1	0	0
Sablefish	*Anoplopoma fimbria*	2128	735	0
Sandpaper Skate	*Bathyraja interrupta*	52	0	0
Sharpchin Rockfish	*Sebastes zacentrus*	505	0	0
Shortbelly Rockfish	*Sebastes jordani*	297	125	0
Shortraker Rockfish	*Sebastes borealis*	26	26	0
Shortspine Thornyhead	*Sebastolobus alascanus*	1569	273	0
Silvergray Rockfish	*Sebastes brevispinis*	1932	1167	0
Slender Sole	*Lyopsetta exilis*	827	0	0
Southern Rock Sole	*Lepidopsetta bilineata*	690	397	0
Splitnose Rockfish	*Sebastes diploproa*	349	0	0
Spotted Ratfish	*Hydrolagus colliei*	742	0	0
Walleye Pollock	*Gadus chalcogrammus*	1296	0	0
Widow Rockfish	*Sebastes entomelas*	63	56	0
Yelloweye Rockfish	*Sebastes ruberrimus*	103	103	101
Yellowmouth Rockfish	*Sebastes reedi*	555	228	0
Yellowtail Rockfish	*Sebastes flavidus*	532	77	0

Hard Bottom Longline Hook Surveys

The Hard Bottom Longline Hook survey program is designed to provide hook by hook species composition and catch rates for all species available to longline hook gear from 20 to 260 m depth. The program is intended to cover areas that are not covered by the synoptic bottom trawl surveys with a focus on inshore rockfish species habitat. The goal of the survey is to provide relative abundance indices for commonly caught species, distributional and occurrence data for all other species, and detailed biological data for inshore rockfish population studies. These data are incorporated into stock assessments, status reports, and research publications.

The Hard Bottom Longline Hook program includes a survey of outside waters funded by the Pacific Halibut Management Association of BC (PHMA) and a survey of inside waters funded by DFO. Each year, approximately half of each survey area is covered and alternates between northern and southern regions year to year.

The "outside" area covers the entire British Columbia coast excluding inlets and the protected waters east of Vancouver Island. The "outside" area was intended to include "hard" bottom areas not covered by the synoptic bottom trawl surveys and was selected by including 95% of all Quillback and Yelloweye rockfish catches reported from the commercial Halibut and rockfish fisheries from 1996 to 2005. The northern region of the outside survey area includes the mainland coast north of Milbanke Sound, Dixon Entrance, and both sides of Haida Gwaii while the southern region includes the mainland coast south of Milbanke Sound, Queen Charlotte Sound, and the north and west coasts of Vancouver Island. The northern region of the outside area was surveyed during even numbered years from 2006 to 2012 and the southern region was surveyed in odd years from 2007 to 2011. The survey had a one-year hiatus in 2013 but resumed in 2014 in the southern region. The current schedule is to survey the northern region in odd numbered years and the southern region in even numbered years.

The "inside" area includes waters east of Vancouver Island. The northern region of the inside area includes Johnstone Strait and the Broughton Archipelago while the southern region includes Desolation Sound, the Strait of Georgia and the southern Gulf Islands. The survey has been conducted annually since 2003 excluding 2006. Currently the northern region is surveyed in odd numbered years while the southern region is surveyed in even numbered years.

The Hard Bottom Longline Hook surveys follow a random depth-stratified design using standardized "snap and swivel" longline hook gear with prescribed fishing protocols including bait, soak time and set locations within the selected blocks. Hard bottom regions within each survey were identified through bathymetry analyses, inshore rockfish fishing records and fishermen consultations. Each survey area is divided into 2 km by 2 km blocks and each block is assigned a depth stratum based on the average bottom depth within the block. The three depth strata for the outside area are 20 to 70 meters, 71 to 150 meters, and 151 to 260 meters. Suitable hard bottom regions in the Strait of Georgia and Johnstone Strait are more limited so the depth strata for the inside area are 20 to 70 meters and 71 to 100 meters.

Both Hard Bottom Longline surveys include detailed hook by hook enumeration of the catch. Up until the 2018 survey, the DFO Inside survey also recorded catch weights. In 2019, the recording of catch weights was suspended in favour of more detailed biological sampling. The catch rate indices from both surveys are calculated using the hook by hook data only so not recording catch weights had no impact on the main goal of the survey. Further, by not spending time and effort weighing the catch, it was possible to incorporate gut contents analysis as part of the biological sampling.

In 2019 the northern region of the outside area and the both the northern and part of the southern region of the inside area were surveyed.

Outside (Pacific Halibut Management Association, PHMA) Survey

The 2019 Outside Hard Bottom Longline Hook Survey was conducted in the northern region but at the time of writing, the data are not yet finalized and so have not been included in this report.

Inside (DFO) Survey

The Inside Hard Bottom Longline Hook Survey was conducted in both the northern and southern regions of the inside area on board the Canadian Coast Guard vessel Neocaligus from July 26 to August 26, 2019. The original schedule for this survey would have just been for the northern region. However, in 2018, we were not able to visit all the selected blocks due to crewing limitations and vessel mechanical issues. As a result, the 2019 survey included additional days to allow time to visit the sites that were missed in 2018. In addition, the 2019 survey included pilot work comparing the standard Hard Bottom Longline survey fishing gear with the standard Strait of Georgia Dogfish Longline survey fishing gear. For this report, which is focused on summarizing general survey activities, the results from all sets in all regions have been combined.

A total of 80 sets were completed including 9 random blocks in the southern region, 71 random blocks in the northern region, and 19 sets in the Strait of Georgia Dogfish Longline sites (Figure 16). The total catch of the survey was 8,234 pieces (Table 7), averaging four different species of fish and invertebrates per set. The most abundant fish species encountered were North Pacific Spiny Dogfish (*Squalus suckleyi*), Quillback Rockfish (*Sebastes maliger*), Yelloweye Rockfish (*Sebastes ruberrimus*), Spotted Ratfish (*Hydrolagus colliei*), and Lingcod (*Ophiodon elongatus*). The number of sets where the species was captured as well as the total catch count and proportion of the total catch of all fish species are shown in Table 8. An annual summary of catch by species in each region is shown in Table 9. Biological data, including individual length, weight, sex, maturity, and age structure were collected from a total of 7872 individual fish of 23 different species (Table 10). An annual summary of the number of fish sampled for biological data in each region is shown in Table 11.

One vertical CTD (conductivity, temperature, and depth recorder) cast was made at as many of the selected blocks as possible during the 2019 Inside Hard Bottom Longline Hook Survey. The CTD also included a dissolved oxygen sensor. In addition, temperature depth recorders were deployed at the start, middle, and end of every fishing set.

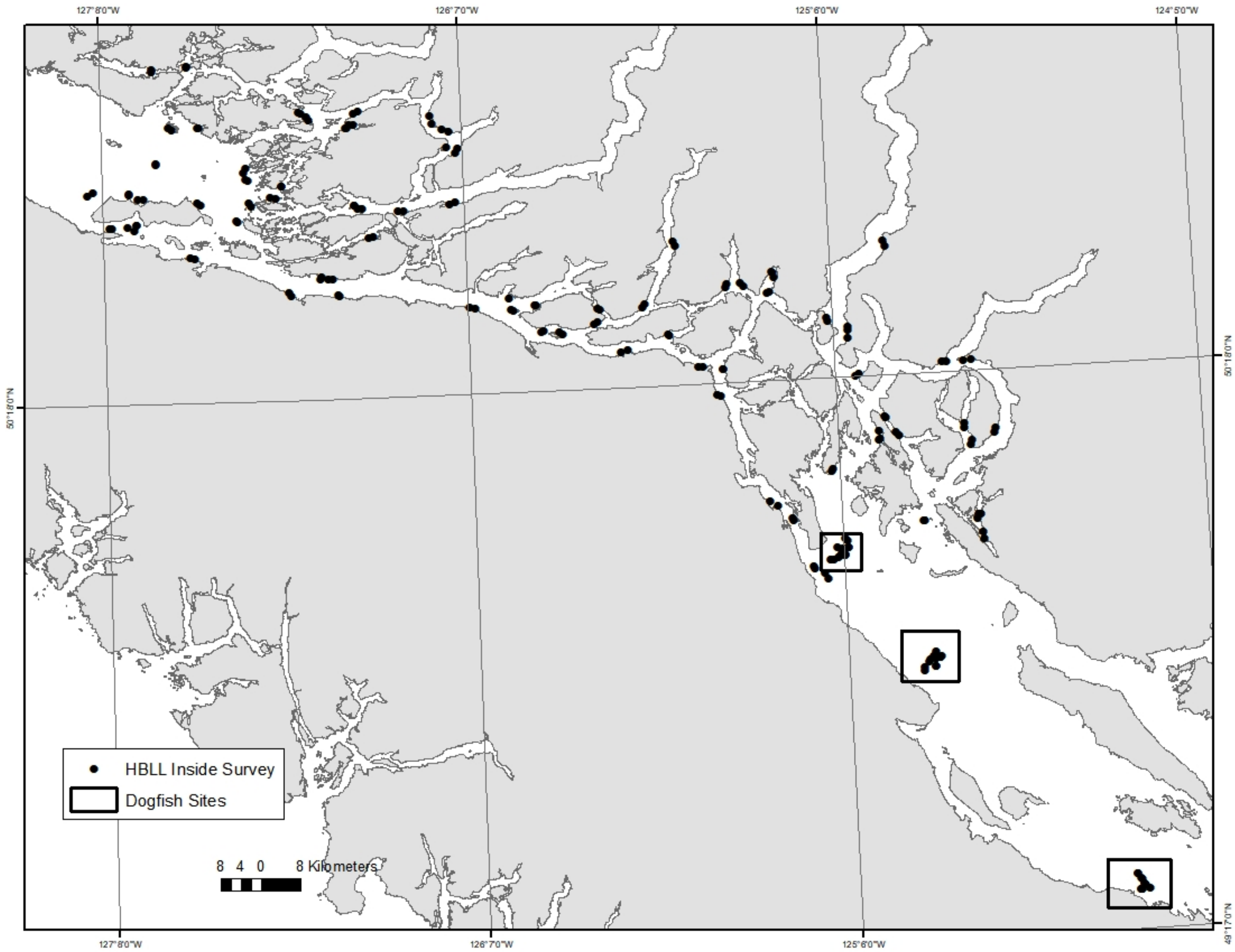


Figure 16. Longline set locations of the 2019 Inside Hard Bottom Longline Hook Survey. The boxes represent the Strait of Georgia Dogfish Longline survey sites that were visited as part of a pilot study to compare gear types and fishing protocols.

Table 7. Total catch, showing piece count by species for the 2019 Inside Hard Bottom Longline Hook Survey.

Species	**Scientific Name**	**Total Catch (count)**
North Pacific Spiny Dogfish	*Squalus suckleyi*	6994
Quillback Rockfish	*Sebastes maliger*	439
Yelloweye Rockfish	*Sebastes ruberrimus*	257
Spotted Ratfish	*Hydrolagus colliei*	84
Lingcod	*Ophiodon elongatus*	76
Sablefish	*Anoplopoma fimbria*	63
Longnose Skate	*Raja rhina*	43
Pacific Halibut	*Hippoglossus stenolepis*	28
Pacific Cod	*Gadus macrocephalus*	23
Cabezon	*Scorpaenichthys marmoratus*	22
Greenstriped Rockfish	*Sebastes elongatus*	11
Canary Rockfish	*Sebastes pinniger*	10
Copper Rockfish	*Sebastes caurinus*	10
Red Irish Lord	*Hemilepidotus hemilepidotus*	9
Big Skate	*Beringraja binoculata*	8
Pacific Sanddab	*Citharichthys sordidus*	3
Great Sculpin	*Myoxocephalus polyacanthocephalus*	2
Pacific Staghorn Sculpin	*Leptocottus armatus*	2
Tiger Rockfish	*Sebastes nigrocinctus*	2
Yellowtail Rockfish	*Sebastes flavidus*	2
Pacific Hake	*Merluccius productus*	2
Southern Rock Sole	*Lepidopsetta bilineata*	1
Flatfishes	Pleuronectiformes	1
Buffalo Sculpin	*Enophrys bison*	1
Brown Cat Shark	*Apristurus brunneus*	1
Sunflower Starfish	*Pycnopodia helianthoides*	31
Sponges	Porifera	21
Inanimate Object(s)	Inanimate object(s)	21
Tube Worms	Sedentaria	12
Red Rock Crab	*Cancer productus*	9
Fish-eating Star	*Stylasterias forreri*	6
Long-armed Sea Star	*Orthasterias koehleri*	5
Starfish	Asteroidea	4
Giant Pacific Octopus	*Enteroctopus dofleini*	3
Scallop	Pectinidae	3
	Luidia	3
Anemone	Actiniaria	3
	Solaster	2
Rose Starfish	*Crossaster papposus*	2
	Halipteris	2
Lampshells	Brachiopoda	2
Mussel	Anodonta	2
True Crabs	Brachyura	1
Box Crabs	Lopholithodes	1
Sea Urchins	Echinacea	1
Pink Short-spined Star	*Pisaster brevispinus*	1
	Evasterias	1
Sea Pen	*Ptilosarcus gurneyi*	1
Sea Whip	*Balticina septentrionalis*	1
	Ceriantharia	1
	Metridium	1

Table 8. Number of sets, catch (piece count), and proportion of the total fish catch for fish species caught during the 2019 DFO Hard Bottom Longline Hook Survey.

Species	Number of Sets	Catch (count)	Proportion of Total Catch (%)
North Pacific Spiny Dogfish	92	6994	86.41
Quillback Rockfish	63	439	5.42
Yelloweye Rockfish	38	257	3.18
Spotted Ratfish	30	84	1.04
Lingcod	33	76	0.94
Sablefish	12	63	0.78
Longnose Skate	23	43	0.53
Pacific Halibut	10	28	0.35
Pacific Cod	6	23	0.28
Cabezon	3	22	0.27
Greenstriped Rockfish	5	11	0.14
Copper Rockfish	6	10	0.12
Canary Rockfish	2	10	0.12
Red Irish Lord	4	9	0.11
Big Skate	3	8	0.10
Pacific Sanddab	2	3	0.04
Pacific Staghorn Sculpin	2	2	0.02
Pacific Hake	2	2	0.02
Great Sculpin	2	2	0.02
Yellowtail Rockfish	2	2	0.02
Tiger Rockfish	2	2	0.02
Southern Rock Sole	1	1	0.01
Flatfishes	1	1	0.01
Buffalo Sculpin	1	1	0.01
Brown Cat Shark	1	1	0.01

Table 9. Annual summary by region of the total catch (piece count) for the top 15 species (by total piece count over all years) for the Inside Hard Bottom Longline Survey.

Species	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2019	Total
Northern Region																
North Pacific Spiny Dogfish	3858	3076	154	2803	1694		2716		2749		3004		2290		3921	26265
Quillback Rockfish	308	275	2	380	60		441		757		526		570		415	3734
Spotted Ratfish	395	336	0	462	8		267		353		142		242		82	2287
Yelloweye Rockfish	135	118	2	66	32		156		170		156		246		195	1276
Sablefish	77	37	0	20	0		26		47		14		137		59	417
Lingcod	22	16	0	20	3		65		75		45		90		71	407
Pacific Halibut	38	16	0	54	3		27		62		79		41		28	348
Pacific Cod	49	20	0	47	0		26		32		22		11		23	230
Longnose Skate	33	14	0	22	5		33		17		8		19		26	177
Greenstriped Rockfish	17	23	0	31	0		10		23		7		13		11	135
Red Irish Lord	2	13	0	66	2		7		25		3		0		9	127
Copper Rockfish	12	1	0	2	4		11		25		10		16		10	91
Pacific Sanddab	32	1	0	1	0		9		21		3		1		3	71
Canary Rockfish	2	6	0	2	1		0		8		17		7		10	53
Cabezon	2	0	0	0	0		2		5		7		0		22	38
Southern Region																
North Pacific Spiny Dogfish	203		8267		3320	2631		5744		5615		5283		5302	564	36929
Yelloweye Rockfish	1		144		127	10		266		223		209		55	47	1082
Quillback Rockfish	3		116		84	27		297		199		154		88	19	987
Copper Rockfish	0		22		34	11		21		21		64		37	0	210
Lingcod	0		36		24	2		17		22		28		60	5	194
Longnose Skate	0		9		10	2		17		13		48		53	0	152
Pacific Cod	0		2		15	8		33		17		33		6	0	114
Canary Rockfish	0		7		2	0		14		14		25		26	0	88
Big Skate	0		3		1	1		1		13		29		23	0	71
Spotted Ratfish	3		12		8	0		4		5		11		11	0	54
Pacific Sanddab	0		10		5	6		3		8		11		2	0	45
Greenstriped Rockfish	0		6		3	3		16		11		3		2	0	44
Southern Rock Sole	0		3		4	1		8		2		6		5	0	29
Cabezon	0		7		2	2		2		2		7		3	0	25
Red Irish Lord	0		2		0	1		1		7		6		0	0	17

Table 10. Number of fish sampled for biological data during the 2019 Inside Hard Bottom Longline Hook survey showing the number of lengths, age structures, and DNA tissue samples that were collected by species.

Species	Scientific Name	Lengths Collected	Age Structures Collected	DNA Tissue Collected
Big Skate	*Beringraja binoculata*	4	0	0
Brown Cat Shark	*Apristurus brunneus*	1	0	0
Buffalo Sculpin	*Enophrys bison*	1	0	0
Cabezon	*Scorpaenichthys marmoratus*	22	0	0
Canary Rockfish	*Sebastes pinniger*	10	0	10
Copper Rockfish	*Sebastes caurinus*	10	10	14
Great Sculpin	*Myoxocephalus polyacanthocephalus*	2	0	0
Greenstriped Rockfish	*Sebastes elongatus*	9	0	0
Lingcod	*Ophiodon elongatus*	64	64	0
Longnose Skate	*Raja rhina*	42	0	0
North Pacific Spiny Dogfish	*Squalus suckleyi*	6845	0	0
Pacific Cod	*Gadus macrocephalus*	20	0	0
Pacific Halibut	*Hippoglossus stenolepis*	23	0	0
Pacific Sanddab	*Citharichthys sordidus*	3	0	0
Pacific Staghorn Sculpin	*Leptocottus armatus*	1	0	0
Quillback Rockfish	*Sebastes maliger*	423	424	10
Red Irish Lord	*Hemilepidotus hemilepidotus*	9	0	0
Sablefish	*Anoplopoma fimbria*	52	28	0
Southern Rock Sole	*Lepidopsetta bilineata*	1	0	0
Spotted Ratfish	*Hydrolagus colliei*	71	0	0
Tiger Rockfish	*Sebastes nigrocinctus*	2	2	2
Yelloweye Rockfish	*Sebastes ruberrimus*	255	252	251
Yellowtail Rockfish	*Sebastes flavidus*	2	0	0

Table 11. Annual summary by region of the number of fish sampled for biological data during the Inside Hard Bottom Longline Survey.

Species	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2018	2019	Total
Northern Region																
North Pacific Spiny Dogfish	3007	2068	89	2724	1686	0	2701	0	2747	0	3195	0	2289	0	3834	24340
Quillback Rockfish	295	264	2	372	61	0	438	0	744	0	520	0	568	0	399	3663
Spotted Ratfish	330	268	0	407	6	0	255	0	339	0	135	0	283	0	70	2093
Yelloweye Rockfish	133	117	2	65	31	0	153	0	169	0	156	0	235	0	193	1254
Sablefish	72	37	0	21	0	0	24	0	47	0	13	0	133	0	48	395
Lingcod	21	15	0	20	2	0	64	0	75	0	45	0	89	0	59	390
Pacific Halibut	32	13	0	1	2	0	26	0	62	0	79	0	37	0	23	275
Pacific Cod	32	16	0	42	0	0	25	0	27	0	18	0	9	0	20	189
Longnose Skate	30	9	0	12	0	0	33	0	15	0	8	0	18	0	26	151
Greenstriped Rockfish	15	19	0	27	0	0	9	0	18	0	7	0	13	0	9	117
Copper Rockfish	12	1	0	2	4	0	11	0	25	0	10	0	16	0	10	91
Pacific Sanddab	23	1	0	0	0	0	8	0	20	0	1	0	1	0	3	57
Canary Rockfish	2	6	0	2	1	0	0	0	8	0	17	0	7	0	10	53
Red Irish Lord	2	13	0	0	1	0	1	0	21	0	3	0	0	0	9	50
Cabezon	0	0	0	0	0	0	2	0	2	0	7	0	0	0	22	33
Arrowtooth Flounder	0	0	0	1	0	0	8	0	8	0	13	0	0	0	0	30
Big Skate	7	3	0	1	0	0	3	0	0	0	1	0	7	0	4	26
Tiger Rockfish	3	1	0	1	2	0	2	0	11	0	1	0	2	0	2	25
Yellowtail Rockfish	2	6	0	4	0	0	3	0	1	0	5	0	2	0	1	24
Southern Rock Sole	0	3	0	0	0	0	6	0	10	0	1	0	1	0	1	22
Great Sculpin	0	0	0	0	0	0	3	0	6	0	3	0	2	0	2	16
Kelp Greenling	0	1	0	1	0	0	3	0	4	0	0	0	6	0	0	15
Silvergray Rockfish	0	1	0	0	0	0	8	0	3	0	0	0	0	0	0	12
Pacific Staghorn Sculpin	0	0	0	0	0	0	1	0	2	0	1	0	1	0	1	6
Buffalo Sculpin	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1	6
Brown Irish Lord	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	5
Redstripe Rockfish	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	3
Northern Ronquil	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
Sharpchin Rockfish	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
Flathead Sole	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Petrale Sole	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1

Table 11. Continued.

Species	2003	2004	2005	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2018	2019	Total
Southern Region																
North Pacific Spiny Dogfish	136	0	4146	0	3303	1156	0	5720	0	5770	0	5274	0	5300	544	31349
Yelloweye Rockfish	1	0	138	0	127	10	0	264	0	222	0	205	0	55	47	1069
Quillback Rockfish	3	0	109	0	77	27	0	290	0	195	0	147	0	83	19	950
Copper Rockfish	0	0	22	0	32	10	0	19	0	20	0	64	0	30	0	197
Lingcod	0	0	33	0	23	2	0	17	0	20	0	28	0	60	5	188
Longnose Skate	0	0	7	0	0	1	0	16	0	13	0	47	0	52	0	136
Canary Rockfish	0	0	7	0	2	0	0	12	0	14	0	25	0	22	0	82
Pacific Cod	0	0	0	0	9	2	0	15	0	17	0	24	0	1	0	68
Big Skate	0	0	3	0	0	1	0	1	0	13	0	27	0	22	0	67
Spotted Ratfish	1	0	3	0	3	0	0	4	0	4	0	6	0	11	0	32
Greenstriped Rockfish	0	0	5	0	3	3	0	4	0	10	0	2	0	0	0	27
Southern Rock Sole	0	0	3	0	3	0	0	6	0	2	0	5	0	4	0	23
Cabezon	0	0	7	0	0	0	0	1	0	2	0	7	0	3	0	20
Pacific Sanddab	0	0	6	0	0	0	0	1	0	2	0	3	0	2	0	14
Red Irish Lord	0	0	2	0	0	0	0	0	0	5	0	6	0	0	0	13
Tiger Rockfish	0	0	7	0	0	0	0	1	0	0	0	0	0	0	0	8
Kelp Greenling	0	0	0	0	1	0	0	0	0	1	0	2	0	1	0	5
Pacific Halibut	0	0	0	0	0	0	0	0	0	3	0	2	0	0	0	5
Silvergray Rockfish	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	4
Walleye Pollock	0	0	0	0	0	0	0	1	0	0	0	2	0	0	0	3
Yellowtail Rockfish	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1	3
Wolf Eel	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Vermilion Rockfish	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Petrale Sole	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Redstripe Rockfish	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Sablefish	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Sandpaper Skate	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Sculpins	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1

Sablefish Research and Assessment Survey

Fisheries and Oceans Canada, in collaboration with the commercial sablefish industry, initiated an annual research and assessment survey of British Columbia Sablefish in 1988. Each year, fishing is conducted at selected localities using trap gear consistent with the commercial fishery. The fishing protocol was refined over the first few years of the survey and was standardized beginning in 1990. These standardized sets were intended to track trends in abundance and biological characteristics at the survey localities. We now refer to these sets as the “Traditional Standardized Program”. Sablefish from standardized sets were tagged and released beginning in 1991. Then, in 1994, sets with the sole purpose of capturing Sablefish for tag and release were added at the existing localities. We now refer to these sets as the “Traditional Tagging Program”. Also, in 1994, sets were made in selected mainland inlet localities. In 1995, additional offshore localities were added specifically for tagging sets. The Traditional Tagging Program has not been conducted since 2007 and the Traditional Standardized Program has not been conducted since 2010.

A pilot stratified random design was introduced for the 2003 survey with the dual purposes of random release of tagged fish and development of a second stock abundance index. The offshore survey area was divided into five spatial strata (Figure 17). Each spatial stratum was further divided into 2 km by 2 km blocks and each block was assigned to one of three depth strata. Each year, blocks are randomly selected within each combination of spatial and depth strata. From 2003 through 2010, the selected blocks were allocated equally among the strata. An analysis was conducted for the 2011 survey to estimate the optimal allocation of blocks and that allocation was used in both 2011 and 2012. In 2013 the number of blocks in the survey was reduced in an effort to reduce the overall cost of the survey. The allocation from 2013 has been used for all subsequent surveys.

The 2019 Sablefish Research and Assessment Survey was comprised of two main components:

A **Randomized Tagging Program** that releases tagged Sablefish at randomly selected fishing locations in offshore waters. These sets also produce a time series of catch rate and biological data that can be used for assessing changes in stock abundance.

An **Inlets Program** that releases tagged Sablefish from fixed-stations at four mainland inlet localities (Figure 18). These sets also provide a time series of catch rate and biological data that can be used for assessing changes in stock abundance.

In addition to the main survey programs, the Sablefish Research and Assessment Survey included a Bottom Contact Research Project to investigate gear interaction with the substrate. Trap-mounted accelerometers recorded motion and orientation of the traps while oceanographic data from trap-mounted recorders collected temperature, depth, and salinity. The autonomous, trap-mounted cameras used in recent years were not deployed in 2019.

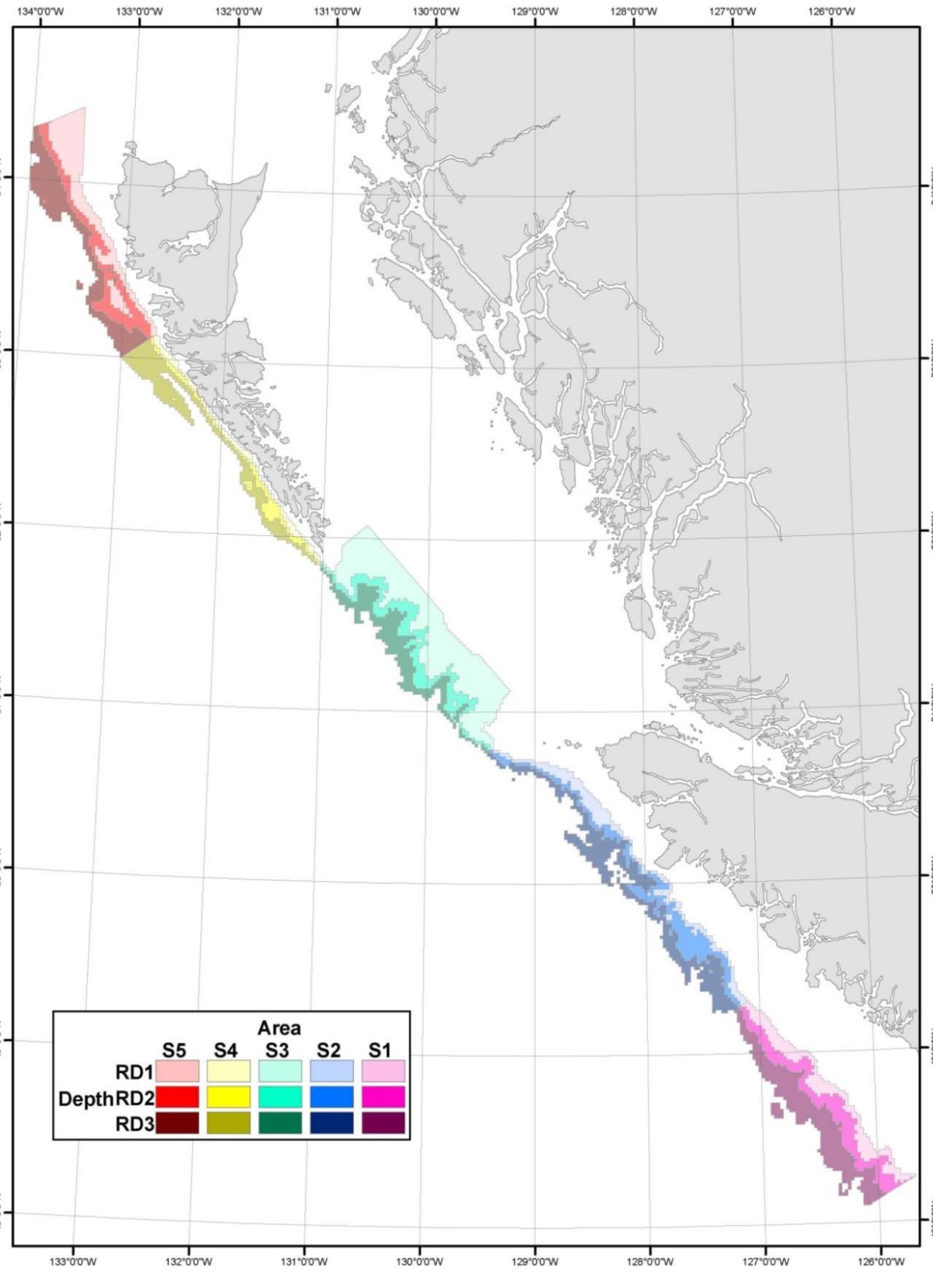


Figure 17. Sablefish Research and Assessment Survey randomized tagging program design showing the boundaries of each of the spatial and depth strata.

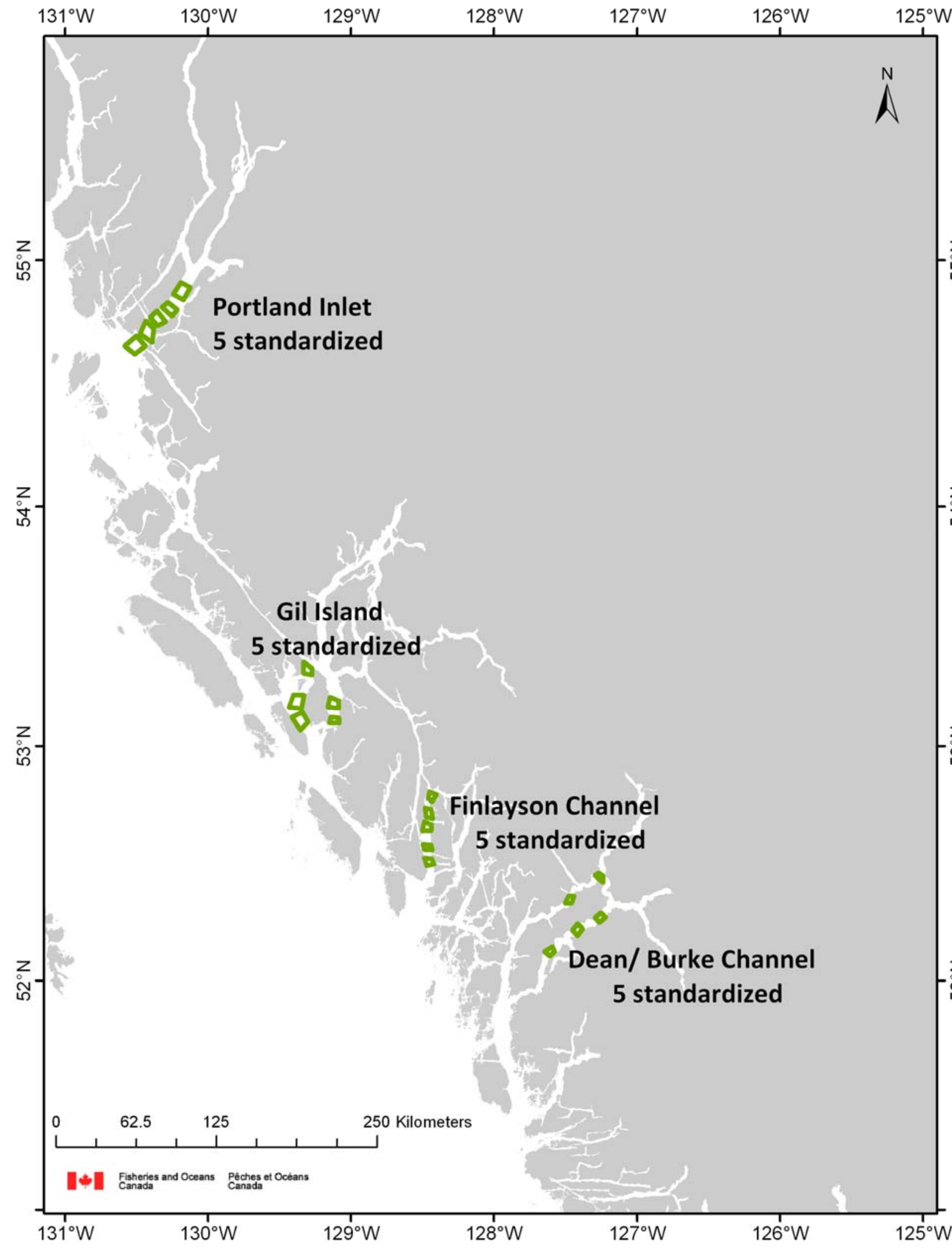


Figure 18. Sablefish Research and Assessment Survey Inlets program locations.

The 2019 Sablefish Research and Assessment Survey was conducted on the Pacific Viking from October 8 to November 25, 2019. A total of 109 sets were completed (Figure 19) including 89 Randomized Tagging Program sets (Table 12) and 20 Inlets Program sets (Table 13).

The total catch of the survey was 148,830 kg (Table 14) and the average catch per set was 1365 kg. The most abundant fish species encountered by weight were Sablefish (*Anoplopoma fimbria*), followed by Pacific Halibut (*Hippoglossus stenolepis*), Lingcod (*Ophiodon elongatus*), North Pacific Spiny Dogfish (*Squalus suckleyi*), and the Rougheye/ Blackspotted Rockfish Complex (*Sebastes aleutianus/ melanostictus*). The number of sets where the species was captured as well as the total catch count, proportion of the total catch, and a breakdown by area for the 25 most abundant species captured during the Randomized Tagging Program are shown in Table 15. Annual summaries of catch for common species are shown for the Randomized Tagging Program in Table 16 and in Table 17 for the Inlet Program. Biological data, including individual length, weight, sex, maturity, and age structure were collected from a total of 18,188 individual fish of 6 different species (Table 18). An annual summary of the number of fish sampled for biological data during the Randomized Tagging Program is shown in Table 19 and in Table 20 for the Inlets Program.

Table 12. Summary of sets completed during the 2019 Sablefish Randomized Tagging Program showing the number of sets in each combination of spatial and depth strata.

	Depth Strata			
Spatial Strata	RD1 (100-250 fm)	RD2 (250-450 fm)	RD3 (450-750)	**Total**
S1 (South West Coast Vancouver Island or SWCVI)	6	8	5	19
S2 (North West Coast Vancouver Island or NWCVI)	6	7	5	18
S3 (Queen Charlotte Sound or QCS)	8	6	5	19
S4 (South West Coast Haida Gwaii or SWCHG)	6	7	4	17
S5 (North West Coast Haida Gwaii or NWCHG)	5	7	4	16
Total	**31**	**35**	**223**	**89**

Table 13. Summary of sets completed during the 2019 Sablefish Inlets Program.

Location	**Number of sets**
Dean/Burke Channel	5
Finlayson Channel	5
Gil Island	5
Portland Inlet	5

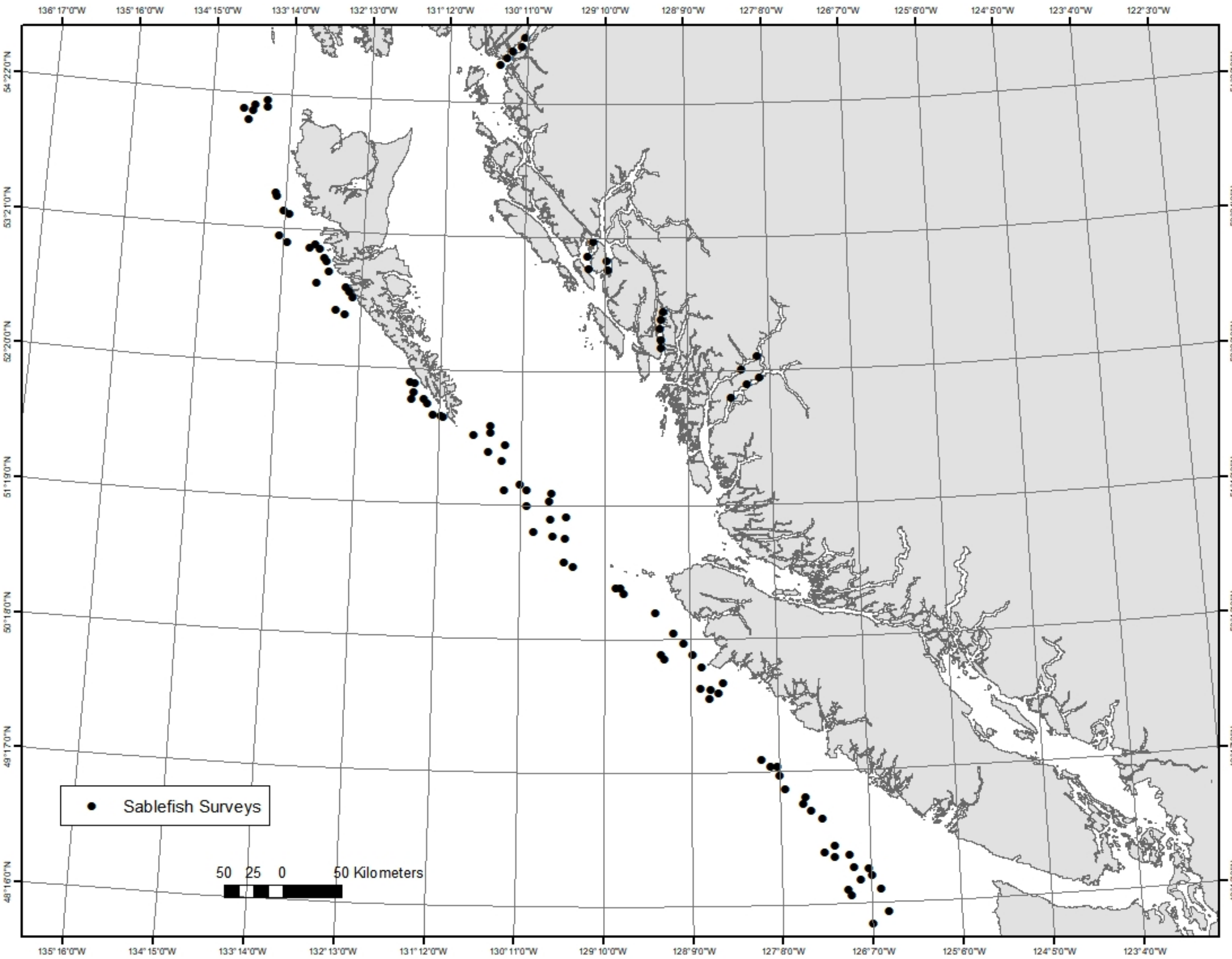


Figure 19. Set locations of the 2019 Sablefish Research and Assessment Survey.

Table 14. Total catch for the top 35 species (by weight) captured during the 2019 Sablefish Research and Assessment Survey.

Species	Scientific Name	Total Catch (count)	Total Catch (kg)
Sablefish	*Anoplopoma fimbria*	78836	141565
Pacific Halibut	*Hippoglossus stenolepis*	256	2130
Lingcod	*Ophiodon elongatus*	200	1887
North Pacific Spiny Dogfish	*Squalus suckleyi*	570	1324
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus complex*	290	501
Redbanded Rockfish	*Sebastes babcocki*	221	386
Arrowtooth Flounder	*Atheresthes stomias*	101	230
Pacific Grenadier	*Coryphaenoides acrolepis*	200	172
Yelloweye Rockfish	*Sebastes ruberrimus*	49	167
Giant Grenadier	*Albatrossia pectoralis*	46	150
Grooved Tanner Crab	*Chionoecetes tanneri*	379	143
Shortraker Rockfish	*Sebastes borealis*	11	45
Shortspine Thornyhead	*Sebastolobus alascanus*	32	30
Pacific Sleeper Shark	*Somniosus pacificus*	2	12
Pacific Cod	*Gadus macrocephalus*	3	9
Oregontriton	*Fusitriton oregonensis*	219	8
	Lithodes couesi	17	8
Dover Sole	*Microstomus pacificus*	8	8
Pink Snailfish	*Paraliparis rosaceus*	9	7
Petrale Sole	*Eopsetta jordani*	3	6
Pacific Flatnose	*Antimora microlepis*	4	6
Yellowmouth Rockfish	*Sebastes reedi*	3	5
Rosethorn Rockfish	*Sebastes helvomaculatus*	8	3
Giant Pacific Octopus	*Enteroctopus dofleini*	1	3
Rockfishes	*Sebastes sp.*	3	2
Silvergray Rockfish	*Sebastes brevispinis*	1	2
Canary Rockfish	*Sebastes pinniger*	1	2
Brown Box Crab	*Lopholithodes foraminatus*	3	1
Fragile Urchin	*Allocentrotus fragilis*	15	1
Aurora Rockfish	*Sebastes aurora*	1	0
	Paralomis multispina	1	0
Longspine Thornyhead	*Sebastolobus altivelis*	4	0
Sharpchin Rockfish	*Sebastes zacentrus*	2	0
	Hippasteria	1	0
	Rathbunaster californicus	1	0

Table 15. Number of sets where the species was captured, total catch count, proportion of the total catch, and a breakdown by area for the 25 most abundant species (by weight) captured during the 2019 Sablefish Research and Assessment Survey Randomized Tagging Program sets.

Species	**Scientific Name**	**Number of Sets**	**Catch (count)**	**Proportion of Total Catch (%)**	**4B**	**3C**	**3D**	**5A**	**5B**	**5C**	**5D**	**5E**
Sablefish	*Anoplopoma fimbria*	109	78836	97.49	0	7144	13516	8183	14506	9264	5445	20778
North Pacific Spiny Dogfish	*Squalus suckleyi*	25	570	0.70	0	233	62	80	96	3	0	96
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus* complex	15	290	0.36	0	17	7	5	19	0	0	242
Pacific Halibut	*Hippoglossus stenolepis*	39	256	0.32	0	20	31	18	85	8	24	70
Redbanded Rockfish	*Sebastes babcocki*	25	221	0.27	0	14	40	33	65	0	0	69
Pacific Grenadier	*Coryphaenoides acrolepis*	15	200	0.25	0	91	29	14	31	0	0	35
Lingcod	*Ophiodon elongatus*	18	200	0.25	0	19	38	64	42	0	0	37
Arrowtooth Flounder	*Atheresthes stomias*	22	101	0.12	0	1	15	12	20	1	0	52
Yelloweye Rockfish	*Sebastes ruberrimus*	7	49	0.06	0	0	2	8	20	0	0	19
Giant Grenadier	*Albatrossia pectoralis*	13	46	0.06	0	34	4	0	1	0	0	7
Shortspine Thornyhead	*Sebastolobus alascanus*	25	32	0.04	0	4	6	3	7	0	0	12
Shortraker Rockfish	*Sebastes borealis*	7	11	0.01	0	0	0	0	3	0	0	8
Pink Snailfish	*Paraliparis rosaceus*	4	9	0.01	0	7	0	0	2	0	0	0
Rosethorn Rockfish	*Sebastes helvomaculatus*	6	8	0.01	0	0	0	5	0	0	0	3
Dover Sole	*Microstomus pacificus*	8	8	0.01	0	2	1	0	1	0	1	3
Longspine Thornyhead	*Sebastolobus altivelis*	3	4	0.00	0	0	4	0	0	0	0	0
Pacific Flatnose	*Antimora microlepis*	2	4	0.00	0	2	0	0	0	0	0	2
Pacific Cod	*Gadus macrocephalus*	2	3	0.00	0	0	0	0	0	0	0	3
Rockfishes	*Sebastes*	1	3	0.00	0	0	3	0	0	0	0	0
Petrale Sole	*Eopsetta jordani*	2	3	0.00	0	0	0	0	3	0	0	0
Yellowmouth Rockfish	*Sebastes reedi*	1	3	0.00	0	0	0	0	3	0	0	0
Sharpchin Rockfish	*Sebastes zacentrus*	1	2	0.00	0	0	2	0	0	0	0	0
Pacific Sleeper Shark	*Somniosus pacificus*	2	2	0.00	0	0	0	0	1	1	0	0
Darkfin Sculpin	*Malacocottus zonurus*	1	1	0.00	0	0	0	0	1	0	0	0
Canary Rockfish	*Sebastes pinniger*	1	1	0.00	0	0	1	0	0	0	0	0

Table 16. Annual summary of the total catch (piece count) for the top 10 species (by total piece count over all years) for the Sablefish Research and Assessment Survey Randomized Tagging Program sets. Data from 2003 through 2006 have been omitted from this table.

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Sablefish	18833	20326	15529	17375	22568	16845	18095	14266	25428	18073	36604	46808	60965	411953
Arrowtooth Flounder	1655	1163	1787	553	1037	921	414	864	610	427	686	336	100	12931
Pacific Grenadier	880	608	829	676	742	715	254	534	686	627	276	346	200	9067
North Pacific Spiny Dogfish	437	162	565	414	868	966	386	287	365	699	158	964	567	8952
Rougheye/ Blackspotted Rockfish	558	513	418	406	266	941	223	488	320	386	257	177	290	6349
Complex Pacific	185	125	224	172	256	342	99	447	444	283	165	323	223	3712
Halibut Redbanded	154	257	150	131	244	208	127	241	295	217	287	219	221	3169
Rockfish Lingcod	201	109	93	97	165	71	88	92	121	154	106	192	200	2090
Giant Grenadier	162	146	179	118	105	195	80	87	206	72	67	106	46	1894
Yelloweye Rockfish	71	58	60	21	106	34	13	17	81	97	22	311	49	1054

Table 17. Annual summary of the total catch (piece count) for the top 10 species (by total piece count over all years) for the Sablefish Research and Assessment Survey Inlet Program sets. Data from 2003 through 2006 have been omitted from this table.

Species	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Sablefish	3453	2498	4339	7507	11034	6213	3271	3341	2708	5050	8110	11607	17871	119027
Pacific Halibut	111	99	78	109	108	113	88	265	333	243	90	64	33	2012
Arrowtooth Flounder	101	108	49	25	11	20	11	49	30	24	14	18	1	554
North Pacific Spiny Dogfish	8	1	2	15	18	12	4	5	44	14	1	0	3	145
Dover Sole	4	23	1	0	0	1	2	5	1	1	2	0	1	50
Walleye Pollock	6	3	3	3	3	4	1	4	2	2	1	0	0	42
Pacific Sleeper Shark	5	4	2	0	1	0	0	2	0	2	0	0	1	30
Shortraker Rockfish	4	5	4	1	3	2	0	0	3	0	0	1	0	27
Pacific Cod	0	8	1	5	0	1	1	2	1	0	1	0	0	20
Rougheye/Blackspotted Rockfish Complex	2	1	1	1	0	2	0	2	0	1	1	3	0	17

Table 18. Number of fish sampled for biological data during the 2019 Sablefish Research and Assessment Survey showing the number of tag releases, lengths, age structures, and DNA tissue samples that were collected by species.

Species	Scientific Name	Tags	Lengths Collected	Age Structures Collected	DNA Tissue Collected
Pacific Halibut	*Hippoglossus stenolepis*	0	247	0	0
Pacific Sleeper Shark	*Somniosus pacificus*	0	1	0	1
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus* complex	0	195	195	193
Sablefish	*Anoplopoma fimbria*	12042	17701	5389	0
Shortraker Rockfish	*Sebastes borealis*	0	11	11	0
Yelloweye Rockfish	*Sebastes ruberrimus*	0	49	49	49

Table 19. Annual summary of the number of common fish species sampled for biological data during the Sablefish Research and Assessment Survey Randomized Tagging Program sets. Data from 2003 through 2006 have been omitted from this table.

Species	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Sablefish	10385	11059	9331	10270	12463	10486	10118	8204	12094	9910	15841	13094	13721	198039
Rougheye/Blackspotted Rockfish Complex	0	282	289	266	240	393	179	373	270	270	183	144	195	3140
Pacific Grenadier	0	461	562	378	471	380	188	0	0	0	0	0	0	2440
Arrowtooth Flounder	0	441	379	245	400	656	140	0	0	0	0	0	0	2261
North Pacific Spiny Dogfish	0	0	219	326	440	674	207	0	0	0	0	0	0	1866
Redbanded Rockfish	0	224	145	131	243	204	113	0	0	0	29	0	0	1089
Giant Grenadier	0	129	141	111	99	195	79	0	0	0	0	0	0	754
Pacific Halibut	0	0	2	60	5	15	0	0	0	0	158	261	216	717
Yelloweye Rockfish	0	55	60	21	106	32	12	0	75	58	21	150	49	639
Shortraker Rockfish	0	53	65	73	18	59	18	13	10	59	26	24	11	437
Pacific Flatnose	0	18	39	27	17	24	11	0	0	10	0	0	0	146
Shortspine Thornyhead	0	1	9	26	22	53	34	0	0	0	0	0	0	145
Lingcod	0	0	27	36	1	3	1	0	0	0	0	0	0	68
Rosethorn Rockfish	0	8	6	2	23	7	3	0	0	0	0	0	0	49
Dover Sole	0	3	1	3	13	18	3	0	0	0	0	0	0	41
Emarginate Snailfish	0	30	0	0	1	0	0	0	0	0	0	0	0	31

Table 20. Annual summary of the number of common fish species sampled for biological data during the Sablefish Research and Assessment Survey Randomized Inlet Program sets. Data from 2003 through 2006 have been omitted from this table.

Species	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Sablefish	2554	1993	3070	5064	5984	3900	2503	2379	2234	3272	4693	3582	3964	64611
Pacific Halibut	0	0	0	0	0	4	0	0	0	0	90	63	31	188
North Pacific Spiny Dogfish	0	0	0	0	8	11	0	0	0	0	0	0	0	25
Arrowtooth Flounder	0	0	0	0	3	18	0	0	0	0	0	0	0	21
Shortraker Rockfish	0	0	3	1	2	2	0	0	3	0	0	1	0	12
Rougheye/Blackspotted Rockfish complex	0	0	0	1	0	2	0	2	0	1	1	3	0	10
Walleye Pollock	0	0	0	0	1	1	0	0	0	0	0	0	0	9

Strait of Georgia Dogfish Longline Hook Survey

The Strait of Georgia Dogfish Longline Hook Survey is designed to provide biological, catch, and effort data for North Pacific Spiny Dogfish in the Strait of Georgia. The survey was first conducted in 1986 and 1989 and then resurrected in 2004 when a gear comparison study was completed. The comparison was necessary because the J shaped hooks used in the 1980s were no longer readily available as commercial fishing had shifted towards circle shaped hooks. The commercial fishery shifted to circle hooks because they are safer to handle and are believed to retain catch better than J hooks. The 2004 study included sets with both gear types as well as different numbers of hooks which allowed the calculation of catch per unit effort correction factors. The modern Strait of Georgia Dogfish Longline Hook survey was conducted with circle hooks in 2005 and then was repeated triennially through 2014. The survey was deferred in both 2017 and 2018 due to staffing limitations and research vessel availability.

The Strait of Georgia Dogfish Longline Hook survey follows a fixed station design using standardized “snap and swivel” longline hook gear with prescribed fishing protocols including bait, and soak time. There are 10 core index sites distributed between Cape Mudge and Active Pass, on both sides of the Strait of Georgia: French Creek, Hornby Island, Cape Lazo, Cape Mudge, Grant Reef, Sinclair Bank, Epsom Point, Sturgeon Bank, Active Pass, Porlier Pass (Figure 20). Entrance Island and Halibut Bank are additional, lower priority sites that are visited if there is sufficient time during the survey.

One longline set is conducted in each of four depth stratum at each index site, and generally one site will be completed per day. The depth strata are as follows: 2: 56 to 110 m, 3: 111 to 165 m, 4: 166 to 220 m, and 5: greater than 220 m. Historically an additional shallow depth stratum (1: less than 56 m) was fished but this stratum has been eliminated from the survey due both to time constraints and to the high rockfish bycatch which typically occurred. Depth stratum five is not fished at the Hornby Island site as there is no habitat greater than 220 m at the site.

Temperature depth recorders were deployed at the start, middle, and end of every fishing set.

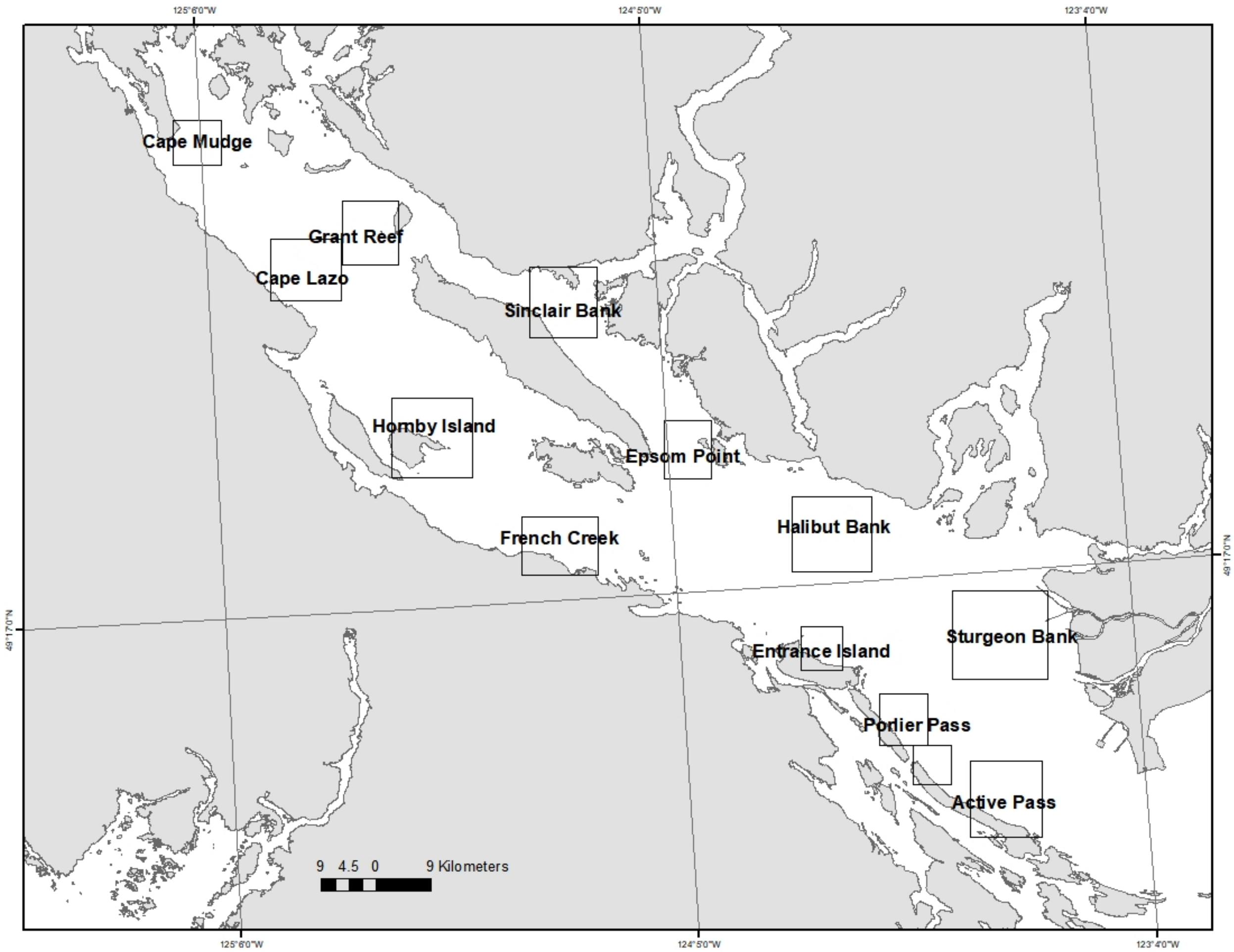


Figure 20. Strait of Georgia Dogfish Longline Hook Survey sites. The Porlier Pass site consists of both a northern and a southern region.

The 2019 Strait of Georgia Dogfish Longline Survey was conducted on board the Canadian Coast Guard vessel Neocaligus from October 1 to 14, 2019. A total of 39 sets were completed at the 10 core sites (Table 21,Figure 21). There was not sufficient time to visit the Halibut Bank and Entrance Island sites.

Table 21. Summary of sets completed during the 2019 Strait of Georgia Dogfish Longline Hook Survey. There is no habitat in depth stratum five at the Hornby Island site.

	Depth stratum				
Site	**2: 56 to 110 m**	**3: 111 to 165 m**	**4: 166 to 220 m**	**5: > 220 m**	**Total**
Cape Mudge	1	1	1	1	**4**
Grant Reef	1	1	1	1	**4**
Cape Lazo	1	1	1	1	**4**
Sinclair Bank	1	1	1	1	**4**
Hornby Island	1	1	1	N/A	**3**
Epsom Point	1	1	1	1	**4**
French Creek	1	1	1	1	**4**
Halibut Bank					
Sturgeon Bank	1	1	1	1	**4**
Entrance Island					
Porlier Pass	1	1	1	1	**4**
Active Pass	1	1	1	1	**4**
Total	**10**	**10**	**10**	**9**	**39**

The total catch of the survey was 5,810 pieces (Table 22), averaging only two different species of fish and invertebrates per set. The most abundant fish species encountered were North Pacific Spiny Dogfish (*Squalus suckleyi*), Yelloweye Rockfish (*Sebastes ruberrimus*) and Quillback Rockfish (*Sebastes maliger*). The number of sets where the species was captured as well as the total catch count and proportion of the total catch of all fish species are shown in Table 23. Biological data, including individual length, weight, sex, maturity, and age structure were collected from a total of 7872 individual fish of 23 different species (Table 24).

Table 22. Total catch, showing piece count by species for the 2019 Strait of Georgia Dogfish Longline Hook Survey.

Species	**Scientific Name**	**Total Catch (count)**
North Pacific Spiny Dogfish	*Squalus suckleyi*	5606
Yelloweye Rockfish	*Sebastes ruberrimus*	85
Quillback Rockfish	*Sebastes maliger*	41
Spotted Ratfish	*Hydrolagus colliei*	26
Longnose Skate	*Raja rhina*	19
Bluntnose Sixgill Shark	*Hexanchus griseus*	6
Copper Rockfish	*Sebastes caurinus*	5
Sablefish	*Anoplopoma fimbria*	4
Petrale Sole	*Eopsetta jordani*	3
Pacific Staghorn Sculpin	*Leptocottus armatus*	2
Greenstriped Rockfish	*Sebastes elongatus*	2
Pacific Sanddab	*Citharichthys sordidus*	1
Canary Rockfish	*Sebastes pinniger*	1
Pacific Hake	*Merluccius productus*	1
Pacific Cod	*Gadus macrocephalus*	1
Unknown Fish	Unknown fish	1
Sunflower Starfish	*Pycnopodia helianthoides*	1
Starfish	Asteroidea	1
Sponges	Porifera	1
Oregontriton	*Fusitriton oregonensis*	1

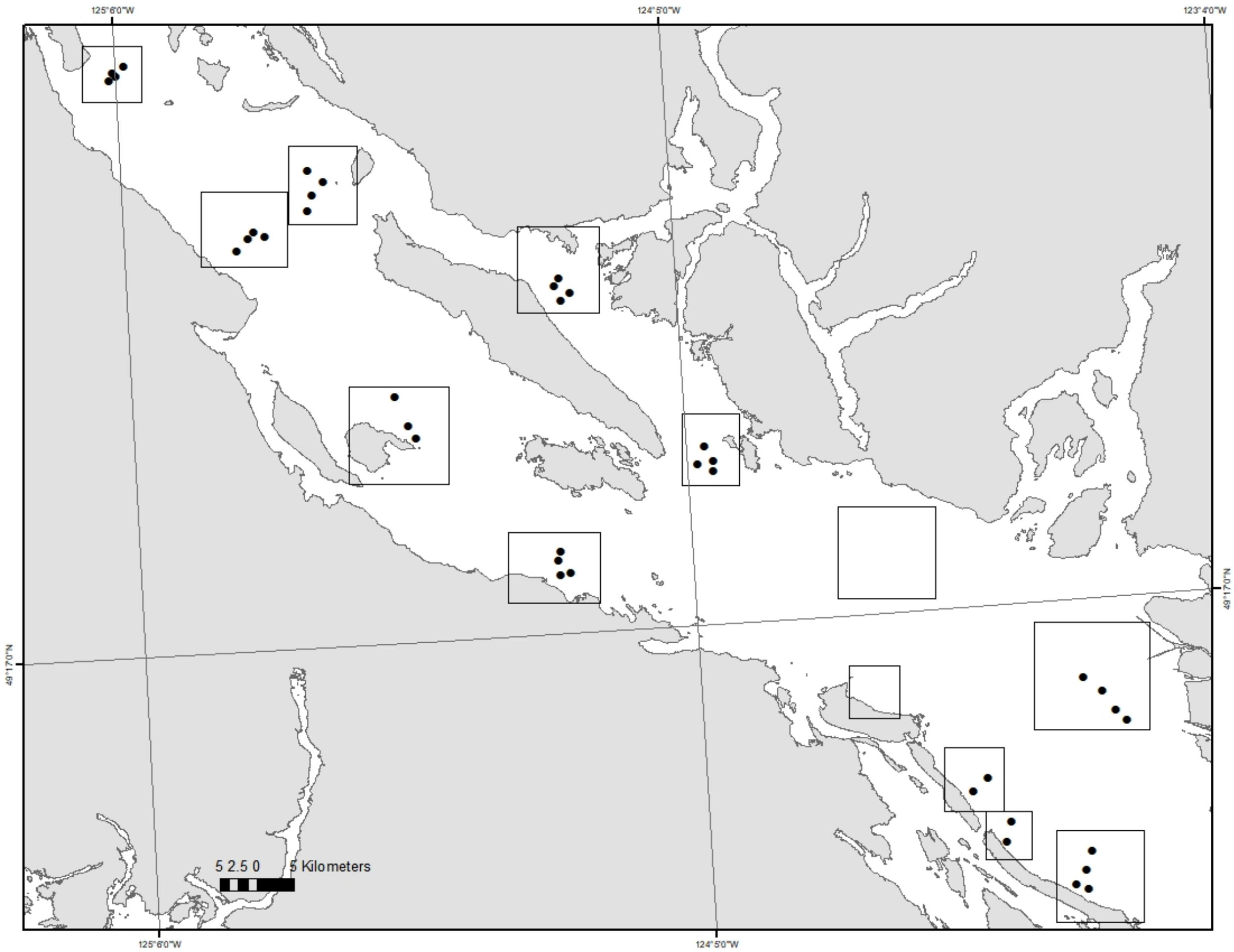


Figure 21. Set locations of the 2019 Strait of Georgia Dogfish Longline Hook Survey.

Table 23. Number of sets, catch (piece count), and proportion of the total fish catch for fish species caught during the 2019 Strait of Georgia Dogfish Longline Hook Survey.

Species	Scientific Name	Number of Sets	Catch (count)	Proportion of Total Catch (%)
North Pacific Spiny Dogfish	*Squalus suckleyi*	39	5606	96.59
Yelloweye Rockfish	*Sebastes ruberrimus*	12	85	1.46
Quillback Rockfish	*Sebastes maliger*	7	41	0.71
Spotted Ratfish	*Hydrolagus colliei*	10	26	0.45
Longnose Skate	*Raja rhina*	10	19	0.33
Bluntnose Sixgill Shark	*Hexanchus griseus*	4	6	0.10
Copper Rockfish	*Sebastes caurinus*	1	5	0.09
Sablefish	*Anoplopoma fimbria*	4	4	0.07
Petrale Sole	*Eopsetta jordani*	3	3	0.05
Greenstriped Rockfish	*Sebastes elongatus*	2	2	0.03
Pacific Staghorn Sculpin	*Leptocottus armatus*	1	2	0.03
Unknown Fish	*Unknown fish*	1	1	0.02
Pacific Sanddab	*Citharichthys sordidus*	1	1	0.02
Pacific Hake	*Merluccius productus*	1	1	0.02
Pacific Cod	*Gadus macrocephalus*	1	1	0.02
Canary Rockfish	*Sebastes pinniger*	1	1	0.02

Table 24. Number of fish sampled for biological data during the 2019 Strait of Georgia Dogfish Longline Hook Survey showing the number of lengths, age structures, and DNA tissue samples that were collected by species.

Species	Scientific Name	Lengths Collected	Age Structures Collected	DNA Tissue Collected
Bluntnose Sixgill Shark	*Hexanchus griseus*	1	0	1
Canary Rockfish	*Sebastes pinniger*	1	0	0
Copper Rockfish	*Sebastes caurinus*	5	5	5
Greenstriped Rockfish	*Sebastes elongatus*	2	0	0
Longnose Skate	*Raja rhina*	19	0	0
North Pacific Spiny Dogfish	*Squalus suckleyi*	5515	0	0
Pacific Cod	*Gadus macrocephalus*	1	0	0
Pacific Sanddab	*Citharichthys sordidus*	1	0	0
Pacific Staghorn Sculpin	*Leptocottus armatus*	2	0	0
Petrale Sole	*Eopsetta jordani*	2	0	0
Quillback Rockfish	*Sebastes maliger*	41	41	0
Sablefish	*Anoplopoma fimbria*	4	0	0
Spotted Ratfish	*Hydrolagus colliei*	22	0	0
Yelloweye Rockfish	*Sebastes ruberrimus*	85	84	85

Multi-species Small-mesh Bottom Trawl Survey

An annual fixed-station survey of commercially important shrimp grounds off the West Coast of Vancouver Island was initiated in 1973. In 1998, areas in Eastern Queen Charlotte Sound were added to the survey. The survey grounds were defined based on commercial fishing and span the 50-200m depth range. Tow locations within the survey grounds were selected using a systematic grid. Over the years some stations have been removed so there are now a set of standard tows that are repeated each year. Catch rates from this survey are directly tied to the shrimp trawl fishery catch quotas.

Given that the survey is conducted using a shrimp bottom trawl without an excluder device, groundfish can make up a significant portion of the catch in many of the tows. Catch rate indices generated by the survey have been used to track the abundances of several groundfish stocks. Although catch rates are useful indicators of stock status, additional information such as the size and age composition of the catch improves the usefulness of the indices. Consequently, a program was initiated in 2003 to collect biological samples from all groundfish species caught during the survey. Groundfish staff provide assistance in catch sorting and species identification and also collect biological samples from selected fish species. From 2010 through 2013, the goal was to collect biological information from as many different species in each tow as possible - as opposed to detailed information from only a few species. As such, two groundfish program staff members were deployed and the biological sampling effort was focused on length by sex data in favour of collecting ageing structures. Starting in 2014, only one groundfish staff member participated in the survey and the biological sampling program was reduced so that a single person could accomplish all the work. In addition, the sampling program was rationalized to only include species where the survey is expected to provide a useful index of abundance.

Starting in 2013, the West Coast Vancouver Island portion of the survey also included locations in Barkley Sound that were surveyed by the Canadian Coast Guard Ship Neocaligus in previous years. In 2014, the Queen Charlotte Sound portion of the survey was not conducted due to the limited number of vessel days available for the program. The Queen Charlotte Sound area was also not visited in 2015, and from 2017 through 2019 due to staffing limitations.

The 2019 survey was conducted onboard the F/V Nordic Pearl and ran from April 30 to May 15. A total of 118 tows were completed, of which 112 were usable (Figure 22). Tows were determined to be unusable if there was insufficient bottom contact time or if the gear was damaged. The total catch weight of all species was 56,320 kg. The mean catch per tow was 502 kg, averaging 36 different species of fish and invertebrates in each. Over all tows over the entire survey, the most abundant fish species encountered were North Pacific Spiny Dogfish (*Squalus suckleyi*), Rex Sole (*Glyptocephalus zachirus*), Dover Sole (*Microstomus pacificus*), Slender Sole (*Lyopsetta exilis*), and Flathead Sole (*Hippoglossoides elassodon*). The number of tows where the species was captured, total catch weight from successful tows, estimated biomass, and relative survey error for the top 25 fish species by weight are shown in Table 25 for the West Coast Vancouver Island tow locations. Biomass indices have not been calculated for the Barkley Sound tow locations as these locations have not yet been used for any groundfish assessments.

Biological data were collected from a total of 8,192 individual fish from 21 different species (Table 26). Most biological samples included fish length and sex but age structures were also collected for Bocaccio (*Sebastes paucispsinis*) and Lingcod (*Ophiodon elongatus*) and both age structures and tissue samples for DNA analysis were collected from Rougheye/ Blackspotted

Rockfish (*Sebastes aleutianus/ melanostictus*) and Yelloweye Rockfish (*Sebastes ruberrimus*). Almost half of all the individual fish measured during the survey were Eulachon (*Thaleichthys pacificus*). Although we include this species in these summaries, the groundfish program staff typically does not directly collect the biological data from this species or American Shad (*Alosa sapidissima*).

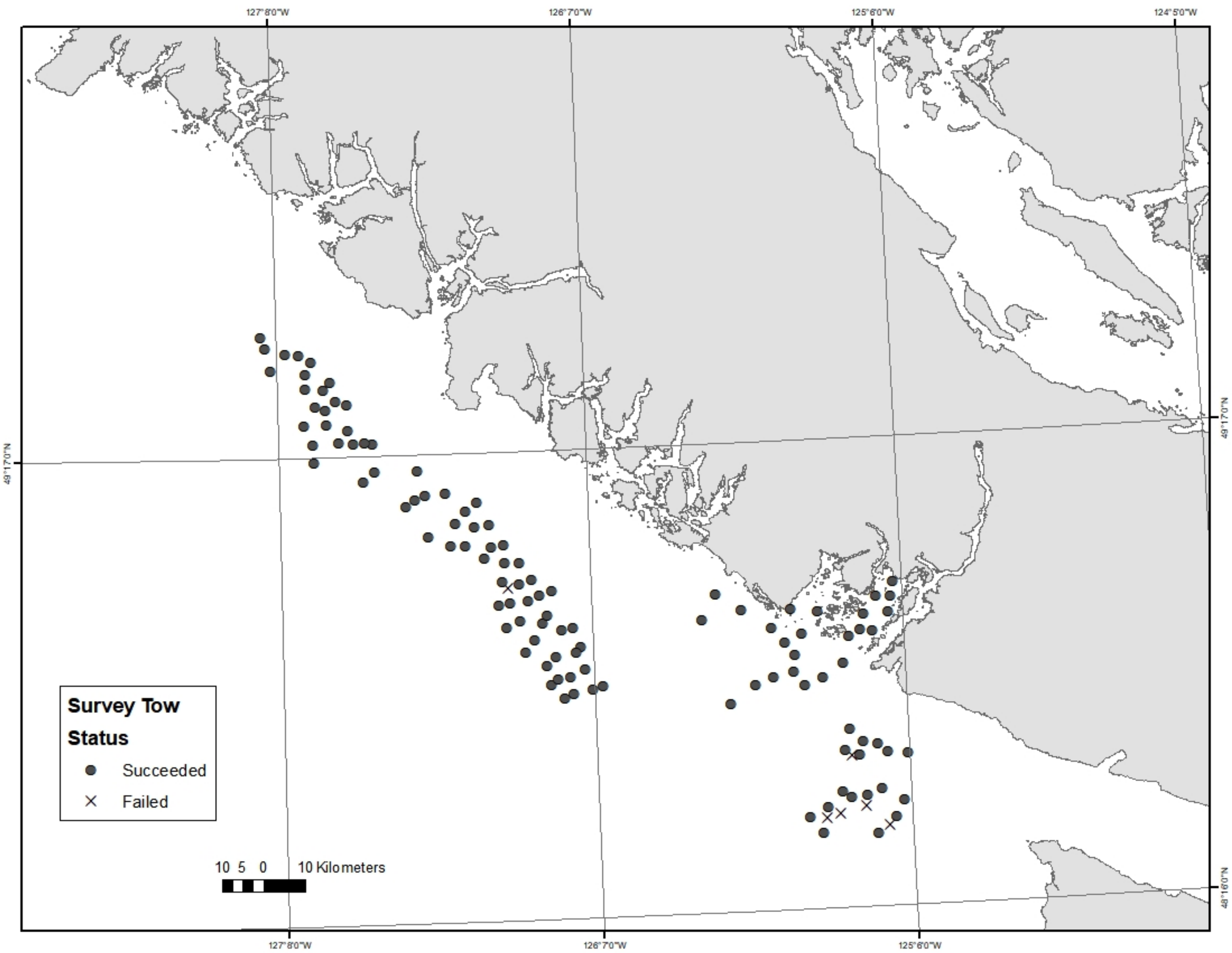


Figure 22. Tow locations of the 2019 Multi-species Small-mesh Bottom Trawl Survey.

Table 25. Number of tows, catch weight from successful tows, estimated biomass, and relative survey error for the top 25 species (by weight) captured in the West Coast Vancouver Island tow locations of the 2019 Multi-species Small-mesh Bottom Trawl Survey.

Species	Scientific Name	Number of Tows	Catch (kg)	Biomass (t)	Relative Error
North Pacific Spiny Dogfish	Squalus suckleyi	51	7163	5485	0.65
Rex Sole	Glyptocephalus zachirus	71	5542	5162	0.06
Dover Sole	Microstomus pacificus	71	3985	3639	0.08
Slender Sole	Lyopsetta exilis	70	3105	2913	0.08
Pacific Sanddab	Citharichthys sordidus	58	1953	1672	0.14
Flathead Sole	Hippoglossoides elassodon	68	1738	1704	0.12
Sablefish	Anoplopoma fimbria	54	1580	1308	0.67
Arrowtooth Flounder	Atheresthes stomias	67	757	696	0.15
Spotted Ratfish	Hydrolagus colliei	69	677	588	0.12
Longnose Skate	Raja rhina	68	544	494	0.11
Eulachon	Thaleichthys pacificus	57	454	396	0.17
Lingcod	Ophiodon elongatus	44	373	367	0.46
Petrale Sole	Eopsetta jordani	49	339	308	0.2
English Sole	Parophrys vetulus	58	247	213	0.14
Yellowtail Rockfish	Sebastes flavidus	44	246	236	0.19
Walleye Pollock	Gadus chalcogrammus	54	230	195	0.26
Greenstriped Rockfish	Sebastes elongatus	51	217	195	0.4
Pacific Cod	Gadus macrocephalus	40	193	192	0.23
Blackbelly Eelpout	Lycodes pacificus	60	136	121	0.17
Pacific Hake	Merluccius productus	37	110	102	0.2
Pacific Halibut	Hippoglossus stenolepis	21	99	88	0.24
Sandpaper Skate	Bathyraja interrupta	52	76	68	0.13
Big Skate	Beringraja binoculata	13	70	61	0.3
Darkblotched Rockfish	Sebastes crameri	47	70	67	0.19
Redstripe Rockfish	Sebastes proriger	13	47	47	0.65

Table 26. Number of fish sampled for biological data during the 2019 Multi-species Small-mesh Bottom Trawl Survey showing the number of lengths and age structures that were collected by species.

Species	Scientific Name	Lengths Collected	Age Structures Collected	DNA Tissue Collected
American Shad	*Alosa sapidissima*	159	0	0
Arrowtooth Flounder	*Atheresthes stomias*	19	0	0
Big Skate	*Beringraja binoculata*	128	0	0
Bocaccio	*Sebastes paucispinis*	60	58	0
Dover Sole	*Microstomus pacificus*	755	0	0
English Sole	*Parophrys vetulus*	53	0	0
Eulachon	*Thaleichthys pacificus*	3897	0	400
Lingcod	*Ophiodon elongatus*	141	94	0
Longnose Skate	*Raja rhina*	732	0	0
Pacific Cod	*Gadus macrocephalus*	16	0	0
Pacific Halibut	*Hippoglossus stenolepis*	31	0	0
Petrale Sole	*Eopsetta jordani*	271	0	0
Pink Shrimp (smooth)	*Pandalus jordani*	0	0	0
Rex Sole	*Glyptocephalus zachirus*	883	0	0
Rougheye/Blackspotted Rockfish Complex	*Sebastes aleutianus/melanostictus* complex	7	6	7
Sablefish	*Anoplopoma fimbria*	334	0	0
Sandpaper Skate	*Bathyraja interrupta*	160	0	0
Sidestripe Shrimp	*Pandalopsis dispar*	0	0	0
Walleye Pollock	*Gadus chalcogrammus*	494	0	0
Whitebait Smelt	*Allosmerus elongatus*	50	0	0
Yelloweye Rockfish	*Sebastes ruberrimus*	2	2	2

International Pacific Halibut Commission Fishery-independent Setline Survey

The International Pacific Halibut Commission's (IPHC) Fishery-independent Setline Survey (FISS) is a fixed-station longline hook survey that extends from southern Oregon to the Bering Sea. This survey serves to index Pacific Halibut (*Hippoglossus stenolepis*) abundance and provide accompanying biological samples to assess the Pacific Halibut stock. The British Columbia (regulatory area 2B) portion of this survey has been conducted annually in various configurations from 1963 to the present (www.iphc.washington.edu).

Since 2003, the IPHC has provided the opportunity to deploy an additional technician during the survey to identify the catch to species level on a hook-by-hook basis and to collect biological samples from rockfish. This information has been collected every year since 2003 except for a one-year hiatus in 2013. This program is designed to fully enumerate the non-halibut catch in the survey and collect biological samples from inshore rockfish species.

At the time of writing, the 2019 IPHC survey data are not yet finalized and so have not been included in this report.

Appendix 2: British Columbia commercial groundfish TACs, landings, and research allocations for 2019.

Table 1. British Columbia Groundfish Total Allowable Catch (TAC) and commercial landings in metric tonnes (t) for 2019. Except where noted, TACs are from the 2019 Groundfish Integrated Fisheries Management Plan (https://waves-vagues.dfo-mpo.gc.ca/Library/40804343.pdf). Landings are from the dockside monitoring program (DMP).

Species or Species Group	**Trawl Sector (t)**		**Combined Line Sectors (t)**		**Total (t)**	
	TAC	**Landings**	**TAC**	**Landings**	**TAC**	**Landings**
Sharks And Skates						
North Pacific Spiny Dogfish	4,480	182	9,520	0	14,000	182
Big Skate	914	189	118	15	1,032	204
Longnose Skate	195	47	263	63	458	110
Pacific Cod	1,450	488	0	4	1,450	492
Walleye Pollock	4,935	6,249	0	0	4,935	6,249
Pacific Hake [1]	7,000 gulf & 156,067 offshore	99,685	0	0	163,067	99,685
Rockfishes						
Rougheye/Blackspotted Rockfish Complex	636	362	484	302	1,120	664
Pacific Ocean Perch	5,192	3,521	1	1	5,193	3,521
Redbanded Rockfish	295	160	284	176	579	336
Shortraker Rockfish	126	15	111	103	237	118
Silvergray Rockfish	1,945	1,619	254	36	2,199	1,655
Widow Rockfish	2,316	1,737	42	0	2,358	1,737
Yellowtail Rockfish	5,440	3,755	60	6	5,500	3,761
Quillback Rockfish	4	0	169	114	173	114
Bocaccio	80	52	0	3	80	55
Canary Rockfish	965	633	135	13	1,100	646
Redstripe Rockfish	2,572	713	1,168	0	3,740	713
Yellowmouth Rockfish	1,521	1,461	43	5	1,564	1,466
Yelloweye Rockfish	2,364	1	78	88	2,442	89
Copper, China, And Tiger Rockfish	1	0	63	47	64	47

Table 1. Continued.

Species or Species Group	Trawl Sector (t)		Combined Line Sectors (t)		Total (t)	
	TAC	Landings	TAC	Landings	TAC	Landings
Thornyheads						
Shortspine Thornyhead	1	161	54	102	55	263
Longspine Thornyhead	735	22	34	0	769	22
Sablefish	405	113	20	2,371	425	2,483
Lingcod	210	178	2,195	786	2,405	963
Flatfishes						
Arrowtooth Flounder	14,000	6,809	0	0	14,000	6,809
Petrale Sole	900	446	0	0	900	446
Southern Rock Sole	1,552	154	0	1	1,552	155
Dover Sole	3,073	1,194	0	0	3,073	1,194
English Sole	822	537	0	0	822	537
Pacific Halibut [2]	0	4	2,287	2,369	2,287	2,373

[1] *Hake offshore TAC is from Fishery Notice FN0573-In-season Allocation of 2019 Offshore Pacific Hake Quota (https://notices.dfo-mpo.gc.ca/fns-sap/index-eng.cfm?pg=view_notice&DOC_ID=222486&ID=all)*

[2] *Halibut weights are dressed, head-off, where dressed, head-off weight = round weight * 0.75.*

Table 2. British Columbia Groundfish research allocations in metric tonnes (t) for 2019. Except where noted, research allocations are deducted from the fish available to the commercial fishery by sector prior to the definition of commercial TACs. Values are copied from the 2019 Groundfish Integrated Fisheries Management Plan (https://waves-vagues.dfo-mpo.gc.ca/Library/40804343.pdf).

Species or Species Group	**Trawl surveys (t)**	**Longline surveys (t)**	**Sablefish surveys (t)**	**Total (t)**
Sharks And Skates				
North Pacific Spiny Dogfish	3.4	--	--	3.4
Big Skate	1.1	0.5	--	1.6
Longnose Skate	0.9	1.2	--	2.1
Pacific Cod	3.4	2.2	--	5.6
Walleye Pollock	4.9	--	--	4.9
Pacific Hake	2.6	--	--	2.6
Rockfishes				
Rougheye/Blackspotted Rockfish Complex	1.3	0.3	--	1.6
Pacific Ocean Perch	21.8	0	--	21.8
Redbanded Rockfish	1.9	2.8	--	1.6
Shortraker Rockfish	0.7	0.2	--	0.9
Silvergray Rockfish	14.6	1.7	--	16.3
Widow Rockfish	0.2	0	--	0.2
Yellowtail Rockfish	3.4	0.1	--	3.5
Quillback Rockfish	0.4	3.1	--	3.9
Bocaccio	0.2	0.1	--	0.3
Canary Rockfish	2	1.2	--	3.2
Redstripe Rockfish	3.9	--	--	3.9
Yellowmouth Rockfish	4.7	--	--	4.7
Yelloweye Rockfish	0.2	15.8	--	16
Copper, China, And Tiger Rockfish	0.2	0.4	--	0.6
Thornyheads				
Shortspine Thornyhead	2.1	--	--	2.1
Longspine Thornyhead	--	--	--	--

Table 2. Continued.

Species or Species Group	Trawl surveys (t)	Longline surveys (t)	Sablefish surveys (t)	Total (t)
Sablefish	5.7	0.6	60	66.3
Lingcod	0.7	3.5	--	4.2
Flatfishes				
Arrowtooth Flounder	34.5	--	--	34.5
Petrale Sole	0.9	--	--	0.9
Southern Rock Sole	2.7	--	--	2.7
Dover Sole	8.4	--	--	8.4
English Sole	9.2	--	--	9.2
Pacific Halibut [1]	4.3	27.2	--	31.5

[1] The halibut poundage for the groundfish trawl survey is part of the trawl fishery's halibut bycatch mortality cap. The groundfish trawl fishery has a bycatch mortality cap of 454 tonnes that is not part of the allocated commercial TAC.

TSC Agency Reports – IPHC 2020

Contents

I. Agency Overview

Management of the Pacific halibut resource and fishery has been the responsibility of the International Pacific Halibut Commission (IPHC) since its creation in 1923, see Figure 1 for a map of the Convention Area. Assessing, forecasting, and managing the resource and fishery requires accurate assessments, continuous monitoring, and research responsive to the needs of managers and stakeholders. The fishery for Pacific halibut (*Hippoglossus stenolepis*) is one of the most valuable and geographically largest in the northeast Pacific Ocean. Industry participants from Canada and the United States of America have prosecuted the modern fishery and have depended upon the resource since the 1880s. Annual removals have been as high as 100 million pounds, and the long-term average of removals is 64 million pounds.

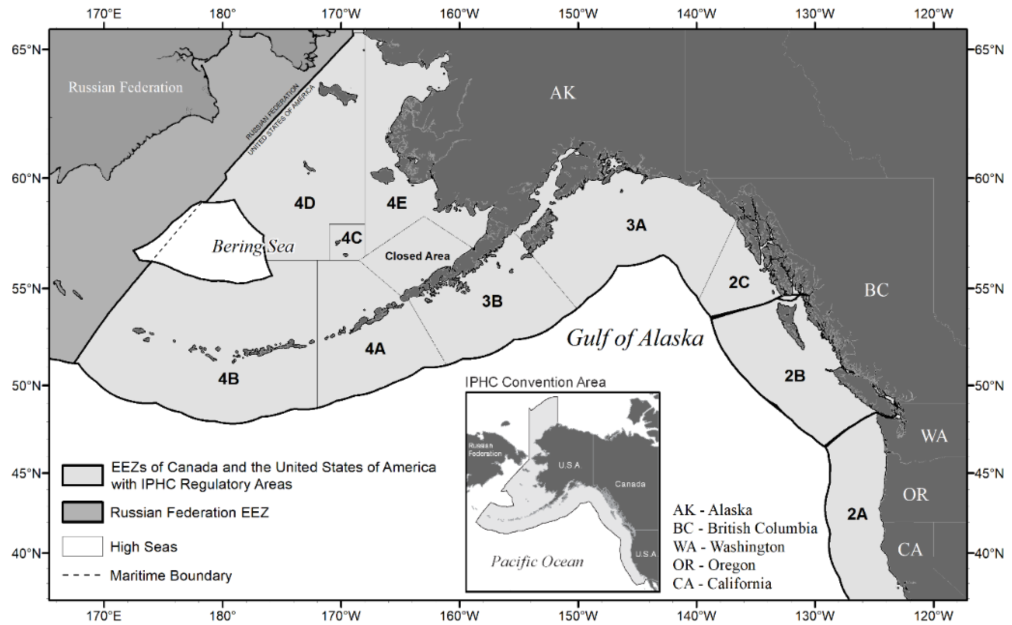


Figure 1. Map of the IPHC Convention Area and IPHC Regulatory Areas.

Staffing Updates: see https://www.iphc.int/locations/map

II. Fishery-Independent Setline Survey (FISS)

Background

The International Pacific Halibut Commission's (IPHC's) fishery-independent setline survey (FISS) provides catch information and biological data on Pacific halibut (*Hippoglossus stenolepis)* that are collected independently of the commercial fishery. These data, which are collected using standardized methods, bait, and gear during the summer of each calendar year, provide an important comparison with data collected from the commercial fishery. The commercial fishery is variable in its gear composition and distribution of fishing effort over time, and presents a broad spatial and temporal sampling of the stock. Pacific halibut biological data collected on the FISS (e.g. the size, age, and sex composition) are used to monitor changes in biomass, growth, and mortality in adult and sub-adult components of the Pacific halibut population. In addition, records of non-target species caught during FISS operations provide insight into bait competition, rate of bait attacks, and serve as an index of abundance over time, making them valuable to the assessment, management, and avoidance of non-target species.

For details on FISS work conducted in 2019, please refer to the following paper: IPHC Fishery-Independent Setline Survey (FISS) design and implementation in 2019

III. Reserves – N/A

IV. Review of Agency Groundfish Research, Assessment, and Management

A. Pacific halibut and IPHC activities

1. Research

The primary biological research activities at the IPHC that follow Commission objectives and selected for their important management implications are identified and described in the Five-Year Research Plan for the period 2017-21:

Overview of research activities in 2019 and planned for 2020

1. Migration. Knowledge of Pacific halibut migration throughout all life stages is necessary in order to gain a complete understanding of stock distribution and the factors that influence it.

1.1. Larval distribution and connectivity between the Gulf of Alaska and Bering Sea. The IPHC Secretariat, in collaboration with AFSC NOAA EcoFoci Group, has recently completed a study investigating the level of early-life stage connectivity of Pacific halibut between the Gulf of Alaska and the Bering Sea. Two year classes, 2005 and 2009, were chosen as the primary focus of this project based on the fact that these represented relatively large and weak year classes, and "warm" and "cold" environmental regimes in the Bering Sea, respectively. Additional "warm" and "cold" years were added to the larval advection modeling component to study the environmental linkage. Larval advection modeling produced information about dispersal pathways and degree of connectivity between spawning and settlement grounds both within and between the Bering Sea and Gulf of Alaska. Results suggest that up to half of the larvae spawned in the western Gulf of Alaska have the potential to be advected into the Bering Sea through Unimak Pass, AK. While Bering Sea environmental regime did not appear to strongly correlate to region of larval delivery in the Bering Sea, there was annual variation. Application of the IPHC-developed space-time model was used to assess distribution of young fish from 2-6 years old as they move away from the settlement grounds. Dispersal is widespread with young Pacific halibut moving further offshore and to deeper depths as they age. A portion of the young fish, especially evident when modeling the 2009 cohort due to higher densities, appeared to move out of Bristol Bay southward along the Alaska Peninsula, arriving at Unimak Pass within 2-3 years. Results from this project provide a new understanding of linkages between spawning grounds, eventual settlement, and subsequent migration of young fish, as well as variability in these pathways under different environmental scenarios.

1.2. Wire tagging of U32 Pacific halibut. Wire tagging of Pacific halibut caught in the NOAA/NMFS trawl surveys, which began in 2015, was continued in 2019. In 2019, 963 and 811 Pacific halibut were tagged in the Bering Sea and Gulf of Alaska, respectively. The wire tagging effort of U32 Pacific halibut that has taken place during the IPHC's FISS in recent years was not implemented in 2019 due to workload commitments on the surveys. However, through 2019, 10,770 U32 Pacific halibut had been wire tagged and 110 of those have been recovered to date.

1.3. Electronic archival tagging. In 2019, as part of a collaborative research project with the Norton Sound Economic Development Corporation (NSEDC) and the University of Alaska Fairbanks, Pacific halibut were tagged in the eastern Bering Sea shelf with pop-up archival satellite (PAT) tags. Pacific halibut (U32 and O32) were tagged in the Norton Sound and St. Lawrence Island regions (n = 56). The PAT tags were programmed to release from their host fish and report their location and archived data during three periods: January 2020 (representing the spawning season); summer of 2020 (investigating site fidelity versus emigration); and summer of 2021 (examining longer-term dispersal). Tags provided by the IPHC were used to tag relative small fish (i.e., 70-90 cm) and were accompanied by tagging of large (>100 cm) Pacific halibut using tags that were purchased by NSEDC. This is designed to produce data that are comparable to the IPHC's prior PAT-tagging research that was conducted to examine adult connectivity and spawning stock structure throughout the managed range, while expanding the work to examine considerably broader stock demographics than any prior electronic archival tagging experiment.

2. Reproduction. Efforts at IPHC are currently underway to address two critical issues in stock assessment for estimating the female spawning biomass: the sex ratio of the commercial landings and maturity estimations.

2.1. Sex ratio of the commercial landings. For the first time, the IPHC has generated sex information of the entire set of aged commercial landings in 2017 and 2018. Genetic assays developed in collaboration with the University of Washington have been conducted at the IPHC biological laboratory using a QuantStudio6 instrument. Fin clips from over 10,000 aged Pacific halibut collected coastwide by IPHC port samplers in 2017 were genotyped and the results indicated that commercial landings were 82% female coastwide. A similar number of tissues from commercial landings collected in 2018 have been genotyped and the results indicate that landings were 81% female coastwide, consistent with the results from the previous year. Plans are underway to genotype the entire set of aged commercial samples collected in 2019 and, therefore, the sex ratio data from commercial landings will be available for three consecutive years (2017, 2018 and 2019). The sex ratio data of the commercial landings are currently being used in stock assessment.

2.2. Maturity estimations. In order to characterize the gonadal maturation schedule, the IPHC is conducting a full characterization of the annual reproductive cycle in female and male Pacific halibut. Biological samples (gonads, blood, pituitary, otolith, fat content) were collected at monthly intervals from female (N=30) and male (N=30) Pacific halibut captured from the Portlock region in the central Gulf of Alaska throughout an entire calendar year, from September 2017 until August 2018. Formalin-fixed gonadal samples were processed for histology in early 2019 and duplicate histological slides for each sampled Pacific halibut gonad (N = 360 per sex) were stained with Hematoxylin and Eosin and are now available for staging. We have completed the analysis of the temporal progression of the four maturity classification stages (macroscopic) used for staging females in the IPHC FISS and of the gonadosomatic index (gonad weight/round weight x 100; GSI) as well as the hepatosomatic index (liver weight/round weight x 100; HSI) for both females and males. In addition, we have described the four maturity classification stages in relation to the GSH and the HSI and established criteria for the classification of the different oocyte developmental stages that is critical for accurate staging. In addition to characterizing the progression of reproductive development throughout an entire annual reproductive cycle (intraseasonal) reproductive samples, the IPHC collected samples in June 2019 in the Portlock region to compare with those collected in the same location in June 2018 and June 2017 in order to evaluate possible differences in interseasonal variation in maturity schedules. Ovarian samples from these three years have been processed for histology and are in the process of being analyzed. In order to determine whether there are spatial differences in maturity schedules, ovarian samples will be collected during the 2020 FISS season from a number of collection areas corresponding to the four biological regions.

3. Growth. In order to improve our understanding of the possible role of growth alterations in the observed historical changes in size-at-age in Pacific halibut, the IPHC Secretariat is conducting studies aimed at: 1) the identification and validation of physiological markers for growth; and 2) the use of growth markers for evaluating growth patterns in the Pacific halibut population and the effects of environmental influences. The IPHC Secretariat is conducting investigations on the effects of temperature variation on growth performance, as well as on the effects of density, hierarchical dominance and handling stress on growth in juvenile Pacific halibut in captivity. These studies are partially funded by a grant from the North Pacific Research Board #1704 to the IPHC and the results on the effects of temperature on growth physiological indicators are being prepared for publication in a peer-reviewed journal.

4. Discard Mortality Rates (DMRs) and Survival Assessment. In order to better estimate post-release survival of Pacific halibut caught incidentally in the directed longline fishery, the IPHC Secretariat is conducting investigations to understand the relationship between fish handling practices and fish physical and physiological condition and survival post-capture as assessed by tagging. These studies are partially funded by a grant from the Saltonstall-Kennedy Grant Program NOAA to IPHC (NA17NMF4270240) and conducted as depicted in the workflow shown below:

4.1. Evaluation of the effects of **hook release techniques** on injury levels and association with the physiological condition of longline-caught Pacific halibut. The IPHC has evaluated the effects of different release techniques on injury levels (Figure 5) and the results indicate that a majority (more than 70%) of Pacific halibut released by careful shake and by gangion cutting are classified in the excellent injury category. In contrast, Pacific halibut that encounter the hook stripper are primarily classified in the medium and poor injury categories. The physiological condition of Pacific halibut subjected to the different hook release techniques is currently being assessed by relating the injury category assigned to each fish with the condition factor, fat levels and levels of blood stress indicators.

4.2. Post-release survival estimations of longline-caught Pacific halibut. In order to evaluate the survival of discarded fish, two types of tagging approaches were used. 1) Classical mark-and-recapture of released fish with wire tags: 1,027 fish (under 33 inches in length) were tagged. 2) Biotelemetric monitoring of released fish with the use of satellite-transmitting electronic archival tags equipped with accelerometers: results from a total of 79 Pacific halibut ranging from 53-81 cm FL allowed us to estimate that the DMR of U32 Pacific halibut that were categorized as being in excellent-condition at the time of their release was approximately 4%.

4.3. Application of electronic monitoring (EM) for capturing the hook release methods in the longline fishery. Evaluation of EM data whereby reviewers recorded the release method and condition of released fish evidenced a high degree (95%-100%) of agreement between the actual release method used and that captured by EM. Therefore, once the survival estimates of fish released by the different hook release techniques are determined, these results strongly suggest that mortality rates could be deduced from EM-captured hook release techniques.

4.4. Discard mortality rates of Pacific halibut in the charter recreational fishery. The IPHC has initiated in 2019 a research project aimed at experimentally deriving DMRs from the charter recreational fishery for the first time. This project has received funding from the National Fish and Wildlife Foundation (Project # 61484). As an initial step in this project, information from the charter fleet on types of gear and fish handling practices used was collected through stakeholder meetings and on dock interviews with charter captains and operators. This information will inform the design of the experimental test fishing that will take place in 2020 and in which fish mortality will be estimated as described in 4.2.

5. Genetics and genomics. The IPHC Secretariat is exploring avenues for incorporating genetic approaches for a better understanding of population structure and distribution and is also building genomic resources to assist in genetics and molecular studies on Pacific halibut.

5.1. Genetics. The main purpose of the proposed studies is to incorporate genetic analyses into migration-related research in order to improve our understanding of Pacific halibut movement and dispersal and of the genetic structure of the Pacific halibut population. Three specific topics will be investigated:

5.1.1. *Analysis of genetic variability among juvenile Pacific halibut in the Bering Sea and the Gulf of Alaska*. The aim of this study is to evaluate the genetic variability among juvenile Pacific halibut in a given ocean basin in order to infer information on the potential contribution from fish spawned in different areas to that particular ocean basin. We hypothesize that genetic variability among juvenile Pacific halibut captured in one particular ocean basin (e.g. eastern Bering Sea) may be indicative of mixing of individuals originating in different spawning grounds and, therefore, of movement. By comparing the genetic variability of fish between two ocean basins (i.e. eastern Bering Sea and Gulf of Alaska), we will be able to evaluate the extent of the potential contribution from different sources (e.g. spawning groups) in each of the ocean basins and provide indications of relative movement of fish to these two different ocean basins. The use of genetic samples from juvenile Pacific halibut collected in the NMFS trawl survey in the eastern Bering Sea and in the Gulf of Alaska, aged directly or indirectly through the length-age key, will allow us to provide genetic information from fish that are at or near their settlement or nursery grounds.

5.1.2. *Analysis of genetic population structure in IPHC Regulatory Area 4B***.** Understanding population structure is imperative for sound management and conservation of natural resources. Pacific halibut in US and Canadian waters are managed as a single, panmictic population on the basis of tagging studies and historical (i.e., pre-2010) analyses of genetic population structure that failed to demonstrate significant differentiation in the eastern Pacific. However, more recent studies have reported significant genetic population on the basis of microsatellites that suggest that Pacific halibut residing in the Aleutian Islands may be genetically distinct from other regions. In particular, differentiation of the population on either side of Amchitka Pass was suggested, with the caveat that genetic analyses were conducted using tissue samples collected in the summer (i.e. non-spawning season) west of Amchitka Pass and it is questionable whether they were truly representative of the local spawning population. The IPHC will begin re-evaluating the suggested structure of the Western Aleutian stock with spawning samples that were successfully collected in early 2020 from spawning fish on either side of Amchitka Pass by an IPHC-funded research charter.

5.1.3. *Identification of potential genetic signatures of origin or spawning groups to revise population structure*. In order to expand our proposed studies evaluating the Pacific halibut population genetic structure to the entire northeast Pacific Ocean covering the IPHC Convention Area, a broader genetic study is proposed that aims at establishing genetic baselines from known spawning groups throughout the geographic area in question. With the genetic samples that were successfully collected in the winter of 2020, together with winter samples collected in the Portlock area (i.e. central Gulf of Alaska) in 2018 and in Haida Gwaii in 2004 and in the Bering Sea (i.e. Pribilof Canyon) in 2004, we plan on establishing genetic signatures of these spawning groups to revise the genetic population structure by whole genome resequencing.

5.2. Genomics. The IPHC Secretariat has recently completed generating a first draft sequence of the Pacific halibut genome in collaboration with the French National Institute of Agricultural Research (INRA, Rennes, France) and the School of Aquatic and Fishery Science of the University of Washington (Seattle, WA). This effort produced a high-quality chromosome-level assembly that revealed a genome of approximately 600 Mb in size and comprised into 24 chromosome pairs. In addition to genome sequencing, the IPHC Secretariat has completed transcriptome sequencing of a wide variety of tissues (N=13) in Pacific halibut including white and red skeletal muscle, liver, heart, ovary, testis, head kidney, brain, gill, pituitary, spleen and retina. Current plans regarding this extensive transcriptomic dataset include generating a reference transcriptome for the species and to create a user-friendly, searchable database to be made public in the IPHC website.

Other ongoing data collection projects

In addition to specific research projects, the IPHC collects data each year through ongoing data collection projects that are funded separately, either as part of the FISS or as part of the commercial fishery data collection program. Ongoing data collections projects include the following:

IPHC FISS

The IPHC FISS provides catch-rate information and biological data on Pacific halibut that are independent of the commercial fishery. These data, which are collected using standardized methods, bait, and gear during the summer of each year, provide an important comparison with data collected from the commercial fishery, and serve as the primary index of abundance, through the use of a spatio-temporal model (https://www.iphc.int/uploads/pdf/am/2020am/iphc-2020-am096-07.pdf) for the annual stock assessment.

Biological data collected on the FISS (e.g., the size, age, and sex composition of Pacific halibut) are used to monitor changes in biomass, growth, and mortality in adult and sub-adult components of the Pacific halibut population. In addition, records of non-target species caught during FISS operations provide insight into bait competition, rate of bait attacks, and serve as an index of abundance over time, making them valuable to the assessment, management, and avoidance of non-target species.

The Commission has conducted the FISS in selected areas during most years since 1963. The majority of the current FISS station design and sampling protocols have been consistent since 1998.

Environmental data collection aboard the IPHC FISS using water column profilers

PIs: Lauri Sadorus, Jay Walker

The IPHC collects oceanographic data using water column profilers during the IPHC FISS. The profilers collect a suite of oceanographic data, including pressure (depth), conductivity (salinity), temperature, dissolved oxygen, pH, and fluorescence (chlorophyll concentration). The IPHC has operated profilers since 2000 on a limited basis, and coastwide since 2009.

IPHC aboard National Marine Fisheries Service groundfish trawl surveys in the Gulf of Alaska, Bering Sea, and Aleutian Islands

PI: Lauri Sadorus

The National Oceanic and Atmospheric Administration (NOAA) Fisheries has conducted annual bottom trawl surveys on the eastern Bering Sea continental shelf since 1979 and the IPHC has participated in the survey on an annual basis since 1998 by directly sampling Pacific halibut from survey catches. The IPHC has participated in the NOAA Fisheries Aleutian Islands trawl survey, which takes place every two years, since 2012. Alternating year by year with the Aleutian Islands trawl survey is the NOAA Fisheries Gulf of Alaska trawl survey, which IPHC has participated in since 1996. The IPHC uses the NOAA Fisheries trawl surveys to collect information on Pacific halibut that are not yet vulnerable to the gear used for the IPHC FISS or commercial fishery, and as an additional data source and verification tool for stock analysis. In addition, trawl survey information is useful as a forecasting tool for cohorts approaching recruitment into the commercial fishery.

Commercial fishery sampling program

The IPHC positions field staff to sample the commercial landings for Pacific halibut in Alaska, British Columbia, Washington, and Oregon. Sampling of commercial landings involves collecting Pacific halibut otoliths, tissue samples, fork lengths, weights, logbook information, and final landing weights.

The collected data are used in the stock assessment and other research and the collected otoliths provide age composition data and the tissue samples provide sex composition. Lengths and weight data, in combination with age data and sex data, provide size-at-age analyses by sex. Mean weights are combined with final landing weights to estimate catch in numbers. Logbook information provides weight per unit effort data, fishing location for the landed weight, and data for research projects. Finally, tags are collected to provide information on migration, exploitation rates, and natural mortality.

In addition to sampling the catch, other objectives include collecting recovered tags, and copying information from fishing logs along with the respective landed weights, for as many Pacific halibut trips as possible throughout the entire season.

2. Assessment

The 2019 stock assessment represented a full analysis, after several years of updates, including both internal Scientific Review Board and external peer review (https://www.iphc.int/management/science-and-research/stock-assessment). The assessment produced the following scientific advice regarding the Pacific halibut stock:

1. Fishing intensity: The 2019 mortality corresponded to a point estimate of SPR = 42%; there is a 59% chance that fishing intensity exceeded the IPHC's reference level of 46%. The Commission does not currently have a coastwide fishing intensity limit reference point, making it difficult to determine if current levels of fishing intensity are consistent with the interim harvest strategy policy objectives. However, given the TAC set for 2020 is projected to produce an SPR of 42%, consistent with the range identified by the IPHC's Management Strategy Evaluation process as meeting coastwide conservation and fishery objectives, on the weight-of-evidence, the stock is classified as **not subject to overfishing**.
2. Spawning biomass: Female spawning biomass at the beginning of 2020 was estimated to be 194 million pounds (87,856 t), which corresponds to an 46% chance of being below the IPHC trigger reference point of $SB_{30\%}$, and less than a 1% chance of being below the IPHC limit reference point of $SB_{20\%}$. The stock is estimated to have been declining since 2016 and is currently at 32% of the unfished state. Therefore, the stock is considered to be '**not overfished**'.
3. Outlook: The stock is projected to decrease with at least a 51% chance over the period from 2021-23 for all mortality levels greater than 18.4 million pounds (~8,350 t), corresponding to a projected SPR of 63% due to reduced low recruitment estimated for 2006-2010. At the reference level of fishing intensity (a projected SPR of 46%) the probability of spawning biomass decline to 2021 is 89%, decreasing to 75% in three years, as the 2011 and 2012 cohorts mature.

For more information on the 2019 stock assessment and the fishery status, as well as the harvest decision table indicating levels of risk associated with various levels of removals, please refer to papers IPHC-2020-AM096-08 and IPHC-2020-AM096-09 at the IPHC website.

3. Management

The International Pacific Halibut Commission (IPHC) completed its 96th Annual Meeting (AM095) in Anchorage, Alaska, United States of America, on 7 February 2020, with Mr. Chris Oliver of the United States of America presiding as Chairperson. More than 200 Pacific halibut industry stakeholders attended the meeting, with over 140 more participating via the web. All of the Commission's public and administrative sessions during the meeting were open to the public and broadcast on the web. Documents and presentations from the Annual Meeting are available on the Annual Meeting page on the IPHC website: https://www.iphc.int/venues/details/96th-session-of-the-iphc-annual-meeting-am096. Decisions arising from this meeting, including management decisions, are documented in the following report: Report of the 96th Session of the IPHC Annual Meeting (AM096)

Other Actions

Harvest Strategy Policy: https://www.iphc.int/the-commission/harvest-strategy-policy

The Commission provided direction to the IPHC Secretariat and the Management Strategy Advisory Board (MSAB) for further work on harvest strategy policy development, noting that scale and distribution components will be evaluated and presented no later than at the 97th Annual Meeting (AM097) in 2021, for potential adoption and subsequent implementation as a harvest strategy.

V. Ecosystem Studies

[See the description of "Environmental data collection aboard the IPHC FISS using water column profilers" in the Research section on ongoing IPHC data collection projects above.]

VI. Publications

International Pacific Halibut Commission. 2019. Annual Report 2019. https://www.iphc.int/uploads/pdf/ar/iphc-2019-annual-report.pdf

Northwest Fisheries Science Center

National Marine Fisheries Service

NOAA Fisheries

Agency Report to the Technical Subcommittee

of the Canada-U.S. Groundfish Committee

April 2020

I. Agency Overview

The Northwest Fisheries Science Center (NWFSC) provides scientific and technical support to the National Marine Fisheries Service (NMFS) for management and conservation of the Northwest region's marine and anadromous resources. The Center conducts research in cooperation with other federal and state agencies and academic institutions. Four divisions, Conservation Biology, Environmental and Fisheries Sciences, Fish Ecology, and Fishery Resource Analysis and Monitoring, conduct applied research to resolve problems that threaten marine resources or that deter their use. The Center's main facility and laboratories are located in Seattle. Other Center research facilities are located in Pasco, Big Beef Creek, Mukilteo, and Manchester, Washington; Newport, Hammond, and Clatskanie, Oregon; and Charleston, North Carolina.

The Fishery Resource Analysis and Monitoring Division (FRAMD) is the source for most of the research reported by the NWFSC to the Technical Subcommittee of the Canada-US Groundfish Committee. The FRAMD works in partnership with state and federal resource agencies, universities, and the groundfish industry to achieve a coordinated groundfish program for the West Coast.

FRAMD consists of a multi-disciplinary team with expertise in fishery biology, stock assessment, economics, mathematical modeling, statistics, computer science, and field sampling techniques. Members of this program are stationed at the NWFSC facilities in Seattle and in Newport, Oregon, with some Observer Program staff located in California. Together, they work to develop and provide scientific information necessary for managing West Coast marine fisheries and strive to provide useful and reliable stock assessment data with which fishery managers can set ecologically safe and economically valuable harvest levels. FRAM researchers develop models for managing multi-species fisheries; design programs to provide information on the extent and characteristics of bycatch in commercial fisheries as they look at methods to reduce fisheries bycatch; characterize essential habitats for key groundfish species; and employ advanced technologies for new assessments.

During 2019, FRAMD continued to: implement a West Coast observer program; conduct a coast wide survey program that includes West Coast groundfish acoustic, hook and line, and trawl surveys; develop new technologies for surveying fish populations; and expand its stock assessment, economics, and habitat research. Significant progress continues in all programs.

For more information on FRAMD and groundfish investigations, contact the Division Director, Craig Russell at Craig.Russell@noaa.gov, (206) 860 – 3402.

Other Divisions at the NWFSC are:

The Conservation Biology Division is responsible for characterizing the major components of biodiversity in living marine resources, using the latest genetic and quantitative methods. It also has responsibility for identifying factors that pose risks to these components and the mechanisms that limit natural productivity. The Division's multi-disciplinary approach draws on expertise in the fields of population genetics, population dynamics, and ecology.

The Environmental and Fisheries Sciences Division conducts research to assess and reduce natural and human-caused impacts on environmental and human health, and to improve methods for fisheries restoration and production in conservation hatcheries and in aquaculture. Environmental health and conservation research examines environmental conditions and the impacts of chemical contaminants, marine biotoxins, and pathogens on fishery resources, protected species, habitat quality, seafood safety, and human health. Fisheries restoration and aquaculture includes research on the challenges associated with captive rearing, nutrition, reproduction, behavior, disease control, engineering, hatchery technology and larval/juvenile quality for protected, depleted and commercially valuable species.

The Fish Ecology Division's role is to understand the complex ecological linkages among important marine and anadromous fishery resources in the Pacific Northwest and their habitats. The Division particularly places emphasis on investigating the myriad biotic and abiotic factors that control growth, distribution, and survival of important species and on the processes driving population fluctuations.

For more information on Northwest Fisheries Science Center programs, contact the Center Director, Dr. Kevin Werner at Kevin.Werner@noaa.gov, (206) 860 – 6795.

II. Surveys

A. U.S. West Coast Groundfish Bottom Trawl Survey

The NWFSC conducted its twenty-second annual bottom trawl resource survey for groundfish off the coasts of Washington, Oregon, and California. The objective of the 2019 survey was to provide information on the distribution and relative abundance of demersal species within this region at depths from 30 to 700 fathoms. Other biological information necessary to assess the status of groundfish stocks (e.g. length, weight, sex and age structures) was collected throughout the survey period.

The NWFSC chartered two commercial fishing vessels to conduct a reduced survey in 2019 using standardized trawl gear. Fishing vessels Last Straw and Excalibur were contracted to survey the area from Cape Flattery, WA to the Mexican border in Southern California (Figure 1), beginning in the later part of May and continuing through October. Each charter was for a period of 11-12 weeks with the Last Straw surveying the coast during the initial survey period from May to July. The Excalibur surveyed the coast during a second pass from mid-August to late October. The survey area was partitioned into ~12,000 adjacent cells of equal area (1.5 nm long. by 2.0 nm lat., Albers Equal Area projection) with each vessel assigned a primary subset of 188 randomly selected cells to sample. An Aberdeen-style net with a small mesh (1 1/2" stretch) liner in the codend was used for sampling. The survey followed a stratified random sampling scheme with 15-minute tows within 2 geographic strata (80% N of Pt. Conception, CA and 20% S) and 3 depth strata. The depth strata were shallow (30-100 fms), middle (100-300 fms), and deep (300-700 fms). The sample design consisted of 752 sampling locations, with a minimum of 30 tows per strata.

In 2019, we continued to utilize an updated back-deck data collection system with improved software applications, and wireless networking. Programming used to gather data for the groundfish survey was rewritten so that the various components were fully integrated, updated to include multiple sensor streams, and enhanced to increase flexibility for data input from special projects and future undefined data sources. The changes in the back-deck programming, wheelhouse programming and data QA/QC process resulted in overall improvements to data collection efficiency and anticipated future decreases in time requirements for data to be made available to the Data Warehouse. Established NOAA national bottom trawl protocols were used throughout the survey. As in prior years, a series of special research projects were undertaken in cooperation with other NOAA groups and various Universities.

Additional data were collected during the trawl survey for collaborative research projects with several NMFS/academic colleagues:

1) Collection of voucher specimens for multiple fish species – Northwest Fisheries Science Center and University of Washington;

2) Collection of DNA and/or whole specimens of rougheye rockfish (*Sebastes aleutianus*), blackspotted rockfish (*Sebastes melanostictus*), darkblotched rockfish (*Sebastes crameri*) and

blackgill rockfish (*Sebastes melanostomus*) to reduce uncertainty in the assessment of morphologically-similar west coast rockfish – Northwest Fisheries Science Center;

3) Collect fin clips and other tissues from all Pacific sharks (*Somniosus pacificus*) to examine genetics – NOAA, NWFSC – Cindy Tribuzio;

4) Request for photographs of lamprey scars – Laurie Weitkamp, NWFSC, Conservation Division, Newport;

5) Identify to species all Pacific Lamprey (*Lampetra tridentata*) then collect and freeze each specimen individually – Laurie Weitkamp, NWFSC, Conservation Division, Newport;

6) Identify to species all river Lamprey (*Lampetra ayresii*) then collect and freeze each specimen individually – Laurie Weitkamp, NWFSC, Conservation Division, Newport;

7) Collection of all biological data and specimens of deepsea skate (*Bathyraja abyssicola*) and broad skate (*Amblyraja badia*) - Moss Landing Marine Laboratories;

8) Collect and freeze all specimens of Pacific black dogfish (*Centroscyllium nigrum*), velvet dog shark (*Zameus squamulosus*) and cookiecutter shark (*Isistius brasiliensis*). – Moss Landing Marine Laboratories;

9) Collection of all unusual or unidentifiable skates, Pacific white skate *(Bathyraja spinossisima)*, fine-spined skate (*Bathyraja microtrachys),* and Aleutian skate (*Bathyraja aleutica)* – Moss Landing Marine Laboratories;

10) Collection of all unidentified or rare skates, ray, shark or chimaera– Moss Landing Marine Laboratories;

11) Collection of North Pacific black ghost shark (*Hydrolagus* melanophasma and pointy-nosed blue chimaera (*Hydrolagus trolli*) – Moss Landing Marine Laboratories;

12) Collection of voucher specimens for multiple fish species – Oregon State University;

13) Coral population genetics - Collect whole specimens of *Desmophyllum dianthus* - in 95% ETOH – Cheryl Morrison;

14) Specimen collection for multiple fish species for teaching purposes for the West Coast Observer Program;

15) Collect sex, total length and photograph dorsal side (including close up of dorsal side of snout) for all big skate (*Beringraja binoculata*), California skate (*Raja inornata*) and starry skate (*Raja stellulata*) captured at depths greater than 300 m – Joe Bizzarro;

16) Retain whole specimens of big skate (*Beringraja binoculata*), California skate (*Raja inornata*) and starry skate (*Raja stellulata*) captured at depths greater than 500 m – Joe Bizzarro;

17) Photograph bamboo coral (with ruler for scale) and collect the base if possible – Carina Fish, UC Davis.

Several other research initiatives were undertaken by the Survey Team including:

1) Use of tissue samples stable isotope analysis to examine the feeding ecology of rockfish (darkblotched, canary, blackgill, blackspotted/rougheye, yelloweye, yellowtail rockfishes and cowcod) and other species (sablefish, lingcod, longspine thornyheads, and shortspine thornyheads);

2) Collection of stomachs for various rockfish (darkblotched, canary, blackgill, blackspotted/rougheye, yelloweye, yellowtail rockfishes and cowcod) and other species (sablefish, lingcod, longspine thornyheads, and shortspine thornyheads);

3) Fin clip collection for DNA analysis of various shelf rockfish species;

4) Collect and/or photograph cold water corals;

5) Collect near-bottom dissolved oxygen data to examine relation with fish distribution;

6) Record composition and abundance of benthic marine debris collected during the 2019 West Coast Groundfish Trawl Survey;

8) Collect ovaries and finclips from bank, brown, copper, blackspotted/rougheye, vermilion/sunset rockfishes;

9) Collect whole ovary and finclips from Pacific cod and yelloweye rockfish;

9) Collect ovaries from longspine thornyheads, Dover sole and Pacific hake (and gonads for males) to assess maturity;

10) Collection of prey items for multiple species for stable isotope analysis;

11) Photograph, tag, bag and freeze deep water species such as arbiter snailfish (*Careproctus kamikawi*) and other rare or unidentified deep water species;

12) Macroscopic analysis of maturity of big skate and longnose skate;

13) Collect a photographic quality specimen of arbiter snailfish (*Careproctus kamikawai*);

14) Collect all specimens of sharpnose sculpin (*Clinocottus acuticeps*) for species confirmation.

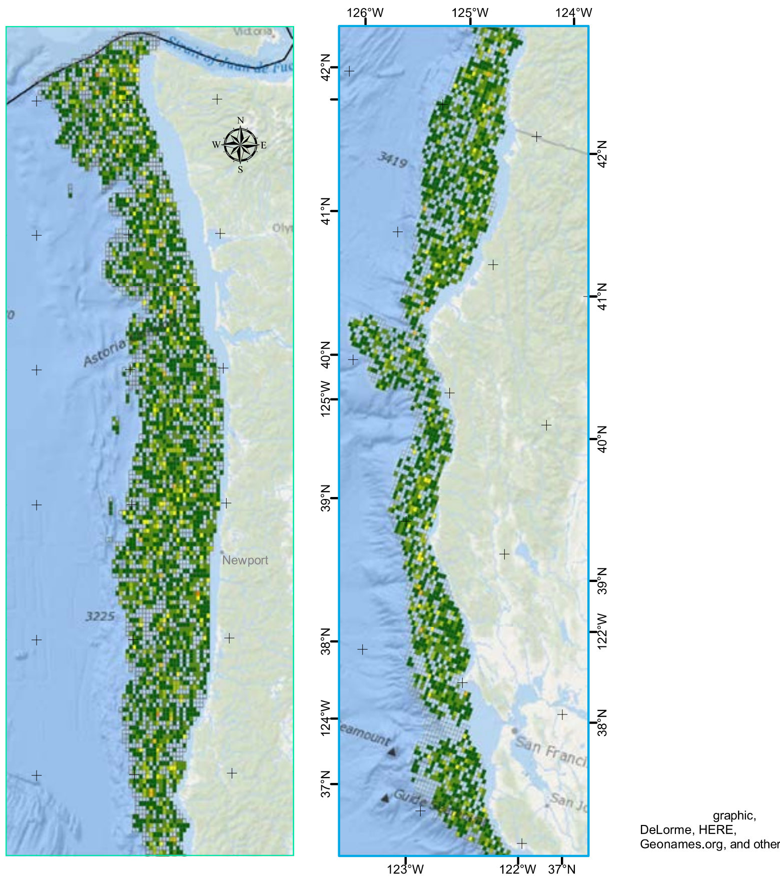


Figure 1. Summary of station locations and frequency for the West Coast Groundfish Bottom Trawl Survey 2003 to 2018.

For more information please contact Aimee Keller at Aimee.Keller@noaa.gov

B. Southern California shelf rockfish hook-and-line survey

In early Fall 2019, FRAM personnel conducted the 17th hook and line survey for shelf rockfish in the Southern California Bight (SCB). This project is a cooperative effort with Pacific States Marine Fisheries Commission (PSMFC) and the southern California sportfishing industry aimed at developing an annual index of relative abundance and time series of other biological information for structure-associated species of groundfish including bocaccio (*Sebastes paucispinis*), bank rockfish (*S. rufus*), copper rockfish (*S. caurinus*), greenspotted rockfish (*S. chlorostictus*), cowcod (*S. levis*) blue rockfish (*S. mystinus*), speckled rockfish (*S. ovalis*), the vermilion rockfish complex (e.g., *S. miniatus* and *S. crocotulus*) and lingcod (*Ophiodon elongatus*) within the SCB.

The F/V Aggressor (Newport Beach, CA), F/V Mirage (Port Hueneme, CA), and F/V Toronado (Long Beach, CA) were each chartered for 14 days of at-sea research, with 13 biologists participating during the course of the survey. The three vessels sampled a total of 201 sites, as well as experimental sampling at 7 sites, ranging from Point Arguello in the north to the U.S.-Mexico EEZ boundary in the south (Figure 2). The survey sampled a depth range of 20 – 125 ft (37 – 229 m). Data from the survey have informed the stock assessments for several rockfish species and have helped monitor the rebuilding of overfished species such as bocaccio (*S. paucispinis*) and cowcod (*S. levis*). The survey also collects information to support ecosystem-level analyses by capturing visual observations of the seafloor habitat via a towed video sled and by deploying a suite of oceanographic sensors as a component of sampling operations.

Including supplementary experimental sampling at 7 sites, the survey encountered 7,054 individual fish representing 40 species. Overall, catches were reduced from 2018 levels by about 15%. Data collected included 6,994 sexed lengths and weights, 4,304 otolith pairs, 5,702 finclips. Approximately 265 ovaries were collected from 8 different species to support the development of maturity curves and fecundity analysis. Several dozen individual fish were retained for use in species identification training for west coast groundfish observers and for a genetic voucher program conducted by the University of Washington. The survey made 4 deployments of an underwater video sled to capture visual observations for habitat analysis, species composition, and fish behavioral studies. The survey continued to descend or release and tag all individuals captured at 6 sites located inside federal marine reserves. To date, approximately 911 individuals have been tagged. 2019 marked the third year since implementation of the HookLogger wireless electronic data collection system on board survey vessels. This system networks two mobile tablet workstations on the back deck with a desktop computer inside the galley with each machine writing to a common database using customized UI and networking software. HookLogger has eliminated the need for post-survey manual data entry and has improved data quality by integrating real-time validations and other error checking. The innovation and efficiency of this software and network system was recognized by NOAA by awarding its developers with the agency’s Bronze award.

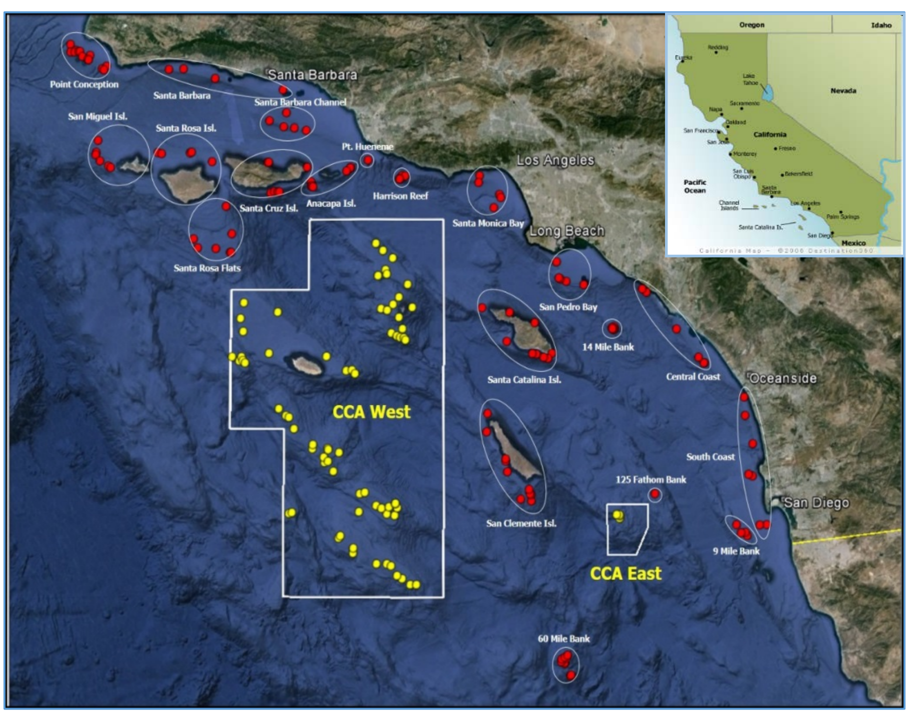


Figure 2. Sampling locations for the 2019 Hook and Line Survey located inside (yellow dots) and outside (red dots) the Cowcod Conservation Areas (CCAs).

For more information, please contact John Harms at John.Harms@noaa.gov

C) 2019 Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey

The Joint U.S./Canada Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey was conducted in U.S. and Canadian waters by a U.S. team (NWFSC/FRAM) on the NOAA Ship Bell M. Shimada from 13 June 2019 to 20 August 2019, and by a Canadian team (DFO/Pacific region) on the Canadian chartered F/V Nordic Pearl from 17 August 2019 to 15 September 2019. Data collected during the survey were processed to provide an estimate of the abundance and spatial distribution of the coastal Pacific hake (*Merluccius productus*) stock shared by both countries. The survey covered the slope and shelf of the U.S. and Canada West Coast with acoustic transects from roughly 34.4°N (south of Point Conception, California) to 54.8°N (Southeast Alaska and Dixon Entrance) (Figure 3). Transects were oriented east-west (except for transects in Dixon Entrance that were oriented north-south) and were spaced 10 nautical miles (nmi) apart through the north end of Vancouver Island, after which spacing increased to 20 nmi. Acoustic data were collected on the Shimada with a Simrad EK60 scientific echosounder system operating at frequencies of 18, 38, 70, 120, and 200 kHz. On the Nordic Pearl, acoustic data were collected with a Simrad EK60 echosounder operating at frequencies of 38 and 120 kHz. The Shimada collected acoustic data from 78 transects and the Nordic Pearl from 35, resulting in a total survey-wide linear distance of 4,504 nmi of acoustical transects that were used for the Hake biomass estimate. Aggregations of adult (age 2+) Hake were detected on 83 transects, ranging from north of Morro Bay, California (roughly 35.7°N) to north of Vancouver Island (roughly 51.1°N). In U.S. waters, Hake concentrations between roughly 36°N and 39°N were comparatively light. North of 39°N, aggregations of observed Hake sign became more consistent and extensive; areas of strong Hake sign were observed between Crescent City, California and Newport, Oregon. North of Newport, Hake sign diminished but still remained fairly consistent; relatively high amounts were observed south of Astoria, Oregon and along the northern half of Washington State. In Canadian waters, although only modest aggregations of Hake were observed along much of Vancouver Island and no Hake were observed further north, higher concentrations of Hake were observed near the northwest tip of the island and west of Barkley Sound. Midwater trawls equipped with a camera system were conducted to verify species composition of observed backscatter layers and to obtain biological information (e.g., size and sex distribution, age composition, sexual maturity). A total of 93 successful midwater trawls (71 by the Shimada—including four open-codend trawls at the end of the survey to test a new stereo camera system—and 22 by the Northern Pearl) resulted in a combined total hake catch of 32,618 kg (14,813 kg from the Shimada and 17,805 kg from the Northern Pearl). Hake accounted for 88% of the catch in U.S. waters. The estimated total biomass of adult hake in 2019 was 1.723 million metric tons, with approximately 89% (1.531 Mt) of observed biomass located in U.S. waters. The 2019 estimate was roughly 20% larger than the average biomass estimate for all surveys conducted since 1995 (1.723 vs. 1.431 Mt), and represented an increase of 0.3 Mt over the 2017 biomass estimate. Age-3 and age-5 Hake contributed most to the 2019 biomass estimate—combining for almost 57%—followed by age-9 hake.

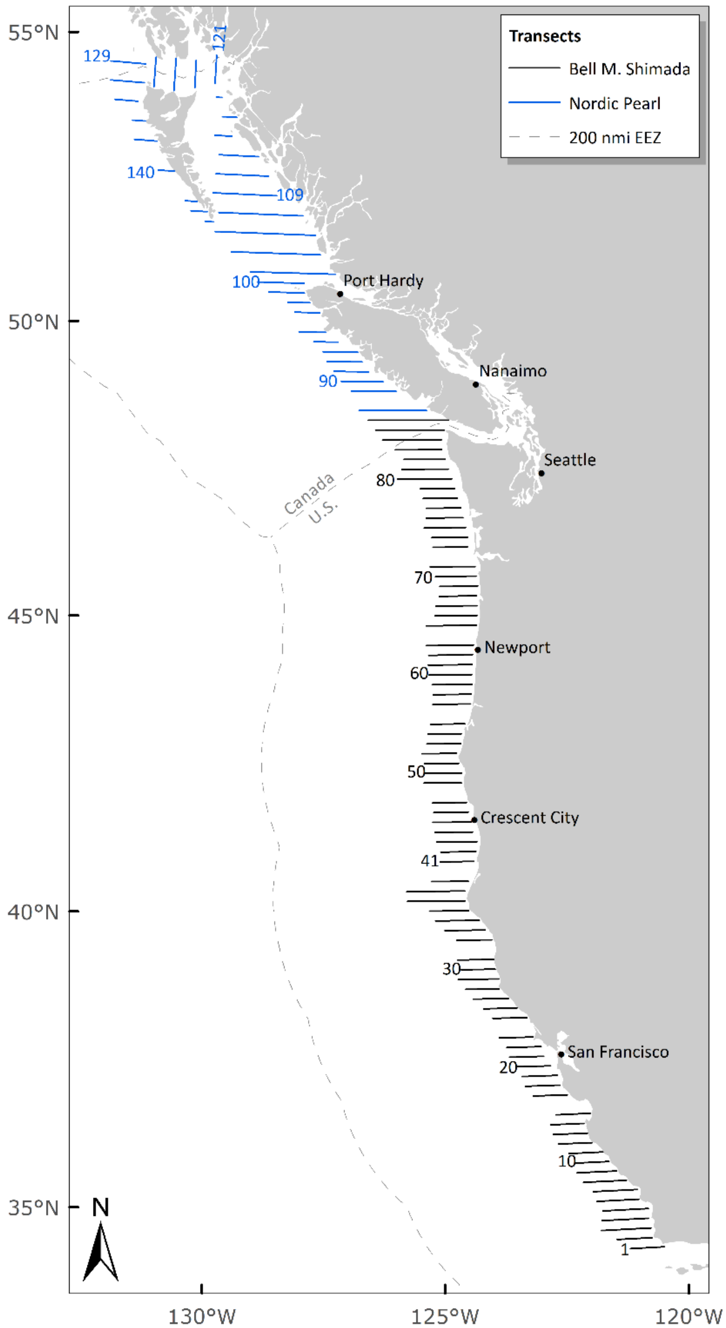


Figure 3. Planned acoustic survey transects in 2019 from roughly 34.4°N (south of Point Conception, California) to 54.8°N (Southeast Alaska and Dixon Entrance).

For more information, please contact Sandy Parker-Stetter at sandy.parker-stetter@noaa.gov.

D. Untrawlable Survey North: comparing different tools for surveying groundfish in rocky habitats

Investigators: Peter Frey, Victor Simon, John Harms, Aimee Keller, Aaron Chappell, Laurel Lam, Keith Bosley, Linda Park, Abi Wells, Matt Blume (ODFW), Leif Rassmuson (ODFW)

Quantitative sampling of groundfish in untrawlable habitats has long been an unrealized goal for managers and fishery stakeholders on the U.S. West Coast. Stock assessors have repeatedly cited this data gap as a source of uncertainty in models, particularly for key fishery-limiting species such as yelloweye rockfish. In November 2019, we tested three visual observation systems as well as environmental DNA (eDNA) collections to compare different methods for sampling groundfish in hard-bottom, rocky habitats of the continental shelf. Our visual tools included two stationary stereo camera systems and a towable camera device developed by research partners at the Alaska Fisheries Science Center and the Oregon Department of Fish and Wildlife. Near-bottom water samples for eDNA analysis of species occurrence were collected using niskin bottles attached to the stationary camera systems and triggered at depth. This project took place over 5 days aboard a chartered commercial fishing vessel at several hard-bottom banks off the central Oregon Coast. During that time, we performed 108 drops of each stationary camera system, collected 84 water samples for eDNA analysis, and made 9 tows using the 'TowCam'. While our analysis from this research is ongoing, we have already learned many valuable lessons about the quality of data produced by each system, the feasibility of expanding spatial coverage, and considerations for untrawlable habitat survey design. This research focused on sampling methods and some preliminary results to compare the data from each system. Ultimately, this research is intended to be a first step towards developing an efficient, standardized time series of groundfish in untrawlable habitats to complement existing data sources and improve fishery management.

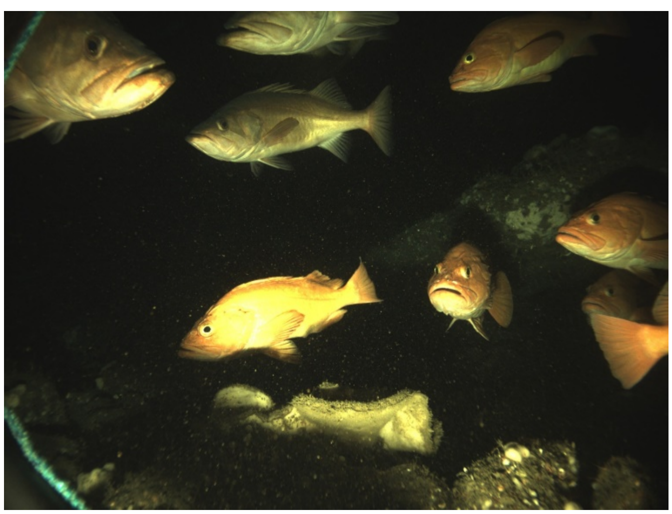


Figure 4. Yelloweye rockfish as seen using the stationary drop camera during the 2019 untrawlable habitat pilot study.

For more information, please contact Aimee Keller at Aimee.Keller@noaa.gov

III. Reserves

a) Changes in long-lived rockfishes after more than a decade of protection within California's largest marine reserve

Investigators: Aimee A. Keller, John H. Harms, John R. Wallace, Colin Jones, Jim A. Benante, and Aaron Chappell

In 2001, the Pacific Fishery Management Council established two large (10,878 km^2 and 260 km^2) Southern California Bight marine reserves called Cowcod Conservation Areas (CCAs) in response to declining abundance of west coast rockfishes, particularly overfished cowcod. Following closure, no fishery independent monitoring took place for groundfishes within the CCAs through 2013. To assess the impact of the closures, we sampled multiple sites inside versus outside CCAs from 2014 to 2016 via the Northwest Fisheries Science Center's Hook and Line Survey. We investigated variations in catch per unit effort (CPUE), size, length frequency and percent of sites with positive catch for 14 abundant groundfishes (bank, bocaccio, chilipepper, copper, cowcod, greenspotted, lingcod, olive, rosy, speckled, squarespot, starry, swordspine and the vermilion-sunset complex). General Linear Models (GLMs) that included area, year, depth and distance from port revealed significantly greater ($p < 0.05$) CPUE inside CCAs for 11 species. CPUE for lingcod, copper rockfishes and vermilion-sunset was significantly ($p < 0.05$) or near-significantly ($p < 0.1$) lower inside the CCAs. We saw significant ($p < 0.05$) or near-significant differences ($p < 0.10$) in size (12 species) and length frequency distributions (10 species) with larger fish present inside CCAs. The percentage of sites positive for individual species tended to be greater inside CCAs (11 species). We also observed significantly elevated species richness (species per site) and total CPUE inside CCAs. Results indicate larger individuals and greater CPUE for multiple rockfishes inside CCAs either as a result of effective management or perhaps pre-existing conditions.

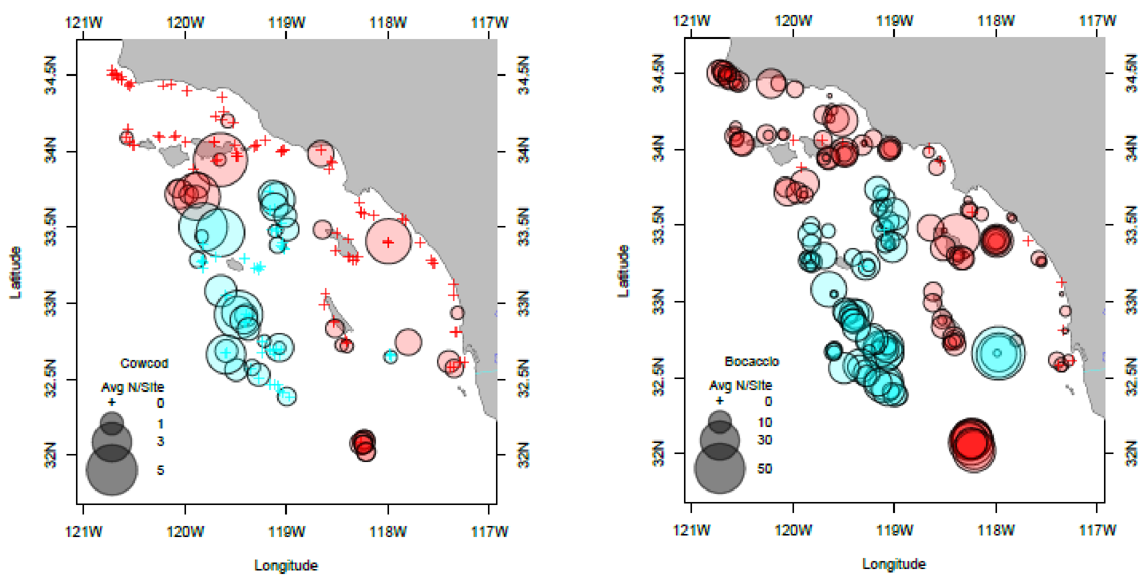


Figure 5. Charts showing distributions and relative abundance (site-specific CPUE averaged across years) inside (blue circles) versus outside (red circles) the CCAs for cowcod and bocaccio Note that the range of CPUE varies as shown in the inset for each chart and + represents zero catch.

For more information, please contact Aimee Keller at Aimee.Keller@noaa.gov

b) Integrated Ecosystem Assessment support of condition reports for west coast National Marine Sanctuaries

Investigators: G. Williams, J. Brown, C. Caldow, K. Andrews, N. Tolimieri, C. Harvey, and numerous contributors from the NWFSC, SWFSC, Office of National Marine Sanctuaries, and partner institutions

The California Current Integrated Ecosystem Assessment (IEA) team has provided extensive support to the Office of National Marine Sanctuaries (ONMS) toward the development of condition reports for sanctuaries located along the west coast. Sanctuary condition reports are tools employed by NOAA to assess the condition and trends of national marine sanctuary resources. Condition reports provide a standardized summary of resources in NOAA’s sanctuaries; drivers and pressures on those resources; current conditions and trends for resources and ecosystem services; and describe existing management responses to the pressures that threaten the integrity of the marine environment. Condition reports include information on the status and trends of water quality, habitat, living resources and maritime archaeological resources, and the human activities that affect them. They present responses to a set of questions posed to all sanctuaries. The reports also rate ecosystem service status and trends. Resource and ecosystem service status are rated on a six-point scale from good to poor, and the timelines used for comparison vary from topic to topic. Trends in the status of resources and ecosystem services are also reported, and are generally based on observed changes in status since the prior condition report, unless otherwise specified.

The primary roles of the IEA team in this collaboration have been: guidance in developing an IEA framework for assessment and management of sanctuaries; the screening of ecosystem indicators and the identification of relevant time series of data; and development of conceptual models of key sanctuary habitats and communities. The first west coast sanctuary condition report to be published that features products from this collaboration is the Channel Islands National Marine Sanctuary condition report in 2019 (citation below); groundfish are broadly represented in indicators and conceptual models under many of the focal questions considered within the Channel Islands condition report.

For more information please contact Mr. Greg Williams at NOAA’s Northwest Fisheries Science Center / Pacific States Marine Fisheries Commission, Greg.Williams@noaa.gov.

IV. Review of Agency Groundfish Research, Assessments, and Management

A. Hagfish

B. Dogfish and other sharks

C. Skates

1. No reported research

2. Assessments

a) Longnose skate stock assessment

Investigators: Vladlena Gertseva, Sean Matson, Ian Taylor, Joseph Bizzarro, John Wallace

Longnose skate (*Beringraja rhina*) is broadly distributed from the southeastern Bering Sea to southern Baja California and the Gulf of California. This assessment reports the status of the longnose skate resource off the coast of the United States from southern California to the U.S. - Canadian border. The species is modeled as a single stock, as there is currently no biological and genetic data supporting the presence of multiple stocks within the assessment region.

Longnose skate is a common bycatch skate species in the groundfish demersal trawl fishery on the west coast of the United States. Historically, skates caught on the U.S. west coast have not been marketed as high-priced fishery products. Available information suggests that prior to the mid-1990s, processors primarily accepted only the skinned pectoral fins (often called "wings"), and most boats simply discarded skates as they did not want to go into the effort of winging the skates on board as low ex-vessel prices would not justify the effort. In the mid-1990s however, demand for whole skates increased in California and Oregon, and processors began accepting whole skates for landing; boats started to retain skates if they had space to hold them, which caused a substantial increase in retention rates and landed catch. After a few years, the whole skate market cooled and currently, west coast skates are marketed both whole and as wings, with skate wings sold fresh or fresh-frozen, as well as dried or salted and dehydrated.

This assessment, conducted in 2019, estimates that the stock of longnose skate off the continental U.S. Pacific Coast is currently at 57 percent of its unexploited level. This is above the overfished threshold of SB25% and the management target of SB40% of unfished spawning biomass. The assessment described the dynamics of the longnose skate stock to be slowly declining from the unfished conditions, with a flat trend from the early 2000s

The time series of total mortality catch (landings plus discards) and estimated depletion for longnose skate are presented in Figure 6.

The assessment model captures uncertainty in estimated size and status of the stock through asymptotic confidence intervals estimated within the model. To further explore uncertainty associated with alternative model configurations and evaluate the responsiveness of model outputs to changes in key model assumptions, a variety of sensitivity runs were performed. A major source of uncertainty in the assessment is related to catchability of the west coast Groundfish Bottom Trawl (WCGBT) Survey, which was found to have a large influence on the perception of current stock size. WCGBT Survey catchability in the assessment is estimated using the prior that accounts for multiple factors affecting survey catchability. These factors include latitudinal, depth and vertical availably of longnose skate to the survey as well as probability of catch in survey net path. Uncertainty from WCGBT Survey catchability is reported via alternate states of nature in the decision table, bracketing the base model results.

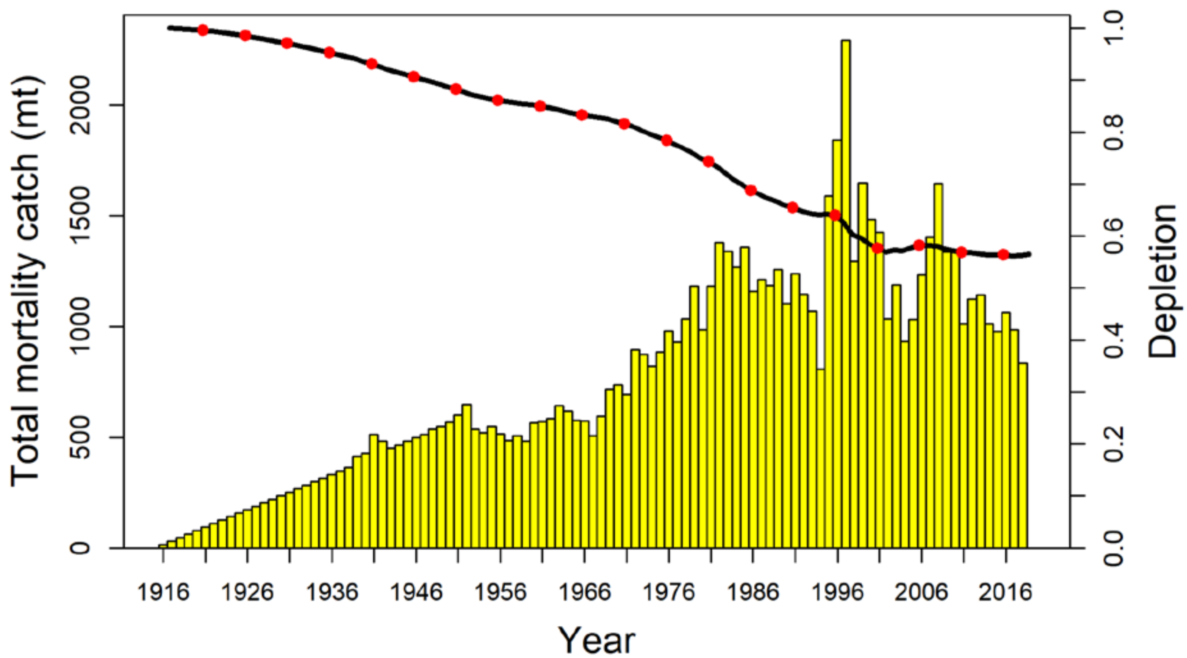


Figure 6. The time series of total mortality catch (bars) and estimated depletion (line) for longnose skate.

For more information on the longnose skate assessment, contact Dr. Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

b) Status of Big Skate (*Beringraja binoculata*) Off the U.S. Pacific Coast in 2019

Investigators: I. Taylor, V. Gertseva, A. Stephens, and J. Bizzarro

Big Skate (*Beringraja binoculata*) is the largest of the skate species in North America with a documented maximum length of 244 cm total length and a maximum weight of 91 kg. The Big Skate is most common in soft-sediment habitats in coastal waters of the continental shelf. The Big Skate is broadly distributed, occurring from the southeastern Bering Sea to southern Baja California and the Gulf of California.

The current assessment is the first for this species on the U.S. west coast. Although the skates are known to be capable of long-distance movements, for purposes of this assessment, the stock is assumed to be a single, unit stock whose dynamics are independent of Big Skate populations off Canada and in the Gulf of Alaska. Big Skate are primarily caught in commercial bottom trawl fisheries. There is a limited market for pectoral fins (skate wings). The majority of Big Skate catch was discarded prior to 1995 when markets for Big Skate and Longnose Skate developed, landings increased, and discarding decreased. Reconstructed history of catch and discards showed total mortality in the range 400-600mt between 1950 and 1995 with reduced mortality in more recent years. The stock assessment was conducted with Stock Synthesis. The assessment is fit to two bottom trawl survey indices of abundance, the Triennial Survey from which an index covering the period 1980-2004 was used here and the West Coast Groundfish Bottom Trawl Survey, which began in 2003 and for which data is available through 2018. Both indices show increasing trends that are not fit well by the model, suggesting that the stock dynamics have been impacted by factors other than fishing. Length and age composition data from the fishery and surveys are fit reasonably well by the stock assessment and provide information on growth. Sex-specific differences in selectivity were included in the model in order to better match patterns in the sex ratios in the length composition data and a new "growth cessation model" was used to model growth as it provided much better fits than the von Bertalanffy growth function. Recruitment is deterministic with steepness of the stock-recruit curve fixed at 0.4. The final model has 44 estimated parameters, most of which are related to selectivity (including sex-specific differences), time-varying retention, and growth (including sex-specific differences).

The scale of the population is not reliably informed by the data due to the combination of surveys that show trends, which cannot be matched by the structure of the model, and length and age data that inform growth and selectivity but provide relatively little information about changes in stock structure over time. Therefore, a prior distribution on the catchability of the WCGBT Survey (centered at 0.701) was applied in order to provide more stable results. The prior distribution is based on a combination of expert judgement and an estimate using fishery catch rates of the fraction of Big Skate biomass unavailable to the WCGBT Survey due to occurring shallower than the 55 m limit of the survey design. Although the assessment model requires numerous simplifying assumptions, it represents an improvement over the simplistic status-quo method of setting management limits, which relies on average survey biomass and an assumption about the fishing mortality associated with maximum sustainable yield. The use of an age-structured model with estimated growth, selectivity, and natural mortality likely provides a better estimate of past dynamics and the impacts of fishing in the future than the status-quo approach.

The 2019 estimated spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass at 79.2% (95% asymptotic interval: 65.5%-92.9%) All sensitivity analyses explored also show the stock to be at a relatively high level.

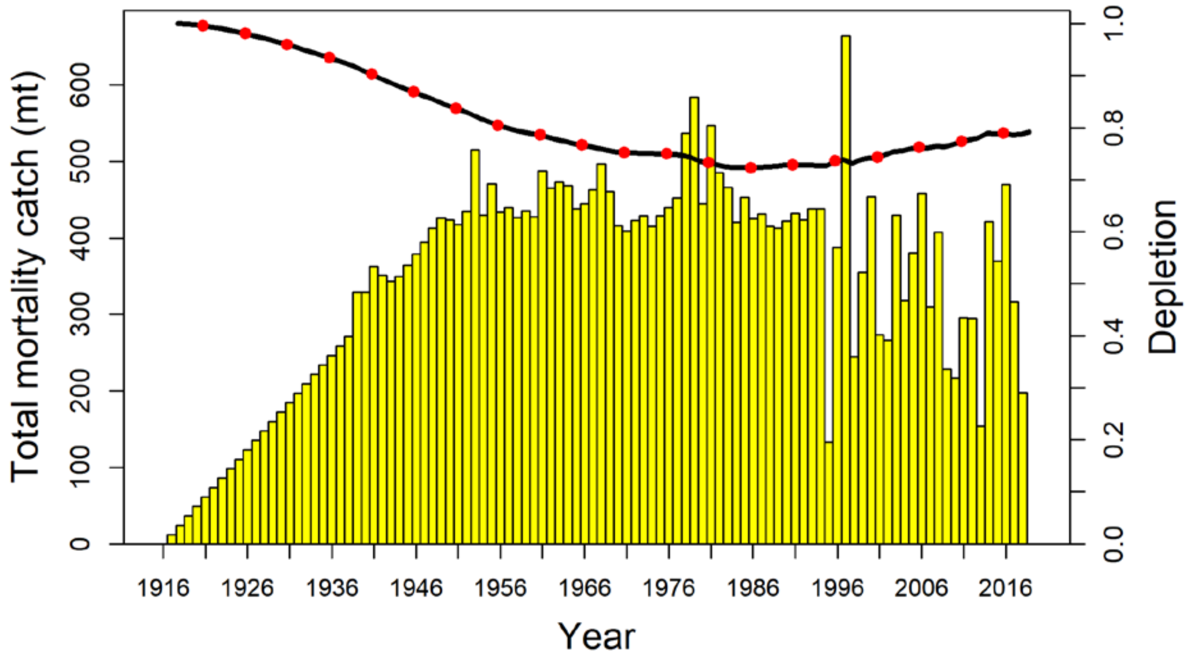


Figure 7. Total mortality catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Big Skate, 1916-2018.

For more information, please contact Ian Taylor at Ian.Taylor@noaa.gov.

D. Pacific cod

E. Walleye Pollock

F. Pacific whiting (hake)

1. Research

a) Pacific Hake Management Strategy Evaluation

Investigator: Kristin Marshall

The Pacific Hake Management Strategy Evaluation (MSE) entered a new iteration in mid-2017. The MSE is a binational effort between the U.S. (NOAA Fisheries) and Canada (DFO) in support of the Pacific Hake/Whiting Treaty. The goals of this iteration of MSE were to: 1) Evaluate the performance of current hake management procedure under alternative hypotheses about current and future environmental conditions, 2) Better understand the effects of hake distribution and movement on both countries' ability to catch fish, and 3) Better understand how fishing in each country affects the availability of fish to the other country in future years.

We developed a spatially explicit (two area) operating model, with age-based movement of fish between areas. Other aspects of the operating model closely resemble the current stock assessment model for Pacific hake. We conditioned this model to the coastwide stock assessment and available country-specific data, including survey biomass, survey age compositions, and fishery age compositions. We worked with the International Hake Treaty management bodies to develop and refine goals, objectives and performance metrics used to evaluate performance. These metrics describe performance in terms of stock status, coastwide catch, catch variability, and spatially explicit exploitation rates.

To address the three goals for the MSE we developed four sets of scenarios to begin to explore how key uncertainties might influence future performance of the current management procedure for hake. These scenarios are: 1) Alternative implementation scenarios that influence how much catch is removed from the stock each year, 2) Future climate scenarios that increase fish movement rates, 3) Alternative selectivity scenarios that change the age composition of catch in each country, 4) Survey frequency scenarios that change how often the acoustic survey is conducted. While each scenario type revealed different sensitivities and tradeoffs, the alternative implementation scenarios had the largest influence on projected stock status and catch. Of the performance metrics we examined, variability in catch was the most responsive across all the scenarios. Assessment error was influenced most by the selectivity scenarios and survey scenarios.

Technical documentation and model output were recently reviewed by the Scientific Review Group of the Pacific Hake Treaty. This new closed-loop simulation model can be used for future MSE questions and applications. The scenarios we explored provide a foundation of results exploring key uncertainties. However, further testing, additional scenarios, and crosses of scenario types may be necessary to more fully explore the model dynamics and to address future questions of interest from hake management bodies.

For more information on the Hake MSE, contact Kristin Marshall (kristin.marshall@noaa.gov)

b) 2018 Unmanned surface vehicle (Saildrone) acoustic survey off the west coasts of the United States and Canada

Investigators: Dezhang Chu, Sandra Parker-Stetter, Lawrence C. Hufnagle, and Stéphane Gauthier

To evaluate the applicability and performance of the Unmanned Surface Vehicles (USVs), the Northwest Fisheries Science Center (NWFSC) and Southwest Fisheries Science Center (SWFSC) of NOAA Fisheries, partnered with NOAA Pacific Marine Environmental Laboratory (PMEL) and the Department of Fisheries and Oceans, Canada (DFO), conducted a coast-wide acoustic survey off the west coasts of the United States and Canada in the summer of 2018 using 5 Saildrones (Saildrone, Inc). The USVs surveyed a total of 5,400 nmi of distance along 124 transects between Vancouver, BC and the Southern California Bight, CA, mirroring the transect design of the NOAA Fisheries Survey Vessel (FSV) Reuben Lasker for the 2018 coastal pelagic species (CPS) survey. The survey design allowed us to compare USV and FSV acoustic data while also evaluating the operational feasibility and performance of the USVs. Despite some initial technical problems with vehicle firmware and navigation, the overall USV operations were stable, reliable, and successful. The performance of the USVs on navigation, operation, and the quality of acoustic data was analyzed and evaluated. The potential applications of using USVs for conducting quantitative ecosystem acoustic surveys is being evaluated.

Figure 8. Saildrone operating at sea off San Francisco, CA

For more information, please contact Dezhang Chu at Dezhang.Chu@noaa.gov

c) Skill and uncertainty of environmentally driven forecasts of Pacific hake distribution

Investigators: Michael J. Malick, Mary Hunsicker, Melissa Haltuch, Sandy Parker-Stetter, Isaac Kaplan, Aaron Berger, Samantha Siedlecki, Nicholas Bond, Albert Hermann, and Emily L. Norton

Changing ecosystem conditions present a challenge for the monitoring and management of living marine resources, where decisions are often made with lead-times of weeks to months. Improvements in the skill of regional ocean models to predict physical ocean states at seasonal time scales provides opportunities to develop early warnings of the biological responses to changing environments and distribution shifts that impact fishery management practices. In this study, we illustrate how regional ocean model predictions can be used in an ecological context using Pacific hake (*Merluccius productus*) summer distribution in the California Current Ecosystem. We used the J-SCOPE regional ocean model to develop 6-8 month lead-time forecasts of thermal conditions at depth, which were then used to force environmentally driven species distribution models for Pacific hake. Using retrospective skill assessments, we show good agreement between hake distribution forecasts and historical observations. Finally, we discuss the utility of using seasonal lead-time ocean predictions in an ecological context to address research questions that can inform current resource management.

For more information, please contact Sandy Parker-Stetter at sandy.parker-stetter@noaa.gov.

d) Sunrise and sunset considerations for daytime surveys

Investigators: Rebecca Thomas, Dezhang Chu, Stephane Gauthier, and Sandra Parker-Stetter

Acoustic surveys are generally designed to match times of day/night when fish are aggregated and acoustically available. However, fish and other organisms may still be vertically migrating during this time period, causing changes in their target strength and ensuing biomass estimate. For Pacific Hake during the summer months, the fish aggregate during the daytime, and the survey is conducted from sunrise to sunset. Changes in Hake backscatter and depth during the initial post-sunrise and final pre-sunset periods were investigated using survey data spanning 15 years. Amid considerable variability, consistent changes in backscatter and aggregation depths were found in the time periods following sunrise and before sunset. The change in TS implied by these changes is described, and contributions from tilt/behavior and swimbladder pressure are considered. Finally, some practical considerations for the survey are examined.

For more information, please contact Rebecca Thomas at Rebecca.Thomas@noaa.gov.

e) The 2017 Joint U.S. and Canada Pacific Hake Integrated Acoustic and Trawl Survey: Cruise Report SH-17-07

Investigator: Steve de Blois

The results presented here are from the 2017 joint U.S. and Canada Pacific hake integrated acoustic and trawl survey. This report provides a brief description of the methods used in the survey and summarizes the distribution, biological composition, and biomass of hake in U.S. and Canadian waters off the Pacific coast. It also summarizes results of acoustic system calibrations, an intervessel calibration (IVC), and secondary survey objectives.

For more information, please contact Steve de Blois at Steve.DeBlois@noaa.gov.

f) Spaced out: Investigating the impact of spatial structure and movement under climate change using management strategy evaluation

Investigators: N. Jacobsen, K. Marshall, A. Berger, and I. Taylor

Fish frequently move across management boundaries, and this movement is likely influenced by environmental conditions. However, fisheries management rarely accounts for fish movement when estimating stock abundance and other related quantities such as the total allowable catch and maximum sustainable yield. Misinformation or changes in movement, such as distribution shifts or altered movement rates resulting from climate change, may induce bias or increase uncertainty for managers. Using the Pacific hake fishery, we apply management strategy evaluation (MSE) to evaluate how alternative hypotheses about spatial stock structure influence how robust management choices are to uncertainty or changes in movement. The MSE employs closed-loop simulations with an operating model that represents real life complexity of hake biology with spatial stock structure mediated by recruitment, age-based movement rates, and fisheries selectivity. The operating model is supplemented by a single-area estimation model similar to the stock assessment model currently used for hake management. By explicitly modeling spatial structure (i.e., movement and spatial recruitment), we show that climate-change-intensified movement of adult hake may cause a median decline in total annual catch and increase annual catch variability, but decrease the risk of fishery closure. The results of the MSE are contextualized in regards to improving current management and assessment of spatially structured fish stocks.

For more information, please contact Kristin Marshall at Kristin.Marshall@noaa.gov

2. Assessment

a) Status of the Pacific (whiting) stock in U.S. and Canadian waters in 2018

Investigators: A. Berger, C. Grandin, I. Taylor, A. Edwards, S. Cox

This stock assessment reported the collaborative efforts of the official U.S. and Canadian JTC members in accordance with the Agreement between the government of the United States and the government of Canada on Pacific hake/whiting. The assessment reported the status of the coastal Pacific Hake (or Pacific whiting, *Merluccius productus*) resource off the west coast of the United States and Canada for 2017. Coast-wide fishery landings of Pacific hake averaged 226 thousand mt from 1966 to 2016, with a low of 90 thousand mt in 1980 and a peak of 363 thousand mt in 2005. Prior to 1966 the total removals were negligible relative to the modern fishery. Recent coast-wide landings from 2007–2016 have been above the long-term average, at 262 thousand mt. Landings between 2013 and 2013 were predominantly comprised of fish from the very large 2010-year class, comprising around 70% of the total removals. In 2016, U.S. fisheries caught mostly 2- and 6-year old fish from the 2010 and 2014 year classes, while the Canadian fisheries encountered mostly 6-year old fish from the 2010 year-class. The Agreement between the United States and Canada establishes U.S. and Canadian shares of the coast-wide TAC at 73.12% and 26.88%.

Data were updated for the 2017 assessment with the addition of fishery catch and age compositions from 2016, reanalyzed acoustic survey biomass and age compositions for 1995 (completing the reanalyzed acoustic survey time series initiated in the 2016 model), and other minor refinements such as catch estimates from earlier years. The assessment used Bayesian methods to incorporate prior information on two key parameters (natural mortality, M, and steepness of the stock-recruit relationship, h) and integrated over parameter uncertainty to provide results that can be probabilistically interpreted. The exploration of uncertainty was not limited to parameter uncertainty as structural uncertainty was investigated through sensitivity analyses. Pacific Hake displays the highest degree of recruitment variability of any west coast groundfish stock, resulting in large and rapid changes in stock biomass. This volatility, coupled with a dynamic fishery, which potentially targets strong cohorts resulting in time-varying selectivity, and little data to inform incoming recruitment until the cohort is age-2 or greater, will, in most circumstances, continue to result in highly uncertain estimates of current stock status and even less-certain projections of future stock trajectory. Uncertainty in this assessment is largely a function of the potentially large 2014 year-class, which has been observed twice by the fishery but has yet to be observed by the acoustic survey, and uncertain selectivity. However, with recruitment being a main source of uncertainty in the projections and the survey not able to monitor the 2014 year-class until they are 3 years old (i.e., summer 2017), short term forecasts are very uncertain.

The base model estimates indicate that since the 1960s, Pacific hake female spawning biomass has ranged from well below to near unfished equilibrium biomass. The model estimates that the stock was below the unfished equilibrium in the 1960s and 1970s, increased toward the unfished equilibrium after two or more large recruitments occurred in the early 1980s, and then declined steadily through the 1990s to a low in 2000. This long period of decline was followed by a brief peak in 2003 as the large 1999-year class matured and subsequently supported the fishery for several years. Estimated female spawning biomass declined to an all-time low of 0.565 million mt in 2009 because of low recruitment between 2000 and 2007, along with a declining 1999-year class. Spawning biomass estimates have increased since 2009 on the strength of large 2010 and 2014 cohorts and an above average 2008 cohort. The 2017 female spawning biomass is estimated to be 89.2% of the unfished equilibrium level (B_0) with a 95% posterior credibility interval ranging from 37% to 271%. The median estimated 2017 female spawning biomass is 2.13 million mt.

Estimates of historical Pacific hake recruitment indicate very large year classes in 1980, 1984, 1999, and 2010. The U.S. fishery shows that the 2014 year-class comprised a very large proportion of the observations in 2016. Uncertainty in estimated recruitments is substantial, especially for 2014, as indicated by broad posterior intervals. The fishing intensity on the Pacific Hake stock is estimated to have been below the $F_{40\%}$ target except for 1999 when the median estimated fishing intensity was slightly above target. Fishing intensity has been substantially below the $F_{40\%}$ target since 2012. Although the official catch targets adopted by the U.S. and Canada have been exceeded only once in the last decade (2002), fishing intensity is estimated to have not exceeded the target rate in the last 10 years. Recent catch and levels of depletion are presented in Figure 9.

Management strategy evaluation tools will be further developed to evaluate major sources of uncertainty relating to data, model structure and the harvest policy for this fishery and compare potential methods to address them. A spatially explicit operating model is needed, so forthcoming research will focus on how best to model these dynamics, including the possible incorporation of seasonal effects and potential climate forcing influences in the simulations.

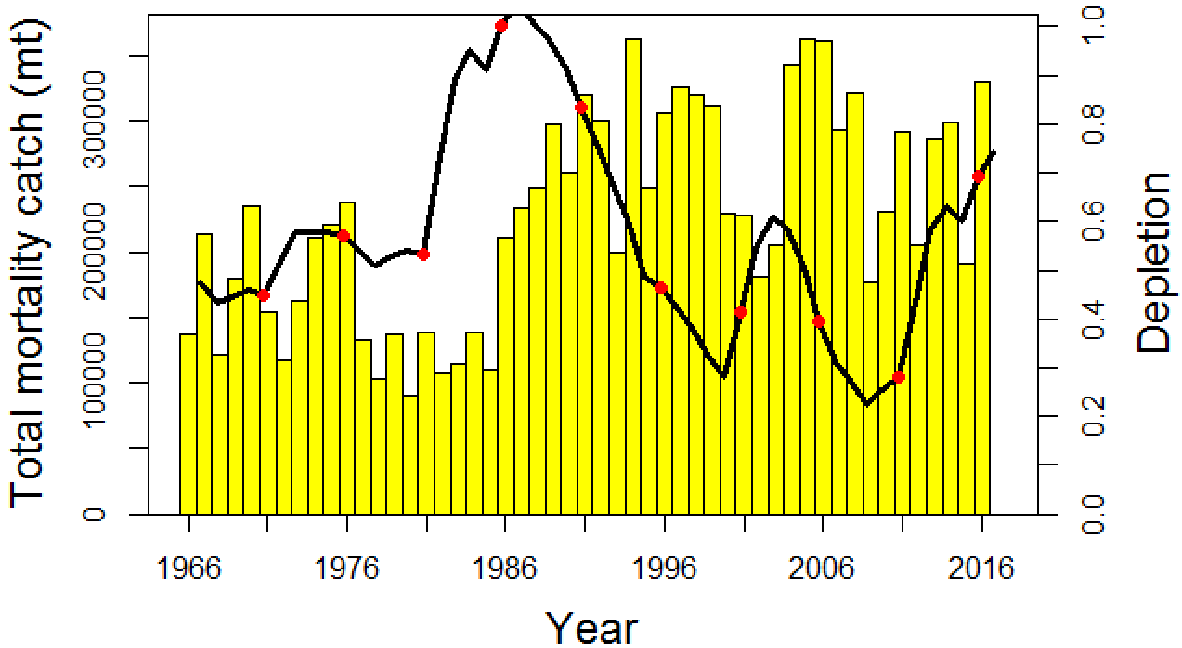


Figure 9. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Pacific hake, 1966-2016.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov.

3. Management

Management of Pacific Hake has been under a treaty (The Agreement) between Canada and the United States since 2011. The stock is managed by the Joint Management Committee (JMC) which is made up of fisheries managers and industry representatives from both the U.S. and Canada. These managers receive advice from the JTC and the Scientific Review Group (SRG), which is a committee responsible for the scientific review of the assessment.

G. Grenadiers

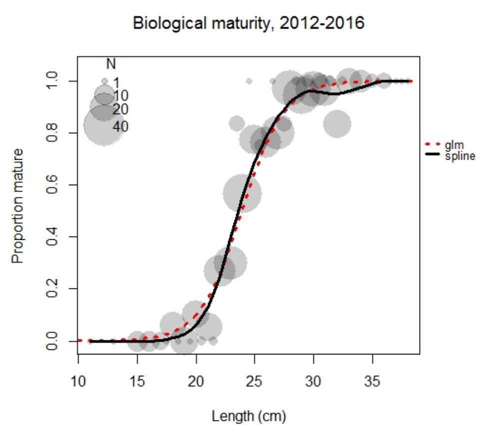
H. Rockfish

1. Research

a) Investigating spatial and temporal variation in reproductive trends in aurora rockfish (*Sebastes aurora*)

Investigators: Melissa A. Head, Jason M. Cope, Sophie H. Wulfing

The authors outline a new method for estimating maturity that incorporates skip or abortive spawning events leading to potentially non-asymptotic behavior in the population maturity schedule. They also introduce a flexible model that captures these functional reproductive changes, including fish that have spawned before but may not in a given year. This new approach aids fisheries managers who seek to understand marine species' responses to different oceanographic regimes over time and space. In an effort to assess shifts in maturity and spawning behavior of west coast groundfish, this new method was used to evaluate spatial and temporal trends in length at maturity, the annual reproductive cycle, and spawning behavior of aurora rockfish (*Sebastes aurora*). Ovaries (n = 538) were collected by the Northwest Fisheries Science Center's West Coast Groundfish Bottom Trawl Survey from 2012 – 2016. The authors estimated biological (presence of physiological maturity markers) and functional (potential spawners in a given year) maturity using a standard logistic and the new flexible spline model. The range in estimated lengths at 50% maturity (biological and functional) varied only slightly between the two modelling methods (23.62 – 23.93 and 25.46 – 25.57 cm). They also investigated geographic trends in length at maturity and found ~2 cm difference in functional maturity between fish sampled north (GLM = 26.48 ± 0.82) and south of Cape Mendocino, CA (GLM = 24.74 ± 0.62). Model sensitivity was examined by changing the maturity estimates in the 2013 aurora rockfish stock assessment using these updated data, and resultant maturity estimates from the logistic and spline models at different spatial scales. The new flexible spline model described in this research has the ability to account for skip spawning in adults, and thus is a better method for estimating potential spawners in a given year. Spawning output, but not relative stock status, was sensitive to model choice, spatial resolution, and the updated data.



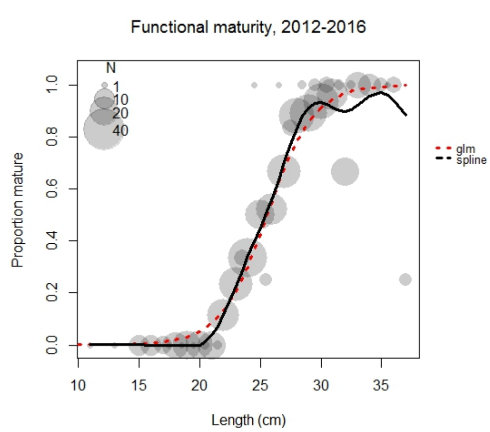


Figure 10. Length (cm) at maturity estimates for Biological maturity coast-wide showing the GLM (red dashed line) and spline (solid black line) fit (upper figure) and Functional maturity coast-wide showing the GLM (red dashed line) and spline (black solid line) (lower figure).

For more information, please contact Melissa Head at Melissa.Head@noaa.gov.

b) Addressing cryptic species issues in stock assessments as exemplified by Blue Rockfish (*Sebastes mystinus*) and Deacon Rockfish (*S. diaconus*)

Investigators: J. Bizzarro, E. Gilbert-Horvath, E.J. Dick, A. Berger, K. Schmidt, D. Person, C. Petersen, L. Katutzi, R. Miller, J. Field, J. Garza

The discovery of cryptic species expands our understanding of biodiversity and provides avenues for further study but also presents significant management challenges, as exemplified in the 2017 stock assessment of the Blue and Deacon Rockfish stock complex. Genetic analyses recently demonstrated that the nominal Blue Rockfish, *Sebastes mystinus*, is actually a cryptic species pair that included Deacon Rockfish, *S. diaconus*. We utilized a variety of approaches to estimate and compare species-specific characteristics of the spatial distribution and life history traits of Blue and Deacon Rockfishes. Genetic assignment of modern fin tissues and historic otoliths to species facilitated subsequent analyses. Deacon Rockfish comprised the majority of individuals sampled between Half Moon Bay and Oregon and were uncommon in southern California. Blue Rockfish were more common from Monterey Bay to southern California. Overall, Deacon Rockfish females grew to larger sizes at slower growth rates than Blue Rockfish females but male growth parameters were similar by comparison. Within species, Deacon Rockfish reached larger sizes at slower growth rates in California. Blue Rockfish reached larger sizes at faster growth rates in Oregon, whereas those south of Point Conception grew larger at faster rates than those in northern California. The multidisciplinary nature of this study and the techniques and protocols we established may provide a model for future stock assessment work on cryptic species. *Fisheries Bulletin in press.*

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

c) Bomb radiocarbon age validation for California Current (CC) rockfish

Investigators: Melissa Haltuch, Andi Stevens, Owen Hamel, Patrick McDonald, John Field, Craig Kastelle

Otolith-derived ages provide an informative piece of data in fisheries stock assessment in regards to estimating recruitments, growth, and exploitation rates. The research and data needs sections of NWFSC stock assessments routinely identify the need for age-determination and age-validation studies. Historical otolith collections that include fish caught by commercial vessels fishing out of northern California ports during the 1960's until present are available at the SWFSC. These historical samples are ideal for the application of bomb radiocarbon age validation methods that require fish with birth years during the late 1950s through the 1970s. Rockfish are the focus of the bomb radiocarbon analyses due to longevity, and thus the likelihood of large ageing bias and variability at older ages. Ongoing radiocarbon age validation work is focusing on black and canary rockfish with the aim of producing more reliable ageing error matrices that will improve stock assessment's ability to model age imprecision and bias, reducing assessment uncertainty.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

d) Steepness for west coast rockfishes: Results from a twelve-year experiment in iterative regional meta-analysis

Investigators: James T. Thorson, Martin W. Dorn, Owen S. Hamel

Theoretical and applied research suggests that survival rates during early life stages will increase when spawning biomass is reduced in marine fishes (termed "recruitment compensation"). However, the magnitude of recruitment compensation is generally difficult to estimate for individual fish stocks, and its average value for marine fishes remains highly contested. Scientists and managers for Pacific rockfishes (*Sebastes* spp.) on the U.S. west coast have used a regional meta-analysis to estimate the likely distribution of the steepness parameter of the Beverton-Holt stock-recruit relationship using stock assessment models since 2007, and the method has been updated every two years as new assessments are conducted (i.e., five biennial updates). Here, we provide a short history of this approach, its methodological assumptions, changes in results over time, and ongoing efforts to validate its assumptions. While the regional meta-analysis has been successful in ensuring a consistent approach to treatment of steepness across assessments, the estimates of mean steepness have been unexpectedly variable as the meta-analysis has been updated. Specifically, we show that the estimated average value of steepness for west coast rockfish increased markedly from 2007 (average: <0.6) to 2011 (average: >0.75), before decreasing somewhat again in the 2017 update. We also show that this value has a strong impact on rockfish rebuilding plans, and showcase the example of canary and widow rockfishes, where the estimated rates of rebuilding are strongly influenced by the assumed value of steepness. We conclude by discussing the bias-variance tradeoff between using global and regional meta-analysis, as well as the likely implications of difficult-to-validate assumptions including: (1) no recruitment autocorrelation within each stock; (2) no correlations among stocks; and (3) no bias from individual stocks resulting from mis-specification of the stock assessment models used in the meta-analysis.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov

e) Integrating formal and citizen-science surveys to develop a young-of-year rockfish monitoring plan for the Puget Sound

Investigators: K.S. Andrews, N. Tolimieri, D. Tonnes, R. Pacunski, S. Larson.

The Rockfish Recovery Plan for two species of rockfish in the Puget Sound/Georgia Basin distinct population segment identifies the development of a young-of-year (YOY) abundance index as one its research priorities. We are working with several stakeholders in the region to develop a plan to monitor these individuals across the Puget Sound region. This will include formal site selection of habitats and locations to monitor, a network of individuals and organizations that would be capable of getting out and surveying for YOY at appropriate times during the year. We are also developing analytical tools that will allow for the integration of data collected by both formal scientific surveys and citizen-science surveys. This analysis will determine if agencies and citizen science surveys can produce an index of YOY abundance using a variety of survey methods or whether a more formal standardization of survey methods needs to be implemented in order to successfully monitor these individuals. This data will be used by the Western Regional Office as one piece of information to help manage and assess the recovery of yelloweye rockfish and bocaccio in the Puget Sound/Georgia Basin region.

For more information please contact Mr. Kelly Andrews at NOAA's Northwest Fisheries Science Center, kelly.andrews@noaa.gov.

f) Survival and movement behavior of yelloweye rockfish in a relatively closed fjord system exposed to low dissolved oxygen levels

Investigators: K.S. Andrews, N. Tolimieri, C.J. Harvey

We tagged 15 yelloweye rockfish *Sebastes ruberrimus* at three locations in Hood Canal with acoustic transmitters to monitor their survival and movement patterns for a period of one year. Three arrays of 5 acoustic receivers were deployed at the locations we captured individuals. These receivers will detect the presence/absence, depth and acceleration of each individual. Each tag emits a unique id code with each transmission of depth and acceleration so that we can monitor the movements of each individual fish. This research has two main objectives. First, we will determine the rate of survival for yelloweye rockfish captured with hook-and-line fishing methods and subsequently returned to the bottom using descending devices. Movement characteristics will determine whether individuals survived the capture event and whether mortality occurred over the following year. Second, we will calculate vertical and horizontal movement characteristics of yelloweye rockfish among these three sites in Hood Canal. This will provide evidence for or against the hypothesis that yelloweye rockfish have very small home ranges and that they do not migrate vertically in the water column like many marine species. Hood Canal is known to experience periods during the year (primarily in autumn months) of very low dissolved oxygen levels and we will use the calculated movement characteristics to investigate whether yelloweye rockfish behave differently under varying levels of dissolved oxygen. Understanding how this species responds to varying environmental conditions will provide necessary information to evaluate potential threats to the recovery of this population and to satisfy criteria for delisting this population from the endangered species list.

For more information please contact Mr. Kelly Andrews at NOAA's Northwest Fisheries Science Center, Kelly.Andrews@noaa.gov.

g) Effects of release timing and location of release on potential larval dispersal for yelloweye and canary rockfish in the Salish Sea.

Investigators: K.S. Andrews, B. Bartos, C.J. Harvey, D. Tonnes, M. Bhuthimethee, P. MacCready

In 2010, three species of rockfish (*Sebastes* spp.) in the Puget Sound/Georgia Basin (PSGB) region were listed under the U.S. federal Endangered Species Act (ESA). Subsequent genetic analyses revealed that yelloweye rockfish *S. ruberrimus* found in these inland waters were genetically differentiated from individuals found on the outer coast, while canary rockfish *S. pinniger* did not show any population structure among these geographic regions. These results confirmed the listing status of yelloweye rockfish as a “distinct population segment” (DPS), whereas canary rockfish in PSGB were not deemed a DPS and were subsequently removed from the Endangered Species List. In this paper, we investigate whether larval dispersal could be a mechanism that contributes to differences in population structure observed between these two rockfish species in Puget Sound. We used an oceanographic model to track larvae of yelloweye and canary rockfish released from sites within and outside of the PSGB region during their 60-day peak parturition period and followed these particles for up to 120 days. Results were similar among both species. Larvae released from sites along the outer coast of Washington state rarely settled within the boundaries of the DPS and larvae released from sites in the Main Basin of Puget Sound, Hood Canal or the Strait of Georgia rarely settled outside of the boundaries of the DPS. Within each species, we observed few differences in the proportion of larvae settling inside vs. outside the DPS depending on age of settlement (90-120 days) or the day of parturition (1-60 days). These results suggest that larval dispersal is not the most likely mechanism responsible for the differences in population structure observed for these two species in PSGB.

For more information please contact Mr. Kelly Andrews at NOAA’s Northwest Fisheries Science Center, Kelly.Andrews@noaa.gov.

2. Assessment

a) Stock assessment update: Status of widow rockfish (*Sebastes entomelas*) along the U.S. west coast in 2019

Investigators: Grant D. Adams, Maia S. Kapur, Kristin McQuaw, Stephanie Thurner, Owen S. Hamel, Andi Stephens, Chantel R. Wetzel

This is an update assessment to last full assessment of widow rockfish (*Sebastes entomelas*) conducted in 2015. Widow rockfish reside in the waters off California, Oregon, and Washington from the U.S. – Canadian border in the north to the U.S. – Mexico border in the south. Widow rockfish inhabit water depths of 25 – 370 m from northern Baja California, Mexico to Southeastern Alaska. Although catches north of the U.S. – Canada border and south of the U.S. – Mexico border were not included in this update assessment; it is not certain if those populations contribute to the biomass of widow rockfish off of the U.S. west coast possibly through adult migration and/or larval dispersion. Total landings of widow rockfish peaked in the early 1980s, increasing from approximately 1,000 metric tons (mt) in 1978 to a peak in landings exceeding 25,000 mt in 1981. After this sudden increase in catch, widow rockfish were given their own market category and often specifically identified in the landings. Uncertainty in species composition is greater in past years, thus landings of widow rockfish are not well known further back in history. The large landings in the early 1980s were curtailed with trip limits beginning in 1982, which resulted in a decline in landings throughout the 1980s and 1990s following sequential reductions 255 in the trip limits. From 2000 to 2003, landings of widow rockfish dropped from over 4,000 mt to about 40 mt and have been slowly increasing since, with a more rapid relative increase starting in 2013, after being declared rebuilt in 2011. Widow rockfish are a desirable market species and it is believed that discarding was low historically. However, management restrictions (e.g., trip limits) resulted in a substantial amount of discarding beginning in 1982. Trawl rationalization was introduced in 2011, and since then very little discarding of widow rockfish has occurred.

The update assessment was conducted using the length- and age-structured modeling software Stock Synthesis (version 3.30, pers. comm. Richard Methot, NMFS). The coastwide population was modeled assuming separate growth and mortality parameters for each sex (a two-sex model) from 1916 to 2019, and forecasted beyond 2019. The data used in the assessment model consisted of survey abundance indices, length compositions, discard data, and age compositions. Model-based biomass indices and length compositions were determined from two different surveys. Length and age data were available for five fisheries (based on gear type). Although there are many types of data available for widow rockfish since the late 1970s, which were used in this update assessment, there is little information about steepness and was fixed at the mean of the prior. Estimates of steepness are uncertain partly because of highly variable recruitment.
The predicted spawning biomass from the base model generally showed a slight decline over the time series until 1966 when the foreign fleet began. A short, but sharp decline occurred, followed by a steep increase due to strong recruitment in 1970 and 1971. The spawning biomass declined rapidly with the developing domestic midwater fishery in the late 1970s and early 1980s. The stock continued to decline until 2001 when a combination of strong recruitment and low catches resulted in a quick increase. The 2019 spawning biomass relative to unfished equilibrium spawning biomass is above the target of 40% of unfished spawning biomass (91.9%), with a low of 36.2% in 2001. The spawning biomass has increased rapidly since the mid-2000s due to low exploitation rates and multiple strong recruitment events in 2008, 2013, and 2014.

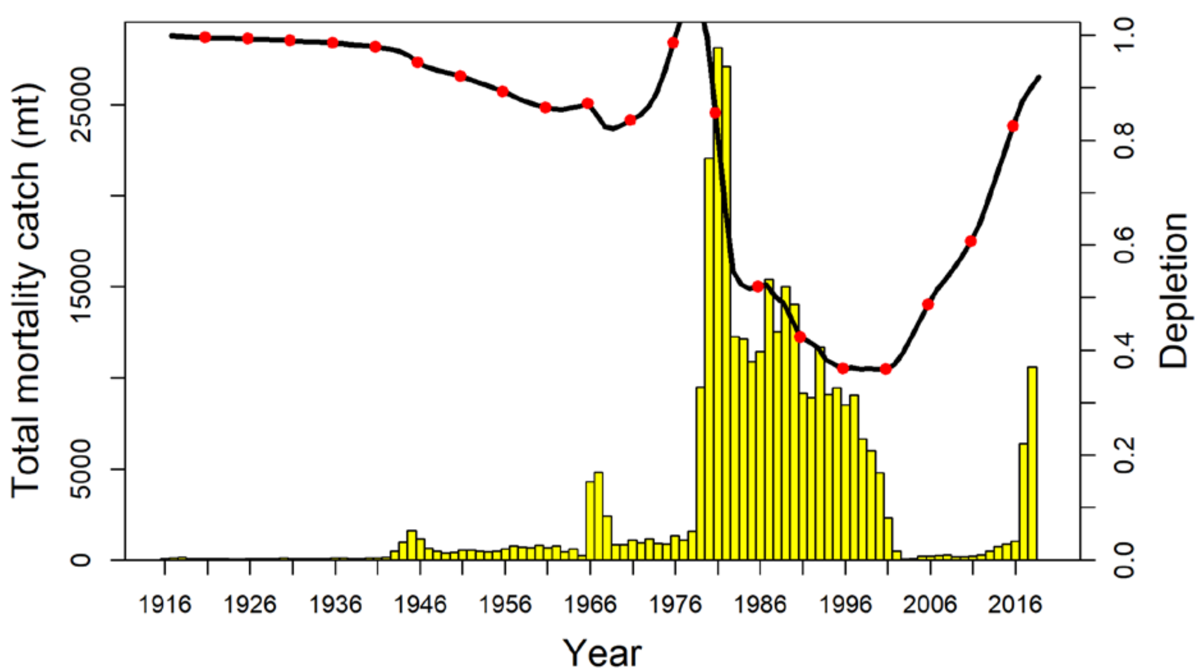


Figure 11. The time series of total mortality catch (bars) and estimated depletion (line) for widow rockfish.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov

3. Management

a) Catch-only Projections

Investigators: Owen Hamel et al.

Catch-only projections were conducted for a number of previously conducted stock assessments, including: black rockfish, blackgill rockfish, blue/deacon rockfishes, brown rockfish, canary rockfish, china rockfish, darkblotched rockfish, Dover sole, lingcod, longspine thornyhead, rougheye/blackspotted rockfishes, shortspine thornyhead, and yelloweye rockfish.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov

I. Thornyheads

J. Sablefish

1. Research

a) Report on the 2018 International Sablefish Workshop

Investigators: K.H. Fenske, A.M. Berger, B. Connors, J. Cope, S. P. Cox, M. Haltuch, D.H. Hanselman, M. Kapur, L. Lacko, C. Lunsford, C. Rodgveller, B. Williams

The Pacific Sablefish Transboundary Assessment Team (PSTAT), comprised of twelve scientists from Canada and the United States, convened April 26-27, 2018 in Seattle, WA for a workshop to discuss sablefish (*Anoplopoma fimbria*) research. Participants included representatives from Alaska Department of Fish and Game, Alaska Fisheries Science Center, Fisheries and Oceans Canada, Simon Fraser University, and the Northwest Fisheries Science Center. The primary objective of the workshop was to bring these scientists from the U.S. and Canada together to discuss range-wide sablefish data, compare stock assessment methods, discuss concerns about sablefish abundance trends, share results of recent and ongoing sablefish research, and to examine the feasibility of developing a set of range-wide operating models (OM) for use in Management Strategy Evaluation (MSE).

Sablefish are a highly mobile, long-lived, commercially valuable groundfish that have high movement rates and range from Southern California to the Bering Sea. Traditional stock assessment and management has taken place at regional levels determined by political boundaries for Alaska federal region, Alaska state region, British Columbia, and the U.S. west coast. Each region assumes that these are closed stocks, however, a recent genetic study suggests that N.E. Pacific sablefish are not genetically distinct within these traditional management areas. This lack of genetic evidence for population structure suggests that regional scale fisheries management may benefit from the consideration of the range-wide structure and dynamics of sablefish (e.g., a range-wide operating model could be developed as a tool for exploring sablefish population structure).

The primary objective of the workshop was to initiate discussion about the development of a range-wide, spatially explicit OM that can be used to explore questions of ecological, biological and management relevance. The PSTAT identified and fleshed out a number of key research activities that need to be undertaken to meet this objective: (1) a synthesis of life history characteristics across the sablefish range, (2) analyses to identify and develop range-wide indices of abundance, (3) evaluation of movement within and among regions, and (4) the development of a panmictic OM based on insights and data from steps 1-3. Steps 1-3 identified above could be developed into stand-alone research products resulting in published manuscripts. Step 4 is a necessary step towards the development of a spatially explicit OM.

A secondary objective of the workshop was to discuss similarities and differences in stock assessment approaches used in each region. The U.S. west coast sablefish assessments are done using the Stock Synthesis modeling platform, with the model beginning in 1900. Sablefish fishery management in British Columbia (B.C.) is based on a management procedure (data collection scheme, assessment approach, and harvest control rule) developed through a MSE process where hypotheses, empirical data, and simulation play a central role in defining management objectives and assessing management performance relative to those objectives. The B.C. sablefish MSE is based on an OM that is fit in AD Model Builder and conditioned on data beginning in 1965. Alaska Department of Fish and Game assesses sablefish in northern southeast inside waters using a yield-per-recruit model scaled to the absolute abundance estimates from a mark-recapture survey, the results of which are used to set the harvest level. Lastly, the Alaska (Federal) sablefish assessment is a custom age-structured model coded in AD Model Builder beginning in 1960.

A draft work plan was developed during the workshop that identified key research priorities moving forward including:

- A range-wide life history synthesis,
- Analysis of range-wide maturation rates,
- Development of range-wide indices of abundance,
- Analysis of range-wide movement,
- Development of a panmictic operating model,
- Development of a spatially-explicit operating model. In addition to these research priorities the group identified the need to work together to secure funding to support ongoing collaborations (e.g., PhD student and funding for in-person meetings) and to develop a common data sharing agreement among regions. The group committed to continue to work together moving forward through regularly scheduled conference calls and email.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

b) Oceanographic features delineate growth zonation in Northeast Pacific sablefish

Investigators: M. Kapur, M.A. Haltuch, B. Connors, L. Rogers, A. Berger, E. Koontz, J. Cope, K. Echave, K. Fenske, D. Hanselman, A.E. Punt

Renewed interest in the estimation of spatial and temporal variation in fish traits, such as body size, is a result of computing advances and the development of spatially-explicit management frameworks. However, many attempts to quantify spatial structure or the distribution of traits utilize a priori approaches, which involve predesignated geographic regions and thus cannot detect unanticipated spatial patterns. We developed a new, model-based method that uses the first derivative of the spatial smoothing term of a generalized additive model to identify spatial zones of variation in fish length-at-age. We use simulation testing to evaluate the method across a variety of synthetic, stratified age and length datasets, and then apply it to survey data for northeast Pacific sablefish (*Anoplopoma fimbria*). Simulation testing illustrates the robustness of the method across a variety of scenarios related to spatially or temporally stratified length-at-age data, including strict boundaries, overlapping zones and changes at the extreme of the range. Results indicate that length-at-age for Northeast Pacific sablefish increases with latitude, which is consistent with previous work from the western United States. Model-detected spatial breakpoints corresponded to major oceanographic features, including the northern end of the Southern California Bight and the bifurcation of the North Pacific Current. This method has the potential to improve detection of large-scale patterns in fish growth, and aid in the development of spatiotemporally structured population dynamics models to inform ecosystem-based fisheries management.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

c) Assessing the effects of climate change on U.S. west coast sablefish productivity and on the performance of alternative management strategies

Investigators: M.A. Haltuch, Z.T. A'mar, N.A. Bond, J.L. Valero,

U.S. west coast sablefish are economically valuable, with landings of 11.8 million pounds valued at over $31 million during 2016, making assessing and understanding the impact of climate change on the California Current (CC) stock a priority for (1) forecasting future stock productivity, and (2) testing the robustness of management strategies to climate impacts. Sablefish recruitment is related to large-scale climate forcing indexed by regionally correlated sea level (SL) and zooplankton communities that pelagic young-of-the-year sablefish feed upon. This study forecasts trends in future sablefish productivity using SL from Global Climate Models (GCMs) and explores the robustness of harvest control rules (HCRs) to climate driven changes in recruitment using management strategy evaluation (MSE). Future sablefish recruitment is likely to be similar to historical recruitment but may be less variable. Most GCMs suggest that decadal SL trends result in recruitments persisting at lower levels through about 2040 followed by higher levels that are more favorable for sablefish recruitment through 2060. Although this MSE suggests that spawning biomass and catches will decline, and then stabilize, into the future under both HCRs, the sablefish stock does not fall below the stock size that leads to fishery closures.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

d) Limitations and applications of macroscopic maturity analyses: A comparison of histological and visual maturity staging in multiple west coast groundfish species

Investigators: Markus A. Min, Melissa A. Head, Jason M. Cope, Jim D. Hastie

Accurate maturity schedules are critical to ensure stock assessment models are able to correctly predict changes in spawning stock biomass. In order to generate updated maturity estimates, the Northwest Fisheries Science Center's (NWFSC) Fishery Resource Analysis and Monitoring (FRAM) Division instituted a reproductive biology program in 2009. This program uses histological analysis of ovaries to determine maturity, a technique that is known to be time consuming and more expensive but also more reliable than the historically used method of macroscopic inspection. As macroscopic maturity data is still being collected by Oregon Department of Fish and Wildlife (ODFW), we evaluated the usefulness of these macroscopic maturity recordings by verifying their accuracy using histological methods. Among the three different species in this study, each representative of a different family of west coast groundfish (flatfish, rockfish, and roundfish), arrowtooth flounder and canary rockfish had a high correspondence between length at 50% biological (physiological) maturity (L50) staged histologically and macroscopically. Sablefish L50 estimates varied significantly between macroscopic and histological methods. Functional maturity (potential spawners in a given year) did not correlate with macroscopic maturity for any of the studied species. In its current form, macroscopic maturity collections have limited application in assessing changes in maturity schedules over time, and a lack of standardization amongst different state departments of fish and wildlife severely hinders any attempt at using macroscopic maturity data to analyze spatial trends in maturity.

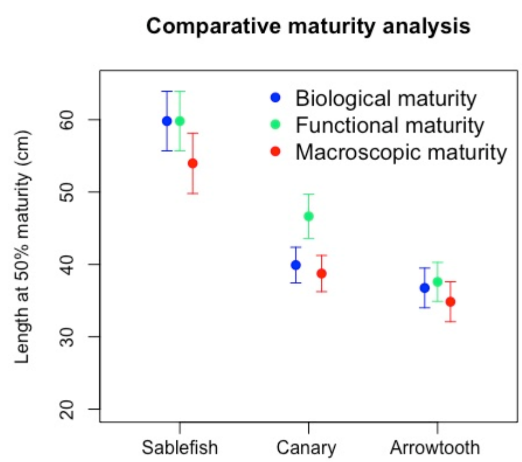


Figure 12. Comparison of L50 estimates calculated using the three different types of maturity data (biological, functional, and macroscopic) for sablefish (*Anoplopoma fimbria*), canary rockfish (*Sebastes pinniger*), and arrowtooth flounder (*Atheresthes stomias*).

For more information, please contact Melissa Head at Melissa.Head@noaa.gov.

2. Assessment

a) 2019 Sablefish Stock Assessment

Investigators: M.A. Haltuch, K.F. Johnson, N. Tolimieri, M.S. Kapur, C.A. Castillo-Jordán

This assessment reports the status of the sablefish (*Anoplopoma fimbria*, or 'black cod') resource off the coast of the United States (U.S.) from southern California to the U.S.-Canadian border using data through 2018. The resource is modeled as a single stock; however, sablefish do disperse to and from offshore sea mounts and along the coastal waters of the continental U.S., Canada, and Alaska and across the Aleutian Islands to the western Pacific. Their movement is not explicitly accounted for in this analysis.

During the first half of the 20th century, it is estimated that sablefish were exploited at relatively modest levels (Figure13). Modest catches continued until the 1960s, along with a higher frequency of above average, but uncertain, estimates of recruitment through the 1970s. The spawning biomass increased during the 1940s to 1970s. Subsequently, biomass is estimated to have declined between the mid-1970s and the early 2010s, with the largest peaks in harvests during the 1970s followed by harvests that were, on average, higher than pre-1970s harvest through the 2000s. At the same time, there were a higher frequency of generally lower than average recruitments from the 1980s forward. Despite estimates of harvest rates that were largely below overfishing rates from the 1990s forward and a few high recruitments from the 1980s forward, the spawning biomass has only recently begun to increase. This stock assessment suggests spawner per recruitment rates higher than the target during some years from the 1990s forward for two reasons. First, there have been many years with lower than expected recruitment. Second, stock assessment estimates of unfished spawning biomass have been steadily declining in each subsequent assessment since 2007. Estimates of unfished biomass scale catch advice.

The estimates of uncertainty around the point estimate of unfished biomass are large across the range of models explored within this assessment, suggesting that the unfished spawning biomass could range from just under 100,000 mt to over 200,000 mt. This uncertainty is largely due to the confounding of natural mortality, absolute stock size, and productivity. The point estimate of 2019 spawning biomass from the base model is 57,444 mt; however, the 95% interval ranges broadly from 32,776 to 82,112 mt. The relative trend in spawning biomass is robust to uncertainty in the leading model parameters. The 2019 point estimate of spawning stock biomass is 39% of the unfished state (95% interval: 26-52%).

Sablefish recruitment is estimated to be quite variable with large amounts of uncertainty in individual recruitment events. A period with generally higher frequencies of strong recruitments spans from the early 1950s through the 1970s, followed by a lower frequency of large recruitments during 1980 forward, contributing to stock declines. The period with a higher frequency of high recruitments contributed to a large increase in stock biomass that has subsequently declined throughout much of the 1970s forward. Less frequent large recruitments during the mid-1980s through 1990 slowed the rate of stock decline, with another series of large recruitments during 1999 and 2000 leading to a leveling off in the stock decline. The above-average cohorts from 2008, 2010, 2013, and 2016 are contributing to a slightly increasing spawning stock size. The 2016 cohort is estimated to be the largest since the mid-1970s.

Equilibrium yield at the fishing mortality that leads to the maximum sustainable yield (FMSY) is 8,077 mt (4,684-11,470, ~95% interval). Although the estimated productivity and absolute scale of the stock are poorly informed by the available data and are, therefore, sensitive to changes in model structure and treatment of data, all sensitivity or alternate models evaluated showed a declining trend in biomass since the 1970s followed by a recent increase. The spawner potential ratio (SPR) exceeded the fishing mortality target/overfishing level (SPR45%) that stabilizes the stock at the target (i.e., 1-SPR/[1-SPR45%]) during the late 2000s and early 2010s, while since 2015 it has been between 83 and 95%.

Unfished spawning biomass was estimated to be 147,729 mt (109,022-186,436, ~95% interval).

The abundance of sablefish was estimated to have dropped below the target reference point of 40% of this estimated value of unfished spawning biomass during the 2000s and generally remained below the target through 2018. The estimate of the target spawning biomass was 59,092 (43,609-

74,574, ~95% interval), which gives a catch of 7,363 mt (4,269-10,456, ~95% interval). The stock was estimated to be just below the target stock size in the beginning of 2019 at 57,444 mt (32,776-

82,112, ~95% interval). The stock was estimated to be above the depletion level that would lead to maximum yield. The estimate of the stock's current level of depletion was 38.9%.

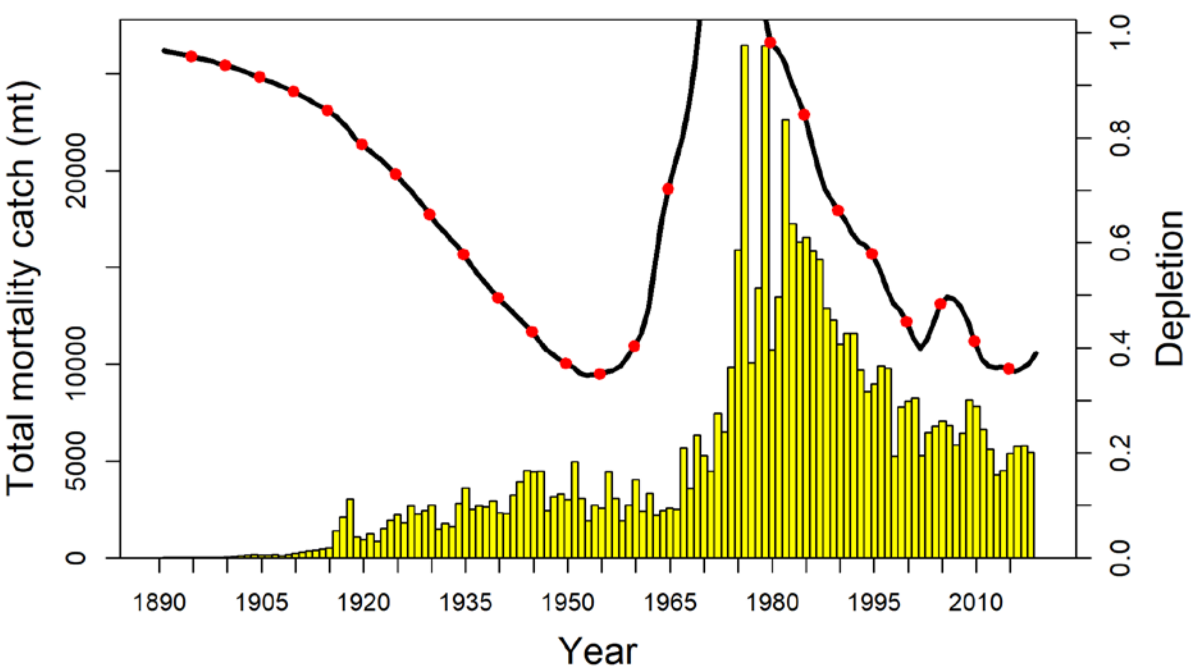


Figure 13. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for sablefish.

3. Management

a) Ecosystem Considerations for sablefish

Investigators: Nick Tolimieri, Chris Harvey, J. Samhouri

We developed an Ecosystem Considerations document as an appendix to the west coast sablefish stock assessment. It provides an analysis and summary of ecological and socio-economic considerations for sablefish. This Ecosystem Considerations section is based on the idea of social-ecological system (SES), which "explicitly acknowledges linkages and feedback between human and biophysical systems". We provide a summary of the SES framework for the California Current. Inclusion of ecological and socio-economic considerations in the sablefish stock assessment will help to move towards an ecosystem-based approach to fisheries management. The SES framework requires that we consider extractive goals and conduct human activities at a level that allows ecological sustainability while also considering human well-being by considering both environmental and human impacts on sablefish, as well as sablefish impacts on the ecosystem and humans.

For more information please contact Dr. Nick Tolimieri at NOAA's Northwest Fisheries Science Center, nick.tolimieri@noaa.gov.

K. Lingcod

1. Research

a) Landscape genomics & life history diversity in lingcod on the U.S. west coast

Investigators: G.C. Longo, L. Lam, B. Brown, J.F. Samhouri, S.L. Hamilton, K. Andrews, G. Williams, M. McClure, K.M. Nichols.

Delimiting intraspecific genetic variation in harvested species is crucial to the assessment of population status for natural resource management and conservation purposes. Here we evaluated genetic population structure in lingcod (*Ophiodon elongatus*), a commercially—and recreationally—important species for fisheries along the west coast of North America. We used 16,749 restriction site associated DNA sequencing (RADseq) markers, in 611 individuals collected from across the bulk of the species range from Southeast Alaska to Baja, Mexico. In contrast to previous population genetic work on this species, we found strong evidence for two distinct genetic clusters, separated latitudinally with a break near The Gulf of the Farallones off central California, and a high frequency of admixed individuals in close proximity to the break. F-statistics corroborate this genetic break between northern and southern sampling sites, although most loci are characterized by low FST values, suggesting high gene flow throughout most the genome. Outlier analyses identified 182 loci putatively under divergent selection, most of which mapped to a single genomic region. When individuals were grouped by cluster assignment (northern, southern, and admixed), 71 loci were fixed between the northern and southern cluster, all of which were identified in the outlier scans. All individuals identified as admixed exhibited near 50:50 assignment to northern and southern clusters and were heterozygous for most fixed loci. Alignments of RADseq loci to three other teleost genomes with chromosome level assemblies show that outlier and fixed loci are heavily concentrated on a single chromosome. Similar genomic patterns have been attributed to chromosomal inversions in diverse taxonomic groups. Regardless of the evolutionary mechanism, these results represent novel observations of genetic structure in lingcod and designate clear evolutionary units that could improve fisheries management.

For more information please contact Dr. Jameal Samhouri at NOAA's Northwest Fisheries Science Center, Jameal.Samhouri@noaa.gov.

b) Assessing the magnitude of rockfish bycatch among bait types while targeting lingcod

Investigators: K.S. Andrews, D. Tonnes

Rockfish in Puget Sound have declined > 70% over the last ~50 years and three species have been listed on the endangered species list. Most commercial fisheries have been ended in Puget Sound and several regulations restricting recreational fishing for bottomfish have been implemented over the last two decades. However, rockfish inhabit similar habitats as other recreationally-targeted species, such as lingcod and halibut and bycatch of rockfish during these fisheries is still a concern for managers trying to recover rockfish populations in the Puget Sound region. Thus, understanding whether there are specific types of bait and/or lures that reduce rockfish bycatch during these fisheries, while retaining similar catch rates for the target species, may provide protection to recovering rockfish populations and additional fishing opportunities. Anecdotal reports from the fishing community suggest that rockfish bycatch is low to non-existent in the lingcod fishery when large flatfish bait is used when compared to small, live baits or artificial lures/jigs. This project has been funded by NOAA's Western Regional Office in order to test whether this hypothesis is true. Preliminary catch data from recreational fishing guides collected in 2014 and 2015 revealed that rockfish bycatch is small when using flounder/sanddab as live bait, but due to confounding variables associated with this data set, the true extent of rockfish bycatch among bait types is difficult to determine. In this project, we will partner with charter boat captains to assess rockfish bycatch in local lingcod fisheries by fishing with different bait types in a controlled experimental design among fishing locations in Central Puget Sound and the San Juan Islands in 2017 and 2018.

For more information please contact Mr. Kelly Andrews at NOAA's Northwest Fisheries Science Center, Kelly.Andrews@noaa.gov.

L. Atka Mackerel

M. Flatfish

1. Research

a) Oceanographic drivers of petrale sole recruitment in the California Current Ecosystem

Investigators: M.A. Haltuch, N. Tolimieri, Q. Lee, M.G. Jacox

This paper investigates environmental drivers of U.S. west coast petrale sole (*Eopsetta jordani*) recruitment as an initial step toward developing an environmental recruitment index that can inform the stock assessment in the absence of survey observations of age-0 and age-1 fish. First, a conceptual life history approach is used to generate life-stage-specific and spatio-temporally specific mechanistic hypotheses regarding oceanographic variables that likely influence survival at each life stage. Seven life history stages are considered, from female spawner condition through benthic recruitment as observed in the Northwest Fisheries Science Center West Coast Groundfish Bottom Trawl Survey (age-2 fish). The study area encompasses the region from 40 to 48°N in the California Current Ecosystem. Hypotheses are tested using output from a regional ocean reanalysis model outputs and model selection techniques. Four oceanographic variables explained 73% of the variation in recruitment not accounted for by estimates based exclusively on the spawning stock size. Recruitment deviations were (a) positively correlated with degree days during the female precondition period, (b) positively correlated with mixed-layer depth during the egg stage, (c) negatively correlated with cross-shelf transport during the larval stage, and (d) negatively correlated with cross-shelf transport during the benthic juvenile stage. While multiple mechanisms likely affect petrale sole recruitment at different points during their life history, the strength of the relationship is promising for stock assessment and integrated ecosystem assessment applications.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

b) Food habit variability of arrowtooth flounder (*Atheresthes stomias*) in the northeast Pacific Ocean

Investigator: Douglas Draper

A diet study of arrowtooth flounder (*Atheresthes stomias*) provided information on the food habits and predator-prey relationships for a northeast Pacific Ocean flatfish described as exhibiting highly piscivorous and opportunistic feeding behavior. Arrowtooth flounder stomachs (n = 472) were collected between 2013 and 2016 from 310 trawls during the Northwest Fisheries Science Center's (NWFSC) west coast groundfish bottom trawl survey (WCGBTS). A total of 299 stomachs (63.3%) contained prey and revealed a highly piscivorous diet across all lengths examined (14 – 71cm). Increased predator length correlated both with an increase in percentage of fish prey consumed and an increase in depth. Smaller, shallower (55-183 m) arrowtooth flounder consumed a relatively high percentage of euphausiids and shrimp. Correspondingly, the larger arrowtooth flounder captured at greater depths (> 184 m) consumed more fish and less shrimp and euphausiids. Arrowtooth flounder from different geographic areas also showed variation among prey, likely resulting from regional differences in prey availability. North of the mean latitude of capture (44.46°N) Pacific hake (*Merluccius productus*) and Pacific herring (*Clupea pallasii*) were the predominant fish in arrowtooth flounder diet, while arrowtooth flounder south of the mean latitude consumed mostly Pacific hake and rockfish (*Sebastes* spp). Euphausiids were also more common in stomachs taken above the mean latitude than in the south. Unidentified teleosts contributed much of the diet across all size, depth, and latitude ranges.

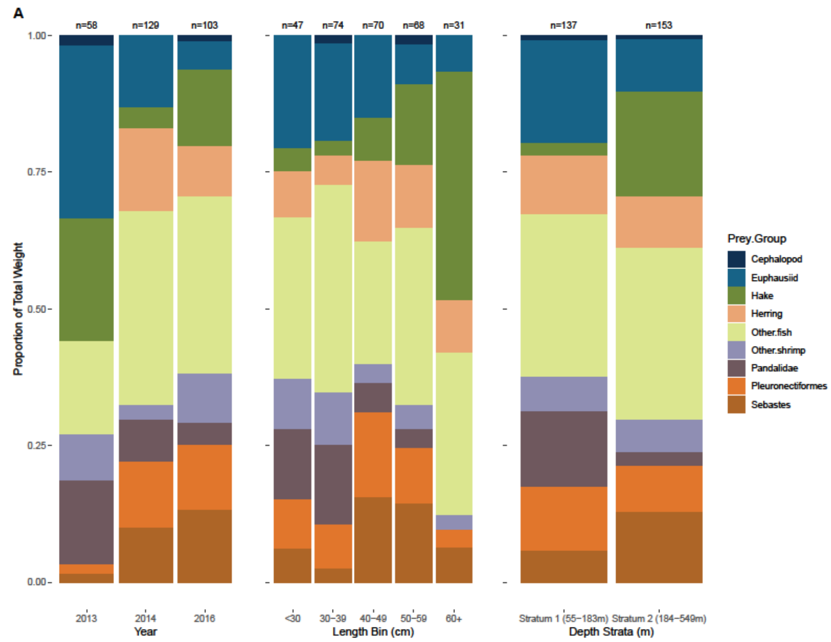


Figure 14. Stacked barplots of diet proportions by weight of arrowtooth flounder prey groups for year, depth strata, and length bins

2. Assessment

a) Status of petrale sole (*Eopsetta jordani*) along the U.S. west coast in 2019

Investigators: Chantel R. Wetzel

Petrale sole were the target of fishing fleets operating off the west coast of U.S. during a winter and summer fishery with high landings starting prior to 1940. The portion of population off the U.S. west coast, which has generally been treated as a single separate stock for assessment and management purposes, was declared overfished in 2009. This assessment was an update assessment, the second conducted since the last full assessment in 2013, assumes that petrale sole off the U.S. west coast are a single, unit stock whose dynamics are independent of petrale sole populations off Canada and Alaska.

The stock assessment was conducted with Stock Synthesis. Data were compiled into four fishing fleets, two catch-per-unit-effort indices, and two fishery-independent indices of relative abundance. The four fishing fleets were commercial trawl fleets segregated by fishing area (California vs. Oregon-Washington) and fishing timing (winter and summer). For these fleets, the model included a retention curve and was informed by observer data on discard rates and length-compositions. Several indices of relative abundance were considered during development of the model, including fishery dependent CPUE indices and fishery independent surveys (Triennial survey and the NWFSC shelf-slope survey). The NWFSC shelf-slope survey provides the longest the time series and is considered the most reliable information on population abundance and data. Selectivity was estimated for each modeled fleet using observations of age and/or length composition data. The NWFSC shelf-slope survey age data were included as conditional age-at-length observations (CAAL). For some fleets both the age and length composition data were included. All fleets and surveys were modeled with double normal selectivity parameterizations. The assessment model was structured to have two sexes and it started from an unfished non-equilibrium state in 1876 with annual recruitment deviations estimated to 2018.

The model estimates that the spawning biomass of petrale sole at the start of 2019 was 13,078 metric tons and was at 39% of its unfished level. The trajectory of spawning output has been increasing steadily since about 2010 because of reduced catches during rebuilding and strong recruitments in 2006, 2007, and 2008. The assessment estimates that the stock's spawning biomass hovered at or slightly below the Council's threshold level (12.5% of unfished) for a period extending from approximately the early-1980s to the late-2000s. The estimated dynamics from this update stock assessment are consistent with the prior assessment.

The composition data for petrale sole were weighted according to the McAllister-Ianelli weighting approach with the composition data, combined with the historical stock trajectory, contained information regarding steepness and natural mortality allowing for estimation within the model. Natural mortality by sex was estimated 0.159 and 0.165 yr^{-1} for females and males, respectively. Steepness was estimated at 0.84 and was strongly correlated with the estimated natural mortality parameters. The previous full assessment in 2013 estimated similar parameter values for natural mortality and steepness, resulting in a similar stock trajectory over the assessed years.

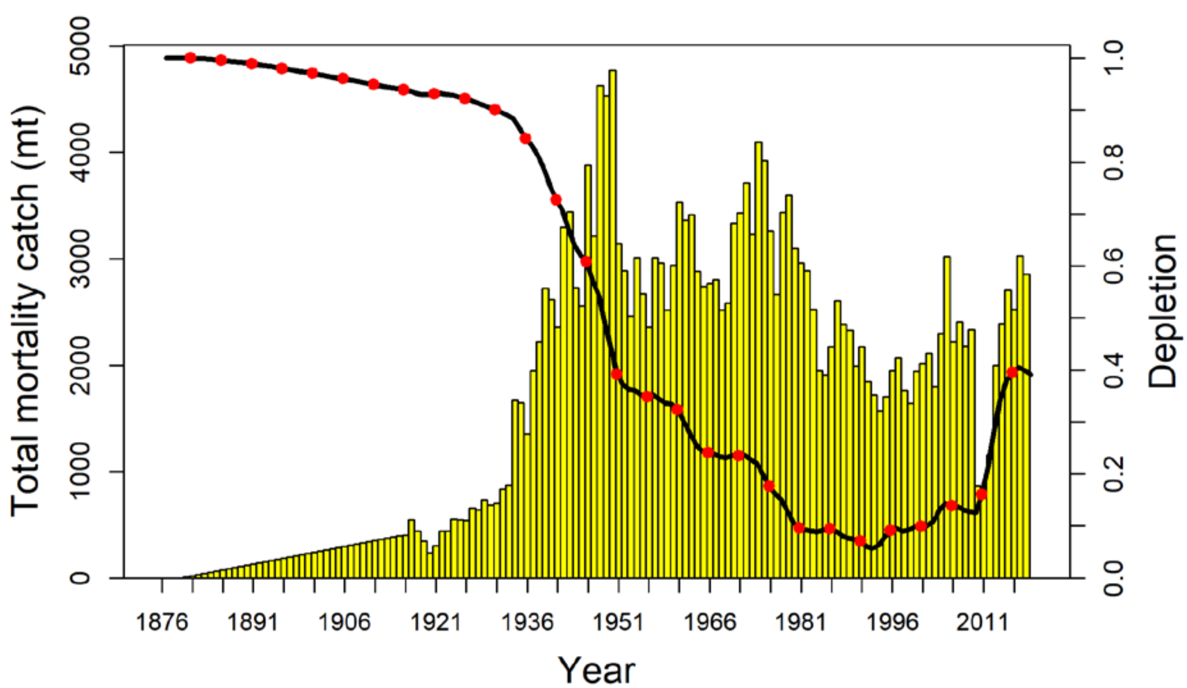


Figure 15. The time series of total mortality catch (bars) and estimated depletion (line) for petrale sole.

For more information, please contact Chantel Wetzel at Chantel.Wetzel@noaa.gov

1. Research

N. Halibut

O. Other Groundfish

1. Research

a) Feeding ecology of select groundfish species captured in the Northwest Fisheries Science Center's west coast bottom trawl survey, using gut contents and stable isotopes

Investigators: Keith Bosley, J. Buchanan, A. Chappell, D. Draper, and K.M. Bosley

We are examining the diets of multiple groundfish species as an ongoing component of the NMFS West Coast Bottom Trawl Survey. Stomachs and tissue samples were collected at sea and preserved for gut content and stable-isotope analyses. We focused on several species of *Sebastes*, sablefish, and some flatfishes, and now have stomach content and stable-isotope data covering multiple years. Yellowtail, darkblotched, canary, sharpchin and stripetail rockfishes prey largely on zooplankton, with euphausiids composing a majority of their diet. Shrimp also contribute significantly to the diets of darkblotched and canary rockfishes, whereas bocaccio, yelloweye and chilipepper rockfishes all share a highly piscivorous diet. Greenstriped and rosethorn rockfishes show a strong preference for benthic prey, greenstriped preferring various shrimp species, and rosethorn preferring a mix of shrimp and galatheid crabs. Finally, widow rockfish and Pacific ocean perch exhibit a more omnivorous feeding strategy, eating a variety of zooplankton, including euphausiids, amphipods, shrimp and gelatinous organisms. Stable isotope values averaged by year indicate that bocaccio and yelloweye rockfish feed approximately one trophic level above Pacific ocean perch and above darkblotched, greenstriped, sharpchin, stripetail and widow rockfishes. All other species in this study feed at mixed trophic levels. Multivariate analyses of diet data show significant differences in diet among species but strong overlap among benthic and bentho-pelagic species. Stable-isotope data also show significant differences among species and years. These results demonstrate the groundfishes in this study are significant consumers in both benthic and pelagic habitats, feeding across multiple trophic levels.

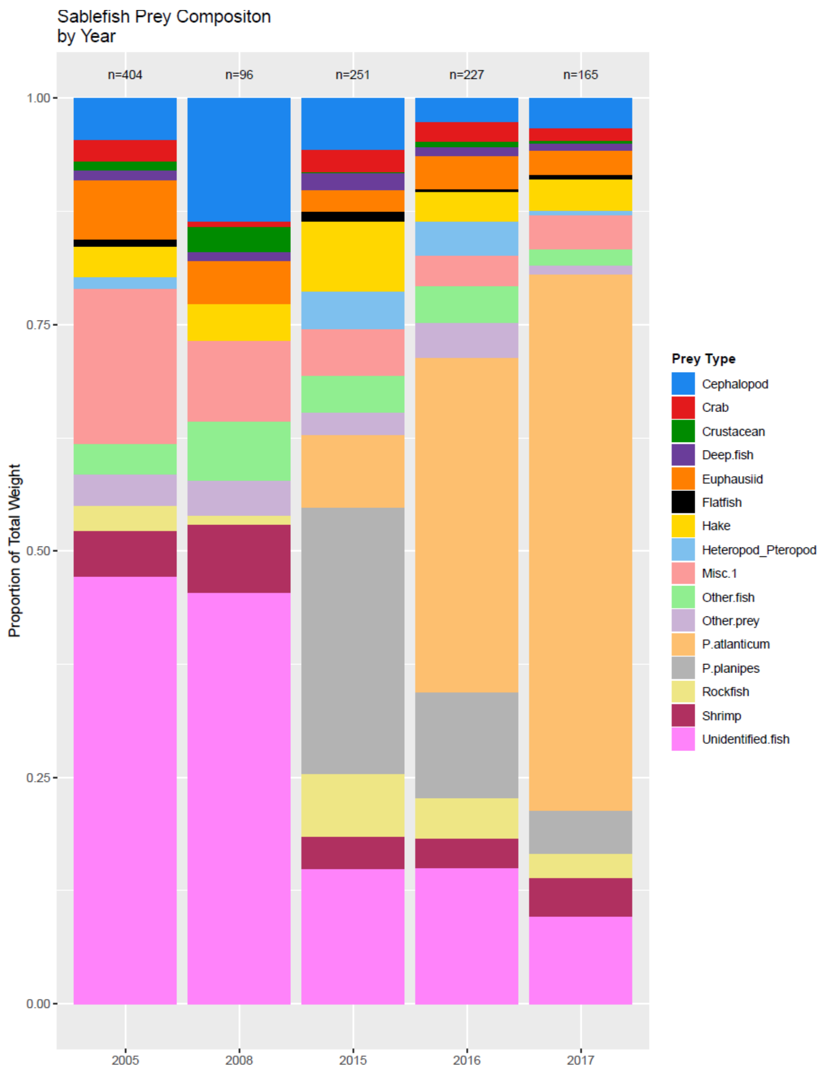


Figure 16. Stacked barplot of diet proportions by weight of sablefish prey groups for 2005, 2008, 2015-2017.

For more information, please contact Keith Bosley at Keith.Bosley@noaa.gov and Doug.Draper@noaa.gov

b) Resolving associative patterns in life history parameters among marine fish stocks in the Northeast Pacific Ocean

Investigators: Sean Matson, Vladlena Gertseva

Knowledge of life history characteristics in marine fishes, including natural mortality, somatic growth, maturity schedule, productivity and others, is essential for successful management and long-term sustainability of marine resources. Patterns exist among these traits within and among taxa to maximize individual fitness and offspring survival, and trade-offs are typical. In this study, we examined life history data from 42 fishery stocks in the Northeast Pacific Ocean using principal component analysis (PCA) and clustering techniques. We identified discrete clustering patterns of stocks corresponding to ecological, taxonomic, and management criteria. Our results revealed additional resolution for complex structure among stocks based on combinations of life history traits, well beyond what was described before, for the diverse group of Sebastes rockfish, which have not been examined in this context previously. One example is clear differentiation between Sebastes demersal species, and those caught with midwater gear, particularly with addition of stock-specific fecundity data; another is bocaccio rockfish, whose life history patterns our results shed new light on. Our results also provide an empirical basis for grouping stocks in meta-analytic studies, which are often used to inform unknown or difficult to estimate parameters in stock assessment. Our results supported important core aspects of previous studies, and rectified others, among a wide range of stocks including highly migratory, coastal pelagic and groundfish stocks. They also reinforce fishery management strategies grounded in life history, among stocks in the Northeast Pacific Ocean and around the world.

For more information, contact Dr. Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

2. Assessments

a) Assessing Cabezon (*Scorpaenichthys marmoratus*) stocks in waters off of California and Oregon, with catch limit estimation for Washington State

Investigators: J. Cope, A. Berger, A. Whitman, J. Budrick, K. Bosley, T-S. Tsou, C. Niles, K. Privitera-Johnson, L. Hillier, K. Hinton, M. Wilson

This assessment reports the status of the Cabezon (*Scorpaenichthys marmoratus*) in U.S. waters off the coast of Southern California, Northern California, and Oregon with consideration for setting catch limits in Washington. This is the fourth full assessment of the population status of Cabezon (for some sub-stocks) off the west coast of the United States, but the first in 10 years. The northern California sub-stock and the southern California sub-stock are demarcated at Point Conception, CA. Separation of these spatial sub-stocks is based on distinguishing localized population dynamics, preliminary population genetics results, and is supported by spatial differences in the fishery, the ecology of nearshore groundfish species, management regulations, and is consistent with current state management needs.

Harvest of Cabezon was primarily from recreational fisheries up until the 1990s and 2000s when the onset of the commercial live-fish fishery (mainly longline and hook and line gears) resulted in increased commercial landings. The main removal period in southern California occurred from the 1980s through the mid-1990s, at which point commercial catch became a major source of removals (Figure 17). Catches have steadily decreased since the early 2000s in southern California. Removals in northern California have been fairly steady since the 1950s, with a major peak in the mid to late 1990s due to the onset of the live-fish fishery (Figure 17). Current removals remain around the long-term average. Total landings in Oregon have generally increased through time, including a near doubling of landings with the onset of the commercial live-fish fishery in the late-1990s (Figure 18). Since that time (post-1996), total landings have largely been between 40-60 mt per year, except during 2013-2016 when total landings were closer to 30 mt. Recent landings continue to be dominated by the commercial live-fish and recreational ocean boat fleets, collectively representing 94% of the total in 2018. Cabezon has not been targeted by fisheries in Washington and annual total removals have been less than 12 mt.

The southern (SCS) and northern (NCS) California cabezon substock models are age structured models separated at Pt. Conception, CA. Two fishing sectors (commercial and recreational) and 5 total fleets (2 commercial and 3 recreational) defined the removal history. Data sources included relative indices of abundance, length compositions and a set of conditional ages at length.

SCS Cabezon spawning output was estimated to be 101 mt in 2019 (~95% asymptotic intervals: 19–183 mt), which when compared to unfished spawning output (262 mt) equates to a relative stock status level of 49% (~95% asymptotic intervals: 11–87% in 2019. In general, spawning output has fluctuated over the past few years after a steady increase in early years. Stock size is estimated to be approaching levels not seen since the 1970s. The stock is estimated to be above the management target of $SB_{40\%}$, and has been mostly above this mark since the 2010.

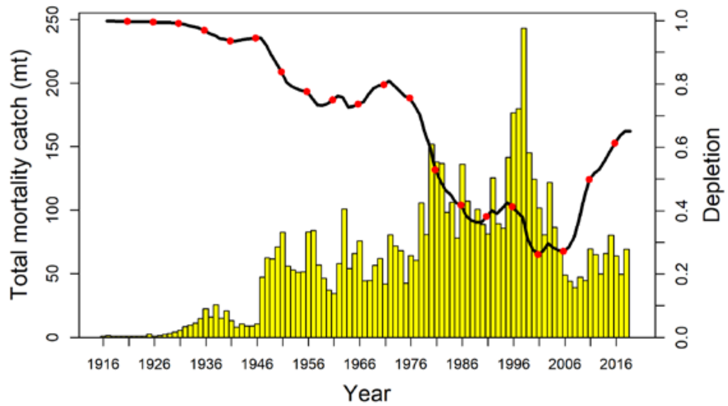
NCS Cabezon spawning output was estimated to be 643 mt in 2019 (~95% asymptotic intervals: 159–1,126 mt), which when compared to unfished spawning output (986 mt) equates to a relative stock status level of 65% (~95% asymptotic intervals: 22–108%) in 2019. The uncertainty in these quantities are very large. In general, spawning output has increased since the late 2000s. Stock size is estimated to be approaching levels not seen since the 1970s. The stock is estimated to be above the management target of $SB_{40\%}$, but measured with high uncertainty, and has been above this mark since around the time of the last assessment in 2009.

The Oregon assessment is structured as a single, sex- and age-disaggregated, unit population, spanning Oregon coastal waters, and operates on an annual time step covering the period 1970 to 2019. The model is conditioned on catch from two sectors (commercial and recreational) divided among 4 fleets, and is informed by four abundance indices, length compositions for each fleet, and age compositions from the recreational fishery, the commercial fishery, and from research surveys.

Cabezon spawning output in Oregon was estimated to be 177 mt in 2019 (~95% asymptotic intervals: 129-226 mt), which when compared to unfished spawning output (335 mt) equates to a depletion level of 53% (~95% asymptotic intervals: 43-63%) in 2019. In general, spawning output has been trending downwards until the early 2000s, after which it became more stable throughout the rest of the time series with a slight increase from 2017 through 2019 due to an above average recruitment estimate for the 2014 year class. Other years with relatively high estimates of recruitment were 1999, 2000, and 2002. Cabezon in Oregon has not been depleted to levels that would provide considerable information on how recruitment changes with spawning output at low spawning output levels. Harvest rates in Oregon have generally increased through time until reaching a more stable (but still variable from year to year) level beginning in the 2000s. The maximum relative harvest rate was 1.16 in 2001 (or 116% of the target level) before declining to around 0.80 in recent years. In 2018, Oregon Cabezon biomass is estimated to have been 1.32 times higher than the target biomass level, and fishing intensity remains lower than the SPR fishing intensity target. Major sources of uncertainty associated with the 2019 Cabezon assessment for Oregon were the size of population scale and value for natural mortality.

The Washington model uses a catch estimator approach to estimate overfishing levels. OFLs for 2021 and 2022, estimated by Simple Stock Synthesis (SSS), are 22.8 mt and 17.3 mt, respectively, given a 2018 depletion of 65% estimated using length-based spawning potential ratio (LBSPR).

Uncertainty in these OFL estimates is also explored and presented in the main document using 15 different scenarios that use three different catch history and five different depletion assumptions. In addition to reporting the median OFLs from each scenario, the scenarios are also combined into two ensembles. One ensemble treats all scenarios as equally plausible and the other weights the 65% depletion assumption and base catch history as more likely. The ensembles only differ by 0.1-0.3 mt from the OFLs produced by the 65% depletion and base catch history SSS run but show much wider uncertainty surrounding the median OFLs. Given the similarities in each approach, using the unweighted version provides the largest measure of uncertainty and may be most consistent with the largest uncertainty assumed for category 3 stocks.



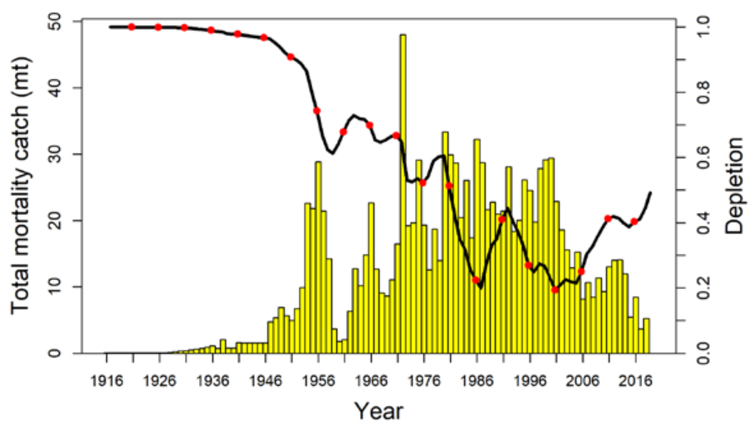


Figure 17. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Cabezon in Southern California (upper) and Northern California (lower), 1916-2018.

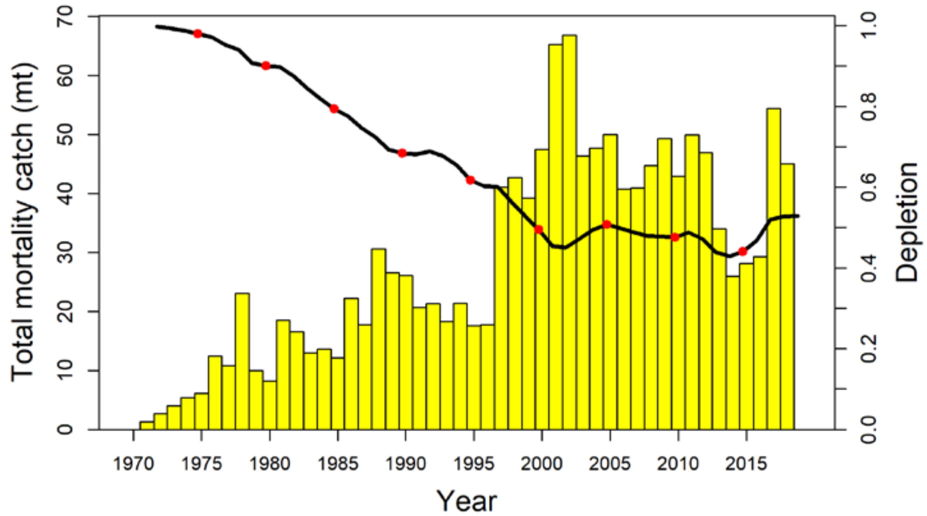


Figure 18. Total catch (mt; bars) and depletion (relative to average unexploited equilibrium level; line) for Cabezon in Oregon, 1970-2018.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov (California and Washington assessments) or Aaron Berger at Aaron.Berger@noaa.gov (Oregon assessment).

V. Ecosystem Studies

A. Socioeconomics

a) Coupled changes in biomass and distribution drive trends in availability of fish stocks to U.S. west coast ports

Investigators: Rebecca L. Selden, James T. Thorson, Jameal F. Samhouri, Steven J. Bograd, Stephanie Brodie, Gemma Carroll, Melissa Haltuch, Elliott Hazen, Kirstin Holsman, Malin Pinsky, Ellen Willis-Norton.

Fishing communities are increasingly required to adapt to environmentally driven changes in the availability of fish stocks. Here, we examined trends in the distribution and biomass of five commercial target species (Dover sole, thornyheads, sablefish, lingcod, and petrale sole) on the U.S. west coast to determine how their availability to fishing ports changed over 40 years. We show that the timing and magnitude of stock declines and recoveries are not experienced uniformly along the coast when they coincide with shifts in species distributions. For example, overall stock availability of sablefish was more stable in southern latitudes where a 40% regional decline in biomass was counterbalanced by a southward shift in distribution of >200 km since 2003. Greater vessel mobility and larger areal extent of fish habitat along the continental shelf buffered northerly ports from latitudinal changes in stock availability. Landings were not consistently related to stock availability, suggesting that social, economic, and regulatory factors likely constrain or facilitate the capacity for fishers to adapt to changes in fish availability. Coupled social–ecological analyses such as the one presented here are important for defining community vulnerability to current and future changes in the availability of important marine species.

For more information, contact Jameal Samhouri at Jameal.Samhouri@noaa.gov or Melissa Haltuch at Melissa.Haltuch@noaa.gov

b) Choice sets for spatial discrete choice models in data rich environments

Investigators: R.L. Hicks, D.S. Holland, P.T. Kuriyama, K.E. Schnier

Failure to properly specify an agent's choice set in discrete choice models will generate biased parameter estimates resulting in inaccurate behavioral predictions as well as biased estimates of policy relevant metrics. We propose a method of constructing choice sets by sampling from specific points in space to model agent behavior when choice alternatives are unknown to the researcher, potentially infinite, and differ according to spatial and temporal factors. Using Monte Carlo analysis, we compare the performance of this point-based sampling method to the commonly used approach of spatially aggregating choice alternatives. We then apply these alternative approaches to modelling location choice in the Pacific groundfish trawl fishery which has a complex spatial choice structure. Both the Monte Carlo and application results provide considerable support for the efficacy of the point-based approaches.

For more information please contact Dr. Dan Holland at NOAA's Northwest Fisheries Science Center, dan.holland@noaa.gov.

B. Assessment Science

1. Integrated Ecosystem Assessment of the California Current

Investigators: C.J. Harvey, N. Garfield, G.D. Williams, and N. Tolimieri, eds.; numerous contributors from the NWFSC, SWFSC and partner institutions

An integrated ecosystem assessment (IEA) is a science support element for ecosystem-based management (EBM); the IEA process involves synthesizing and analyzing information through steps that include scoping, indicator development, risk analysis, and evaluating management strategies. The primary goal of the California Current IEA is to inform the implementation of EBM by melding diverse ecosystem components into a single, dynamic fabric that allows for coordinated evaluations of the status of the California Current ecosystem. We also aim to involve and inform a wide variety of stakeholders and agencies that rely on science support for EBM, and to integrate information collected by NOAA and other federal agencies, states, non-governmental organizations, and academic institutions. The essence of IEAs is to inform the management of diverse, potentially conflicting ocean-use sectors. As such, a successful California Current IEA must encompass a variety of management objectives, consider a wide-range of natural drivers and human activities, and forecast the delivery of ecosystem goods and services under a multiplicity of scenarios. This massive undertaking will evolve over time.

The California Current IEA team develops an ecosystem status report (ESR) of the California Current each year, which describes the status and trends of many ecosystem indicators, including some related to groundfish. The ESR is presented to the Pacific Fishery Management Council and developed into an annual tech memo. ESRs and tech memos can be found at https://www.integratedecosystemassessment.noaa.gov/regions/california-current-region/index.html. Also, the California Current IEA team is conducting in-depth quantitative analysis of ecosystem indicators; assessing the risk posed by natural and anthropogenic stressors to key ecosystem resources and human wellbeing; and evaluating potential management strategies to determine which strategies are most effective in moving the ecosystem toward management goals and objectives, and to identify potential management tradeoffs. Many of these efforts also involve analyses related to groundfish.

For more information please contact Dr. Chris Harvey at NOAA's Northwest Fisheries Science Center, Chris.Harvey@noaa.gov.

2. Cooperative Ageing Unit

The Cooperative Ageing Project (CAP) operates under a grant from the Northwest Fisheries Science Center to Pacific States Marine Fisheries Commission, and provides direct support for U.S. west coast groundfish stock assessments by providing fish ages derived primarily from otoliths. In 2019, CAP production aged 20,318 age structures, production double read 7,977 age structures. Production ages supported the 2019 assessments on Pacific hake, sablefish, petrale sole, big skate and widow rockfish. Resources were also allocated to produce age estimates on anticipated assessments in 2021. CAP continued the practice of recording otolith weights prior to breaking and burning most specimens when possible. Over 11,000 otolith weights were collected in 2019 to support of research into alternative methods of age determination. Four CAP personnel attended the 2019 C.A.R.E conference (Committee of Age Reading Experts) in Seattle Washington.

For more information, please contact Jim Hastie at Jim.Hastie@noaa.gov

3. Modeling

a) The effect of survey frequency and intensity on U.S. west coast stock assessment estimates

Investigators: Owen S. Hamel, Ian G. Taylor, Jason M. Cope, Vladlena Gertseva, Melissa A. Haltuch, Aimee Keller, Andi Stephens, James T. Thorson, John R. Wallace, Chantel R. Wetzel

Fisheries management systems rely on stock assessments to inform management. Stock assessments, in turn, rely on well-designed and comprehensive surveys to provide data necessary to estimate scale and trends in fish populations. Given limited budgets and the financial demands of conducting surveys and the concomitant laboratory and analytical requirements, it is important to consider tradeoffs in designing surveys and evaluate alternative ways to reduce survey effort if required. We conducted a retrospective analysis of the impact of reducing the intensity or frequency of the U.S. West Coast Groundfish Bottom Trawl survey across eleven recently assessed species. Survey effort was reduced by approximately half through either an every-other year survey or reducing the number of vessels from four to two in each year. The influence of the survey reductions on assessment outputs and catch limits depend upon species life history, frequency of occurrence in the current survey, and the data-richness of each assessment. All approaches to reducing survey sampling led to increased uncertainty in stock assessment results, while variability in assessment results among survey configurations was greater for species that are less commonly encountered in the survey, species with less information from other sources, species that have not been heavily exploited, and for data-moderate assessments, which rely more heavily on survey indices.

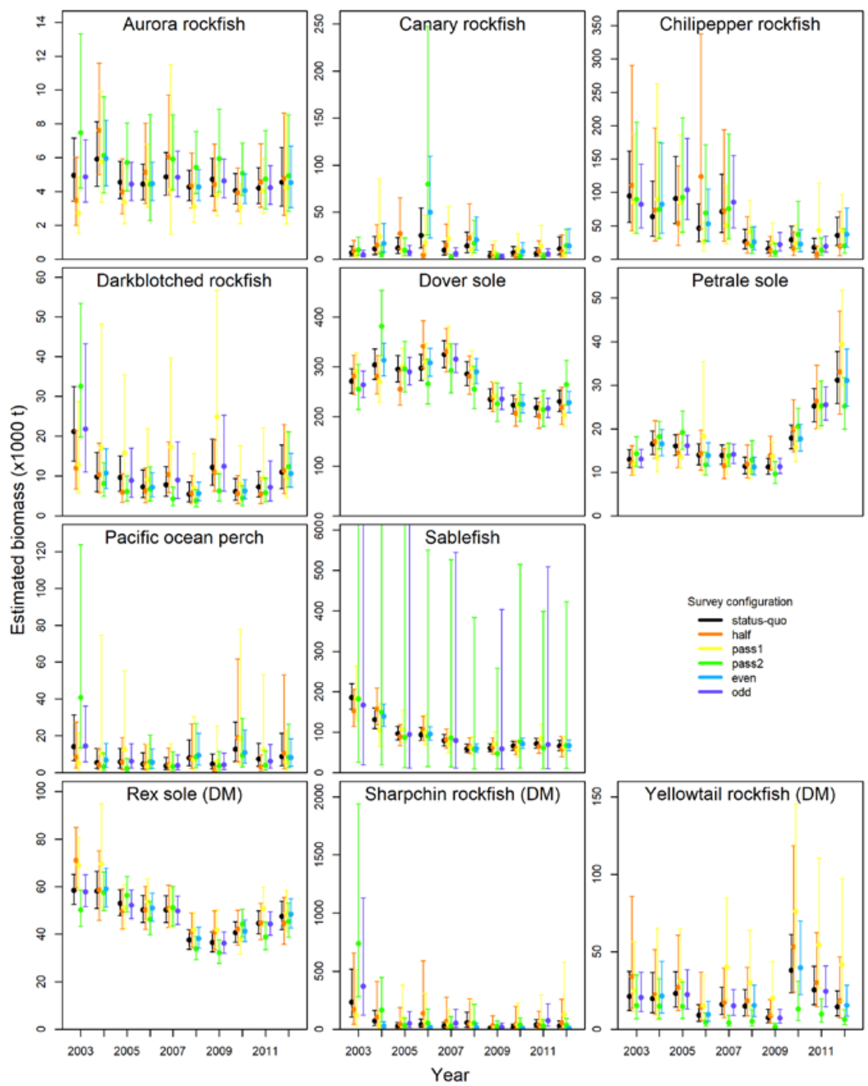


Figure 19. GLMM-derived indices of abundance and 75% lognormal confidence intervals for each survey configuration for each species. "DM" indicates species with Data Moderate stock assessments. The upper limit of the confidence intervals for sablefish that extend beyond the range of the figure are 1,451,000 t and 777,000 t for "odd" in 2003 and 2005, and 1,314,000 t, 1,131,000 t, and 616,000 t for "pass2" in 2003-2005.

For more information, please contact Owen Hamel at Owen.Hamel@noaa.gov

b) Evaluating the consequences of misdiagnosing population structure within spatial stock assessment models

Investigators: K. Bosley, A. Schueller, A. Berger, J. Deroba, D. Goethel, K. Fenske, D. Hanselman, B. Langseth

Contemporary spatially explicit assessment models have the ability to inform fine-scale processes and spatial management of heterogeneous populations. For example, estimates of productivity may be improved by simultaneously modeling individual spawning components instead of aggregating data and parameters across the entire spatial domain. Although spatial models provide a more realistic representation of the true population dynamics, few studies have evaluated the potential risk associated with incorrect assumptions regarding population structure. We simulated the dynamics of a long-lived demersal species (sablefish) under different assumptions of population structure (panmictic, spatial heterogeneity, and metapopulation), then applied various assessment approaches (panmictic, fleets-as-areas, and spatially explicit) to simulated data. Model performance was evaluated for scenarios where the assumptions of spatial population structure in the assessment either matched or incorrectly diagnosed the underlying spatial population dynamics. Parameter estimates were generally unbiased at the system level even when the spatial structure was incorrectly specified, however, area-specific values were often biased unless spatial structure was correctly identified in the assessment model. Fleets-as-areas models performed poorly primarily because the method does not explicitly account for movement or spatial variation in recruitment. Models that incorporated tagging data improved the estimation of area-specific parameters even when the models were misspecified. These results elucidate how incorrect assumptions regarding population structure influence the estimation of key parameters used in fisheries management and which model parameterizations are robust to lack of information on the true population structure. Spatial models are advantageous because outputs are generated at scales relevant to important sources of variability, therefore they can inform spatial management even if incorrectly specified. *ICES.*

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

c) Overcoming challenges of harvest quota allocation in spatially structured populations

Investigators: K. Bosley, D. Goethel, A. Berger, J. Deroba, K. Fenske, D. Hanselman, B. Langseth, A. Schueller

Ignoring spatial population structure in the development of fisheries management advice can affect population resilience and yield. However, the resources required to develop spatial stock assessment models that match the spatial scale of management are often unavailable. As a result, quota recommendations from spatially aggregated assessment models are commonly divided among management areas based on empirical methods. We developed a spatially explicit simulation model to 1) explore how variation in population structure influences the spatial distribution of harvest that produces maximum system yield, and 2) contrast the performance of empirical quota allocation methods in approximating ideal spatial harvest strategies. Spatial scenarios that included post-recruitment movement resulted in a broader range of spatial management options (e.g., setting regional total allowable catch) that achieved near maximum system yield compared to scenarios without movement. Stochastic projections showed that using the proportion of total survey biomass in each management area to spatially allocate quota performed best for maximizing system yield when the true spatial structure was unknown, considerably outperforming equal allocation and allocation based on a recruitment index. However, with all methods, area-specific harvest rates sometimes led to unintended depletion within management units. Improved data and understanding of spatial stock dynamics can reduce the need for ad hoc approaches for spatial harvest allocation, allow for a greater range of management options, and increase the efficacy of spatial management procedures.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

d) Exploring the utility of different tag-recovery experimental designs for use in spatially explicit, tag-integrated stock assessment models

Investigators: D. Goethel, K. Bosley, D. Hanselman, A. Berger, J. Deroba, B. Langseth, A. Schueller

The need for spatial stock assessment models that match the spatiotemporal management and biological structure of marine species is growing. Spatially explicit, tag-integrated models can emulate complex population structure, because they are able to estimate connectivity among population units by incorporating tag-recovery data directly into the combined objective function of the assessment. However, the limited scope of many small-scale tagging studies along with difficulty addressing major assumptions of tagging data has prevented more widespread utilization of tag-recovery data sets within tag-integrated models. A spatially explicit simulation-estimation framework that simulates metapopulation dynamics with two populations and time-varying connectivity was implemented for three life history (i.e., longevity) scenarios to explore the relative utility of tagging data for use in spatial assessment models across a range of tag release designs (e.g., annual, historical, periodic, and opportunistic tagging). Model scenarios also investigated the impacts of not accounting for incomplete tag mixing or assuming all fish were fully selected (i.e., that the age composition of tagged fish was unknown). Results demonstrated that periodic tagging (e.g., releasing tags every five years) may provide the best balance between tag program cost and parameter bias. For cost-effective tagging programs, tag releases should be spread over a longer time period instead of focusing on release events in consecutive years, while releasing tags in tandem with existing surveys could further improve the practicality of implementing tag-recovery experiments. However, care should be taken to fully address critical modeling assumptions (e.g., by estimating tag mixing parameters) before incorporating tagging data into an assessment model.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

e) Recent advances in management strategy evaluation: introduction to the special issue "Under pressure: addressing fisheries challenges with Management Strategy Evaluation"

Investigators: D. Goethel, S. Lucey, A. Berger, S. Gaichas, M. Karp, P. Lynch, J. Walter

Management strategy evaluation (MSE) is an increasingly popular tool for developing, testing, and implementing fisheries management regimes, oftentimes utilizing participatory modeling. This special issue, “Under pressure: addressing fisheries challenges with Management Strategy Evaluation”, includes eleven articles highlighting cutting edge MSE approaches and perspectives on improving stakeholder engagement. The special issue is the culmination of a two-session MSE symposium held during the 147th American Fisheries Society Annual Meeting in Tampa, Florida. We summarize the themes from the symposium and special issue articles. Contributions demonstrated that important strides have been made in quantifying and exploring risk (by including more sophisticated multispecies and socioeconomic components), developing and testing data limited harvest control rules, acknowledging and diagnosing limitations of MSE (e.g., identifying exceptional circumstances), and dealing with issues of stakeholder engagement and dimensionality (e.g., determining appropriate representation, communication techniques, and participation levels). Although MSE is a not a panacea for marine policy and resource utilization issues, it is a useful tool for implementing co-management regimes that should become increasingly robust as the multidisciplinary nature of MSE processes continues to expand.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

f) Character of temporal variability in stock productivity influences the utility of dynamic reference points

Investigator: A. Berger

Reference points identify benchmarks, thresholds, or decision points for fisheries management, and are commonly defined by stock status indicators that presume equilibrium population conditions in the absence of fishing (e.g., equilibrium biomass, B_0). However, equilibrium population biomass may be an inappropriate reference level when stock productivity is influenced by environmental change, predator-prey dynamics, ecosystem thresholds, and myriad other factors. Simulations were conducted to compare equilibrium-based (static B_0) and non-equilibrium based (dynamic B_0) indicators of stock status under alternative states of nature driven by time-varying recruitment dynamics (productivity regime), fishing dynamics (mortality regime), and species life history. Using dynamic B_0 often implied a different state of the stock under directional productivity regime shifts, but was more similar to static B_0 reference points under cyclic or white noise productivity scenarios. Uncertainty in stock status arising from incorrectly identifying changes in system productivity generally outweighed the uncertainty associated with initial equilibrium conditions. Empirical results across 18 U.S. west coast groundfish stock assessments indicated predominantly small differences (<10%) between static B_0 and dynamic B_0 indicators of stock status, although in some cases differences were large (up to 72%) or spanned reference points that trigger management action. Although caution is warranted when considering dynamic reference points, this paper shows these approaches are likely to be most useful when stock productivity shifts directionally, if that productivity signal can be correctly ascertained.

For more information, please contact Aaron Berger at Aaron.Berger@noaa.gov

g) Realizing the potential of trait-based approaches to advance fisheries science.

Investigators: L. Barnett, N. Jacobson, J. Thorson, J.M. Cope.

Analyzing how fish populations and their ecological communities respond to perturbations such as fishing and environmental variation is crucial to fisheries science. Researchers often predict fish population dynamics using species-level life-history parameters that are treated as fixed over time, while ignoring the impact of intraspecific variation on ecosystem dynamics. However, there is increasing recognition of the need to include processes operating at ecosystem levels (changes in drivers of productivity) while also accounting for variation over space, time and among individuals. To address similar challenges, community ecologists studying plants, insects and other taxa increasingly measure phenotypic characteristics of individual animals that affect fitness or ecological function (termed "functional traits"). Here, we review the history of trait-based methods in fish and other taxa, and argue that fisheries science could see benefits by integrating trait-based approaches within existing fisheries analyses. We argue that measuring and modelling functional traits can improve estimates of population and community dynamics, and rapidly detect responses to fishing and environmental drivers. We support this claim using three concrete examples: how trait-based approaches could account for time-varying parameters in population models; improve fisheries management and harvest control rules; and inform size-based models of marine communities. We then present a step-by-step primer for how trait-based methods could be adapted to complement existing models and analyses in fisheries science. Finally, we call for the creation and expansion of publicly available trait databases to facilitate adapting trait-based methods in fisheries science, to complement existing public databases of life-history parameters for marine organisms.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

h) Testing methods of determining relative stock abundance priors when setting catch recommendations using data-limited approaches.

Investigators: A. Chrysafi, J.M. Cope

Data-limited methods for managing stocks have expanded greatly over the last decade due to the necessity of quantitatively assessing exploited populations with limited information. A special category of such approaches is based on stock reduction analysis. These "catch-only" methods provide a way to handle low data availability, but also require as an input relative stock status (e.g., current biomass/initial biomass), a difficult to determine value that leads to large sensitivity in method output and performance. Published methods have been developed to devise informative priors for this quantity, but have not been evaluated together with the assessment methods. Here, relative stock abundance priors derived from elicited expert knowledge, vulnerability analysis and catch trends are compared to the common assumption of a stock being at B40% (40% of the initial biomass). The performance of each prior source is evaluated both in the degree of bias in estimating stock status and in the estimation procedure of catches for ten data-rich stocks with six stock assessment models that require stock abundance input. The results from both performance metrics show that these alternative sources can provide more accurate priors than assuming current biomass equals B40%, with priors elicited from stock assessment experts performing best.

Finally, based on the findings of this work and the data requirements to construct a stock abundance prior, we make recommendations on how to navigate the options for devising a relative stock status prior.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

i) Performance evaluation of data-limited length-based stock assessment methods

Investigators: L. Chong, T. Mildenberger, M.B. Rudd, M.H. Taylor, J.M. Cope, T.A. Branch, M. Wolff, M. Stabler.

Performance evaluation of data-limited, length-based methods is instrumental in determining and quantifying their accuracy under various scenarios and in providing guidance about model applicability and limitations. We conducted a simulation–estimation analysis to compare the performance of four length-based stock assessment methods: length-based Thompson and Bell (TB), length-based spawning potential ratio (LBSPR), length-based integrated mixed effects (LIME), and length-based risk analysis (LBRA), under varying life history, exploitation status, and recruitment error scenarios. Across all scenarios, TB and LBSPR were the most consistent and accurate assessment methods. LBRA is highly biased, but precautionary, and LIME is more suitable for assessments with time-series longer than a year. All methods have difficulties when assessing short-lived species. The methods are less accurate in estimating the degree of recruitment overfishing when the stocks are severely overexploited, and inconsistent in determining growth overfishing when the stocks are underexploited. Increased recruitment error reduces precision but can decrease bias in estimations. This study highlights the importance of quantifying the accuracy of stock assessment methods and testing methods under different scenarios to determine their strengths and weaknesses and provides guidance on which methods to employ in various situations

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

j) Performance of catch-based and length-based methods in data-limited fisheries

Investigators: M. Pons, J.M. Cope, L. Kell

The quantity of data from many small-scale fisheries is insufficient to allow for the application of conventional assessment methods. Even though in many countries they are moving to close-loop simulations to assess the performance of different management procedures in data limited situations, managers in most developing countries are still demanding information on stock status. In this study we use the common metric of harvest rate to evaluate and compare the performance of the following catch-only and length-only assessment models: Catch-Maximum Sustainable Yield (Catch-MSY), Depletion Based Stock Reduction Analysis (DBSRA), Simple Stock Synthesis (SSS), an extension of Catch-MSY (CMSY), Length Based Spawning Potential Ratio (LBSPR), Length-Based Integrated Mixed Effects (LIME), and Length-Based Bayesian (LBB). In general, results were more biased for slightly depleted than for highly depleted stocks, and for long-lived than for short-lived species. Length-based models, such as LIME, performed as well as catch-based methods in many scenarios and, among the catch-base models the one with the best performance was SSS.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

k) When are model-based stock assessments rejected for use in management and what happens then?

Investigators: A.E. Punt, G. Tuck, J. Day, C. Canales, J. Cope, C. De Moor, M. Dickey Collas, B. Elvarsson, M. Haltuch, O. Hamel, A. Hicks, C. M. Legault, P. D. Lynch, M. Wilberg

Model-based stock assessments form a key component of the management advice for fish and invertebrate stocks worldwide. It is important for such assessments to be peer-reviewed and to pass scientific scrutiny before they can be used to inform management decision making. While it is desirable for management decisions to be based on quantitative assessments that use as much of the available data as possible, this is not always the case. A proposed assessment may be found to be unsatisfactory during the peer-review process (even if it utilizes all of the available data), leading to decisions being made using simpler approaches. This paper provides a synthesis across seven jurisdictions of the types of diagnostic statistics and plots that can be used to evaluate whether a proposed assessment is 'best available science', summarizes several cases where a proposed assessment was not accepted for use in management, and how jurisdictions are able to provide management advice when a stock assessment is 'rejected.' The paper concludes with recommended general practices for reducing subjectivity when deciding whether to accept an assessment and how to provide advice when a proposed assessment is rejected.

For more information, please contact Jason Cope at Jason.Cope@noaa.gov

l) Investigating the value of including depth during spatiotemporal index standardization

Investigators: Kelli F. Johnson, James T. Thorson, André E. Punt

There are many methods available for estimating the current abundance of fish species. Design-based estimators, which assume random sampling within the sampling domain, have conventionally been used to provide relative indices of abundance. More recently, the use of spatiotemporal models has increased because of their ability to explicitly account for spatial heterogeneity and higher precision relative to design-based estimators. In theory, the inclusion of covariates (e.g., depth) should also improve precision by explaining a portion of the variability in fish abundance. We used a simulation experiment to evaluate the bias and precision of results from spatio-temporal index-standardization models when the true process was and was not governed by depth. The simulation was conditioned on fits to data for darkblotched rockfish (*Sebastes crameri*) because of the known preference of older individuals for deeper water, coupled with their limited migration after recruiting to the fishery. Trends in the simulated indices of abundance were estimated without bias, although individual parameters were not necessarily unbiased. Incorrectly including depth when it did not govern the true process was less problematic than not including it when it should have been included. Akaike Information Criterion correctly identified overfitting when the true dynamics were not governed by depth. Results illustrate how spatiotemporal models can include covariates, but additional testing is needed with respect to the utility of including dynamic covariates that vary in space and time or covariates that do not covary with latitude or longitude.

For more information, please contact Kelli Johnson at kelli.johnson@noaa.gov

m) Operationalizing model ensembles to provide scientific advice for fisheries management

Investigators: Ernesto Jardim, Jon Brodziak, Manuela Azevedo, Elizabeth Brooks, Kelli F. Johnson, Nikolai Klibansky, Coilin Minto, Colin Millar, Iago Mosqueira, Richard Nash, Paris Vasilakopoulus, Brian Wells

Providing scientific advice to fisheries managers can be a risky activity! It's not uncommon that a model which was working perfectly fails to properly fit an additional year of data, or to find that projections made in the past did not materialize when new information was made available. Scientists deal with very complex systems, with many unknown or poorly understood processes and limited information, which make advisory tools sensitive to alternative system representations, model assumptions or new data. Our approach to mitigate the potential lack of robustness and instability of fisheries advice is to expand its basis to integrate structural uncertainty using model ensembles. Two main reasons to use model ensembles are: to include structural uncertainty captured by differences across models of the same system, and to integrate across initial conditions and process errors in projections. This paper discusses and speculates about the utility and implementation of model ensembles for scientific advice to fisheries management. We discuss ensemble utilization, ensemble types, weighting metrics, model space and model expansion. We make the case for using ensembles in three main situations: to estimate stock status, to set future fishing opportunities, and to build operating models for management strategy evaluation.

For more information, please contact Kelli Johnson at kelli.johnson@noaa.gov

n) Visualizing and reporting model uncertainty in stock assessments

Investigators: Jason Cope, Vladlena Gertseva

We developed a visual representation of fisheries stock assessment model outputs to rapidly examine and effectively communicate results of sensitivity tests and model comparisons. This approach allows rapid identification of which stock assessment model configurations deserve further attention when quantifying uncertainty in model outputs important to management decisions. A detailed table aids identification as to what caused the major changes in those models identified as significantly different. The method can be used within a stock assessment of any stock around the world, and it was successfully applied in several groundfish stock assessments on the U.S. west coast.

For more information contact Dr. Jason Cope at Jason.Cope@noaa.gov and Dr. Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

o) Right on target: Using data from targeted stocks to inform stock assessment of bycatch species.

Investigators: Vladlena Gertseva, Sean Matson

Fisheries stock assessments heavily rely on historical catch information, to understand how a stock responds to exploitation and make meaningful forecast into the future under alterative management and environmental scenarios. However, for many bycatch species historical removals are virtually unknown as large portion of the catch is discarded at sea. For example, historical discard of elasmobranch species, such as skates and sharks, have been reported to be over 95% of the total catch based on available data. The longnose skate is one the most abundant groundfishes on the outer continental slope and upper continental slope of the U.S. Pacific Coast by biomass and the most abundant skate species in the Northeast Pacific Ocean. We developed a method to estimate catch of longnose skate on the U.S. west coast from catch of Dover sole, a targeted species that longnose skate co-occurs with and is often caught together. This method allowed us to reconstruct historical longnose skate catches back to the beginning of the bottom trawl fisheries and improve stock assessment for this species. Our method is not limited to specific case of longnose skate and can be easily adopted for other species and areas.

For more information, contact Dr. Vladlena Gertseva at Vladlena.Gertseva@noaa.gov

p) Unraveling the recruitment problem: A review of environmentally-informed forecasting and management strategy evaluation

Investigators: M.A. Haltuch, J. Brodziak, L. Brooks, J. Devine, A. Frank, K. Johnson, N. Klibansky, R. Nash, M. Payne, K. Shertzer, S. Subbey, B. Wells

Studies describing and hypothesizing the impact of climate change and environmental processes on vital rates of fish stocks are increasing in frequency, and concomitant with that is interest in incorporating these processes in fish stock assessments and forecasting models. Previous research suggests that including environmental drivers of fish recruitment in forecasting is of limited value, concluding that forecasting improvements are minimal while potential spurious relationships were sufficient to advise against inclusion. This review evaluates progress in implementing environmental factors in stock-recruitment projections and Management Strategy Evaluations (MSEs), from the year 2000 through 2017, by reviewing studies that incorporate environmental processes into recruitment forecasting, full-cycle MSEs, or simulations investigating harvest control rules. The only successes identified were for species with a short pre-recruit survival window (e.g., opportunistic life-history strategy), where the abbreviated life-span made it easier to identify one or a limited set of key drivers that directly impact dynamics. Autoregressive methods appeared to perform as well, if not better, for species with a longer pre-recruit survival window (e.g., seasonal, inter-annual) during which the environment could potentially exert influence. This review suggests that the inclusion of environmental drivers into assessments and forecasting is most likely to be successful for species with short pre-recruit survival windows (e.g., squid, sardine) and for those that have bottlenecks in their life history during which the environment can exert a well-defined pressure (e.g., anadromous fishes, those reliant on nursery areas). The effects of environment may be more complicated and variable for species with a longer pre-recruit survival window, reducing the ability to quantify environment-recruitment relationships. Species with more complex early life histories and longer pre-recruit survival windows would benefit from future research that focuses on relevant species-specific spatio-temporal scales to improve mechanistic understanding of abiotic-biotic interactions.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

q) How does growth misspecification affect management advice derived from an integrated fisheries stock assessment model?

Investigators: C.C. Stawitz, M.A. Haltuch, K. Johnson

Analysts must make many decisions regarding model specification when fitting integrated fishery stock assessment models. While variation in vital rates (i.e., recruitment, somatic growth, and natural mortality) is common, capturing this variation in models fit to available data is often infeasible or impractical. Failing to account for this variation can result in underestimates of uncertainty and even biased estimates of stock status used for management advice. Here, we seek to determine how growth misspecification affects management advice derived from integrated stock assessment models that use the Stock Synthesis platform. We conduct a simulation-based case study on California Current petrale sole (Eopsetta jordani) to test whether and how the inclusion or omission of somatic-growth variation introduces bias into management reference points when estimation models misspecify growth. Scenarios we explored included inter-annual and regime-like changes in two key parameters (k, the initial slope of the growth curve, and L2, the asymptotic maximum length) used to model somatic growth in Stock Synthesis. We find misspecification of growth can overestimate management quantities, particularly the estimate of current biomass relative to the unfished biomass (stock depletion). This results in an overly optimistic view of stock status. This bias may be mitigated or eliminated if the assessment model includes growth variation. Including growth variation in the estimation model can also reduce the uncertainty in estimated management quantities by correctly attributing process error to somatic growth. However, the magnitude of detected biases is exceeded by the uncertainty when data are limited, suggesting that estimating growth variation is helpful only in relatively data-rich stock assessment models. We suggest investigators of data-rich assessments consider incorporating time-varying growth parameters into assessment models or decision tables more frequently to account for potential biases and reduce uncertainty caused by temporal growth variation.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

r) A review of methods for quantifying spatial predator–prey overlap

Investigators: G. Carroll, Holsman, K., Brodie, S., Thorson, J., Hazen, E., Bograd, S., Haltuch, M.A., Kotwicki, S., Samhouri, J., Spencer, P., Willis-Norton, E., Selden, R.

Background: Studies that attempt to measure shifts in species distributions often consider a single species in isolation. However, understanding changes in spatial overlap between predators and their prey might provide deeper insight into how species redistribution affects food web dynamics.

Predator–prey overlap metrics: Here, we review a suite of 10 metrics [range overlap, area overlap, the local index of collocation (Pianka's O), Hurlbert's index, biomass weighted overlap, asymmetrical alpha, Schoener's D, Bhattacharyya's coefficient, the global index of collocation and the AB ratio] that describe how two species overlap in space, using concepts such as binary co-occurrence, encounter rates, spatial niche similarity, spatial independence, geographical similarity and trophic transfer. We describe the specific ecological insights that can be gained using each overlap metric, in order to determine which is most appropriate for describing spatial predator–prey interactions for different applications.

Simulation and case study: We use simulated predator and prey distributions to demonstrate how the 10 metrics respond to variation in three types of predator–prey interactions: changing spatial overlap between predator and prey, changing predator population size and changing patterns of predator aggregation in response to prey density. We also apply these overlap metrics to a case study of a predatory fish (arrowtooth flounder, *Atheresthes stomias*) and its prey (juvenile walleye pollock, *Gadus chalcogrammus*) in the Eastern Bering Sea, AK, USA. We show how the metrics can be applied to understand spatial and temporal variation in the overlap of species distributions in this rapidly changing Arctic ecosystem.

Conclusions: Using both simulated and empirical data, we provide a roadmap for ecologists and other practitioners to select overlap metrics to describe particular aspects of spatial predator–prey interactions. We outline a range of research and management applications for which each metric may be suited.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

s) Trade-offs in covariate selection for species distribution models: a methodological comparison

Investigators: Stephanie Brodie, Gemma Carroll, James T. Thorson, Elliott L. Hazen, Steven Bograd, Melissa Haltuch, Kirstin Holsman, Stan Kotwicki, Ellen Willis-Norton, Jameal Samhouri, Rebecca Selden

Species distribution models (SDMs) are a common approach to describing species' space-use and spatially-explicit abundance. With a myriad of model types, methods and parameterization options available, it is challenging to make informed decisions about how to build robust SDMs appropriate for a given purpose. One key component of SDM development is the appropriate parameterization of covariates, such as the inclusion of covariates that reflect underlying processes (e.g. abiotic and biotic covariates) and covariates that act as proxies for unobserved processes (e.g. space and time covariates). It is unclear how different SDMs apportion variance among a suite of covariates, and how parameterization decisions influence model accuracy and performance. To examine trade-offs in covariation parameterization in SDMs, we explore the attribution of spatiotemporal and environmental variation across a suite of SDMs. We first used simulated species distributions with known environmental preferences to compare three types of SDM: a machine learning model (boosted regression tree), a semi-parametric model (generalized additive model) and a spatiotemporal mixed effects model (vector autoregressive spatiotemporal model, VAST). We then applied the same comparative framework to a case study with three fish species (arrowtooth flounder, Pacific cod and walleye pollock) in the eastern Bering Sea, USA. Model type and covariate parameterization both had significant effects on model accuracy and performance. We found that including either spatiotemporal or environmental covariates typically reproduced patterns of species distribution and abundance across the three models tested, but model accuracy and performance was maximized when including both spatiotemporal and environmental covariates in the same model framework. Our results reveal trade-offs in the current generation of SDM tools between accurately estimating species abundance, accurately estimating spatial patterns, and accurately quantifying underlying species–environment relationships. These comparisons between model types and parameterization options can help SDM users better understand sources of model bias and estimate error.

For more information, contact Melissa Haltuch at Melissa.Haltuch@noaa.gov

C. Survey Science

1. Research

a) Accounting for seasonal and composition-related variability in acoustic material properties in estimating copepod and krill target strength

Investigators: Serdar Sakinan, Gareth Lawson, Peter Wiebe, Dezhang Chu, Nancy Copley

Estimation of abundance or biomass, using acoustic techniques requires knowledge of the frequency dependent acoustic backscatter characteristics, or target strength, of organisms. Target strength of zooplankton is typically estimated from physics-based models that involve multiple parameters, notably including the acoustic material properties (i.e., the contrasts in density and sound speed between the animal and surrounding seawater). In this work, variability in the acoustic material properties of two zooplankton species in the Gulf of Maine, the copepod (*Calanus finmarchicus*) and krill (*Meganyctiphanes norvegica*), was investigated relative to changing season as well as, for the copepod, temperature and depth. Increases in the density and sound speed contrasts of these species from fall to spring were observed. Target strength predictions based on these measurements varied between fall and spring by 2-3 dB in krill. Measurements were also conducted on *C. finmarchicus* lipid extract at changing temperature and pressure. The density contrast of the extract varied negatively with temperature, while the sound speed contrast changed by more than 10 % over the temperature and pressure ranges that the organism expected to occupy. *C. finmarchicus* target strength predictions showed that the combined effect of temperature and pressure can be significant (more than 10 dB) due to the varying response of lipids. The large vertical migration ranges and lipid accumulation characteristics of these species (e.g., the diapause behaviour of *Calanus* copepods) suggest that it is necessary for seasonal and environmental variability in material properties to be taken into account to achieve reliable measurements.

For more information, please contact Dezhang Chu at Dezhang.Chu@noaa.gov

c) ZooScatR—An R package for modelling the scattering properties of weak scattering targets using the distorted wave Born approximation

Investigators: Sven Gastauer, Dezhang Chu, Martin Cox

A thorough understanding of the scattering characteristics of marine organisms is a prerequisite for robust quantitative fisheries acoustic data processing or interpretation. Target strength models, such as the distorted wave Born approximation (DWBA) can be used to improve the understanding of field recordings of weakly scattering targets. With acoustic methods now being used by a wide audience, allowing access to such models becomes a necessity. To ease access to the DWBA model, an r package (zooscatr) which includes a web application and the ability to parameterize the model either through the web application, text files, or pure scripting has been developed and is now freely available on Github.

For more information, please contact Dezhang Chu at Dezhang.Chu@noaa.gov

d) The Joint U.S.-Canada integrated ecosystem and Pacific hake acoustic-trawl survey: Growing beyond a single-species focus

Investigators: Sandra Parker-Stetter, Stéphane Gauthier, Julia Clemons, Michael Malick, Elizabeth Phillips, Alicia Billings, Dezhang Chu, Steve de Blois, Jackie Detering, John Pohl, Ben Snow, Chelsea Stanley, Rebecca Thomas

The Integrated Ecosystem and Pacific Hake Acoustic-Trawl Survey has been conducted along the coasts of California, Oregon, Washington, and British Columbia since 1992. Beginning in 2003, the Survey has been a biennial partnership between the Northwest Fisheries Science Center (NWFSC) and Fisheries and Oceans Canada (DFO), including a 3-year shared effort with Southwest Fisheries Science Center (2012, 2013, 2015). The joint NWFSC-DFO survey supports the Pacific Hake (*Merluccius productus*) stock assessment under the U.S.-Canada Pacific Hake/Whiting Treaty. The original survey goal was simple: use acoustic data and midwater trawling to estimate age-2+ Hake biomass and provide biological information for the age-based stock assessment. Over time, survey sampling and data products have expanded in response to changing capabilities and needs. Acoustic analyses now include age-1 Hake and euphausiids/krill (a key prey item for Hake), with anticipated future inclusions of pelagic rockfish and mesopelagic fish. Oceanographic data, once limited to temperature-depth measurements during midwater trawls, now include continuous day/night Acoustic Doppler Current Profiler (ADCP) data, nighttime Conductivity-Temperature-Depth (CTD) rosette casts, and daytime Underway CTD casts. Many of these data have been processed and are becoming publicly available. Environmental data are being used to groundtruth forecasts of Hake horizontal distribution, integrated into models of Hake and euphausiid habitat use, and as inputs to bioenergetics models of Hake growth. Upcoming projects will evaluate the potential role of dissolved oxygen in Hake and euphausiid vertical distributions. From a biological standpoint, the Survey supports a host of regular and on-demand joint and partner projects, including studies of maturity, physiology, tagging, stable isotopes, and genetic studies. With its large spatial coverage, the Survey is the platform for the coast-wide Harmful Algal Bloom (HAB) sampling and also completes 5-6 sampling lines for zooplankton between CA and BC. In 2019, the Survey's CTD rosettes provided water samples for the eDNA Strategic Initiative, and the NOAA Ship Bell M. Shimada's flow-through system was used to evaluate potential utility of a continuous phytoplankton sampler (CytoBot). While the Survey maintains its strong ties to fisheries management, it continues to evolve to efficiently meet broader acoustic, biological, oceanographic, and ecosystem data and sampling needs.

For more information, please contact Sandra Parker-Stetter at Sandra Parker-Stetter@noaa.gov.

e) Small scale acoustic surveys, mapping prey fields and sizing fish – Portable and on a budget

Investigators: Sven Gastauer, Lachlan Philipps, Adam Wilkins, Robert Harcourt, Ian Jonsen, Gemma Carroll, Ben Pitcher, Dezhang Chu, Martin Cox

The use of acoustics as a non-invasive sampling technique to monitor marine resources has largely been accepted. A main limitation of the technology is that it generally requires large, expensive research vessels. Besides the economic limitations, this also limits surveys to the open ocean. Yet inshore coastal systems are ecologically and economically important. We examined a portable system that can be easily transported and mounted on small (>5m) boats to enable acoustic surveys to be run without the need for a dedicated, scientific survey vessel. The usefulness of small-scale surveys was illustrated based on an acoustic prey-field survey for foraging penguins. Further the variability of high- and low-density single targets on broadband data were illustrated and methods on how to determine fish size based on acoustic data only demonstrated.

For more information, please contact Dezhang Chu at Dezhang.Chu@noaa.gov

f) How much more informative are broadband compared to narrowband echoes for biological interpretation?

Investigators: Wu-Jung Lee, Dezhang Chu, Stan Dosso

The recent availability of commercial broadband echosounders has elicited wide interests in their potentials for enhancing the effectiveness, efficiency, and accuracy of acoustic sensing capability for monitoring mid-trophic level marine organisms. However, despite the significantly improved temporal and spatial resolutions, it remains unclear how the additional spectral information provided by broadband echosounders contribute to achieving these goals. In this study, we use a Bayesian inversion framework to compare the estimation uncertainty between broadband and narrowband echo data for biological model parameters, such as organism length, tile angle, numerical density and aggregation composition. We employ the Markov Chain Monte-Carlo (MCMC) sampling technique to construct the posterior probability density (PPD) of biological parameters given simulated zooplankton and calibrated fish echo data in the form of volume backscattering strength (Sv). The data are simulated for frequency ranges commonly employed in marine ecological and fisheries surveys. We investigate the changes in PPD in response to variations in echo spectral information, with specific emphasis on the correlation structure among model parameters and whether and how broadband information reduces the uncertainty in inferring biological information from acoustic quantities available from field surveys. [Work supported by NMFS Office of Science and Technology Advanced Sampling Technology Working Group].

For more information, please contact Dezhang Chu at Dezhang.Chu@noaa.gov

g) Spatio-temporal trends in west coast groundfish reproduction: A case study of ecologically important species with varying life history strategies

Investigators: Melissa A. Head, Jason M. Cope, Aimee Keller

Ecosystem-based fisheries management (EBFM) aims to support strong fisheries and communities by considering variables that affect a species' health and productivity, i.e. spatio-temporal trends, environmental changes, and fishing pressure. Fisheries managers use life history data to inform stock assessment models. A critical component to this is estimating spawning stock biomass. Reproduction is a fundamental process of population dynamics and changes in its success contribute to a large portion of variability in marine populations. Understanding the timing of maturity, and factors that influence spawning capability are important to measure reproductive potential. Stock assessments conducted at the Northwest Fisheries Science Center (NWFSC) aim to implement EBFM practices by incorporating spatio-temporal varying life history parameters. To accomplish this, the NWFSC implemented a reproductive program in 2011. Since its creation, we have collected ~21,000 gonad samples from 39 groundfish species using seven sampling platforms. We have histologically assessed ~15,000 of these, evaluating biological (physiological) and functional maturity (potential spawners in a given year). This data set now spans multiple years across a large geographical range, and has provided a unique opportunity to explore EBFM concepts, i.e. spatio-temporal changes in maturity, timing of spawning, and reproductive development. We have evaluated this for multiple groundfish species that span the entire U.S. west coast. We found differences in maturity and skip spawning between important biogeographical regions of the coast (Cape Mendocino and Pt. Conception, CA) for several of the species. In addition to the spatial trends, we found temporal differences in the reproductive cycle.

For more information, please contact Melissa Head at Melissa.Head@noaa.gov

2. Habitat

a) Relating groundfish diversity and biomass to deep-sea corals and sponges in the northeast Pacific Ocean

Investigators: K.L. Bosley, K.M. Bosley, A.A. Keller, C.E. Whitmire

Deep-sea corals and sponges (DSCS) inhabit the world's oceans and are often associated with high fish abundance; however, the precise nature and extent of any association is difficult to quantify and remains poorly understood. We investigated the associations between DSCS and demersal fish using data from the Northwest Fisheries Science Center's bottom trawl survey (2003-2015). General linear models (GLMs) showed that average species density of groundfish was slightly higher and groundfish biomass slightly lower in hauls with DSCS. Multivariate analyses were used to examine relationships among fish community structure, DSCS densities, and environmental parameters (depth, latitude and bottom temperature). No strong correlations occurred between the community structure of groundfish and DSCS densities, but bottom temperature and depth were the primary drivers of community composition. Indicator species analysis also showed various species-specific associations with DSCS. Specifically, some flatfish species exhibited relationships with coral and sea pen densities, whereas some rockfishes were associated with high sponge densities. Our results provide information on the broad-scale associations among DSCS and demersal fishes that may be useful for developing studies focused on the functional value of DSCS as essential fish habitat and the role they play in groundfish life-history and ecology.

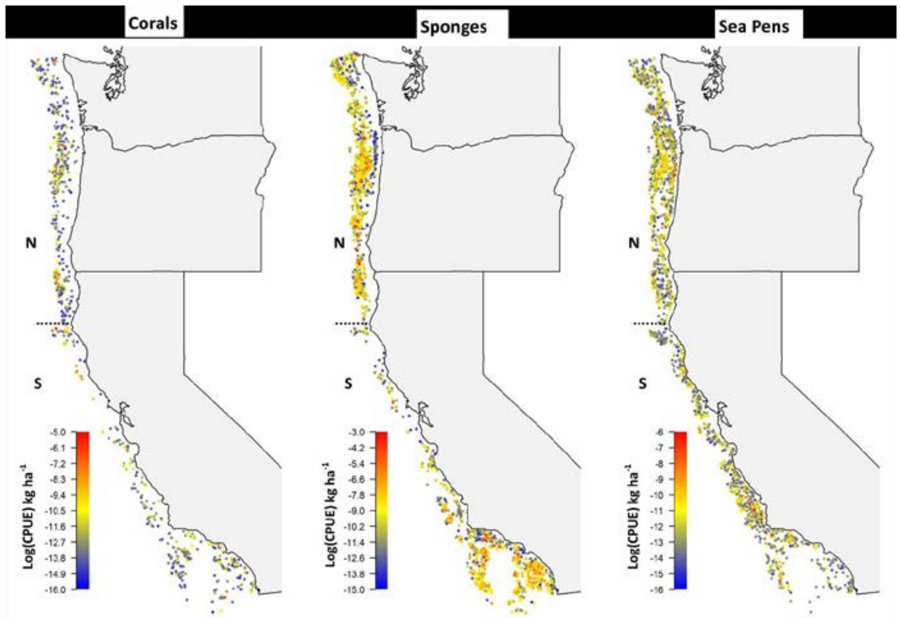


Figure 20. Location of trawls containing corals, sponges and sea pens during the bottom trawl survey 2003 to 2015. Density is on a log scale to better represent low CPUE (ka ha^{-1}). Dashed line shows delineation between the northern and southern geographic groups at Cape Mendocino, CA (40°26'18" N).

For more information, please contact Keith Bosley at Keith.Bosley@noaa.gov

b) The abundance and habitat use of demersal fishes on a rocky offshore bank using the ROPOS remotely operated vehicle

Investigators: N. Tolimieri, M.E. Clarke, J. Clemons, W. Wakefield, A. Powell

Offshore rocky banks are ecologically important refuge habitats for a number of U.S. commercial groundfish species. However, they are challenging to survey, and data on the abundance and ecology of fish populations at deep banks are limited. We used the remotely operated vehicle ROPOS to carry out visual surveys at two sites on Cherry Bank in the Southern California Bight, eastern Pacific Ocean. We observed differences in fish assemblages related to depth and habitat type and found that rockfishes (*Sebastes* spp.) made up 65% of fishes recorded. Rockfishes and combfish (*Zaniolepis* spp.) were associated with relatively shallow areas with hard substrate whereas flatfishes (Pleuronectiformes) and poachers (Agonidae) were found on unconsolidated sediments. Thornyheads (*Sebastolobus* spp.) and hagfishes (Myxinidae) mainly occurred in areas of patchy habitat. Habitat and depth explained 52% of the variation in fish assemblages between transects with habitat explaining a greater proportion of the variation than depth. We observed large differences in the number of juvenile rockfishes and *Sebastomus* rockfishes between study sites with hard substrates and also had higher abundances of juvenile rockfishes versus sites characterized by mixed substrates. With the exception of unidentified *Sebastomus*, the current design had relatively low power to reliably detect observed differences for most taxa, so we report the number of additional transects that would be required to detect a 50% increase in densities. These data provide a baseline on groundfish densities and habitat associations at Cherry Bank and key information for the design of future work including Bayesian approaches to estimating coast-wide abundance.

For more information please contact Dr. Nick Tolimieri at NOAA's Northwest Fisheries Science Center, nick.tolimieri@noaa.gov.

c) Fish condition and implications for recruitment in the Northeast Pacific

Investigators: Jennifer L. Boldt[1], Christopher N. Rooper[2] , Gerald Hoff[2] , Robyn Forrest[1], Keith Bosley[3]

[1] Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC, Canada. E-mail: Jennifer.Boldt@dfo-mpo.gc.ca

[2] National Marine Fisheries Service, Alaska Fisheries Science Center, Seattle, WA, USA

[3] National Marine Fisheries Service, Northwest Fisheries Science Center, Newport, OR, USA

Ecosystem responses to climate change vary across space and time in the North Pacific. Increasing water temperatures and changes in lower trophic level productivity have implications for fish growth on both regional and basin scales. Responses of fish growth to environmental drivers can be examined by comparing fish condition over time and space. Fish condition, measured as length-weight residuals, is an indicator of somatic growth and ecosystem productivity, and a fish's condition has implications for its survival and recruitment. Condition was compared among fish species and ecosystems in the Northeast Pacific - from the Bering Sea to the northern California Current. For example, in the Eastern Bering Sea, there has been a negative trend in Pacific cod condition since 2003, and age 2+ walleye Pollock condition in 2017 was the second lowest on record. For most species, condition metrics varied over space and time. Fish were generally in better condition on the outer shelf, compared to shallower regions. There is an absence of consistent trends within species among different areas, but within an area, condition often is observed to change in synchrony among species, suggesting that local conditions might be driving observed patterns for multiple species.

For more information, please contact Keith Bosley at Keith.Bosley@noaa.gov

d) Sub-regional differences in groundfish distributional responses to anomalous ocean temperatures in the northeast Pacific

Investigators: Lingbo Li, Anne Hollowed, Edward Cokelet, Steve Barbeaux, Nicholas Bond, Aimee Keller, Jackie King, Michelle McClure, Wayne Palsson, Phyllis Stabeno, Qiong Yang

Although climate-induced shifts in fish distribution have been widely reported at the population level, studies that account for ontogenetic shifts and sub-regional differences when assessing responses are rare. In this study, groundfish distributional changes were assessed at different size classes by species within nine sub-regions using indicators of shifts in depth, latitude, and longitude. We examined large, quality-controlled datasets of depth-stratified, random bottom trawl surveys conducted during summer in three large regions – the Gulf of Alaska and the west coast of Canada and the U.S. – over the period 1996-2015, a time period punctuated by a marine "heat wave". Temporal biases in bottom temperature were minimized by subdividing each region into three sub-regions, each with short-duration surveys. Near-bottom temperatures, weighted by stratum area, were unsynchronized across sub-regions and exhibited varying sub-regional interannual variability. The weighted-mean bottom depths in the sub-regions also vary largely among sub-regions. The centroids (centers of gravity) of groundfish distribution were weighted with catch per unit effort (CPUE) and stratum area for ten commercially important groundfish species by size class and sub-region. Our multivariate analyses showed that there were significant differences in aggregate fish movements of temperature responses across sub-regions but not among species or sizes. Groundfish demonstrated poleward responses to warming temperatures only in a few sub-regions and moved shallower or deeper to seek colder waters depending on the sub-region. They likely form geographically distinct thermal ecoregions, instead of continuously moving northward along northeast Pacific shelf under global warming. Shallow-depth species exhibited greatly different distributional responses to temperature changes across sub-regions while deep-depth species of different sub-regions tend to have relatively similar temperature responses. Future climate studies would benefit by considering fish distributions on small sub-regional scales.

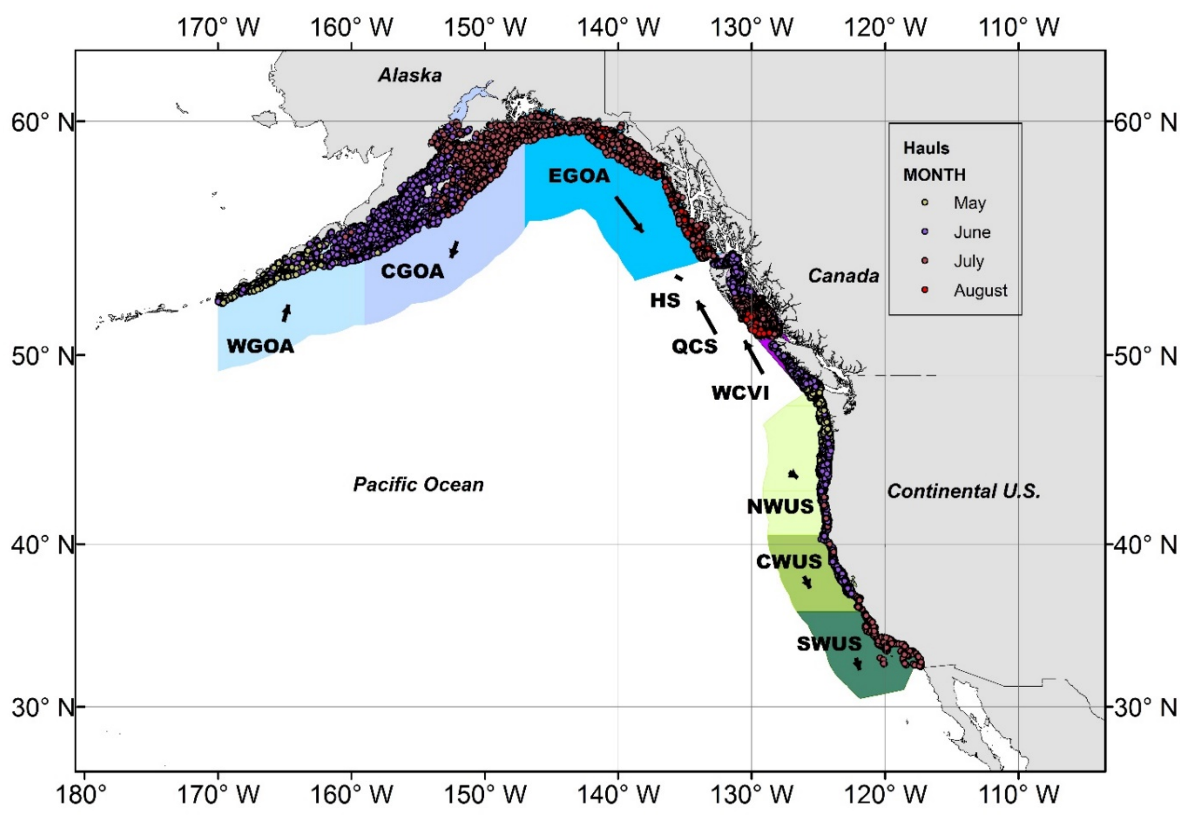


Figure 21. The study area (Mercator Projection) of northeast Pacific including bottom trawl hauls (filled circles) in three surveys, which were divided into nine sub-regions. Polygons of sub-regions in the GOA and U.S. west coast are consistent with fishery management areas. Arrows are scaled to average standardized temperature responses in latitude and longitude for each sub-region, indicating that these groundfish tended to form three thermal ecoregions, W-CGOA, EGOA-HS-QCS-WCVI, and U.S. west coast, under global warming.

For more information, please contact Aimee Keller at Aimee.Keller@noaa.gov

e) Effects of warming ocean conditions on feeding ecology of small pelagic fishes in a coastal upwelling ecosystem: a shift to gelatinous food sources.

Investigators: R.D Brodeur, M.E. Hunsicker, A. Hann, T.W. Miller

Forage fish play a central role in the transfer of energy from lower to higher trophic levels. Ocean conditions may influence this energy pathway in the Northern California Current (NCC) ecosystem, and we may expect it to differ between warm and cold periods in the northeast Pacific Ocean. The recent unprecedented warming in the NCC provides a unique opportunity to better understand the connection between ocean conditions and forage fish feeding habits and the potential consequences for predators that depend on them for sustenance. Here we present findings from gut content analysis to examine food sources of multiple forage fishes (northern anchovy *Engraulis mordax*, Pacific sardine *Sardinops sagax*, jack mackerel *Trachurus symmetricus*, Pacific herring *Clupea pallasii*, surf smelt *Hypomesus pretiosus*, and whitebait smelt *Allosmerus elongatus*) off the Washington and Oregon coasts. Analyses were applied to fish collected in May and June during recent warm years (2015 and 2016) and compared to previous collections made during cool (2011, 2012) and average (2000, 2002) years. Results of the diet analysis indicate that fish feeding habits varied significantly between cold and both average and warm periods. Euphausiids, decapods, and copepods were the main prey items of the forage fishes for most years examined; however, gelatinous zooplankton were consumed in much higher quantities in warm years compared to cold years. This shift in prey availability was also seen in plankton and trawl surveys in recent years and suggests that changing ocean conditions are likely to affect the type and quality of prey available to forage fish. Although gelatinous zooplankton are generally not believed to be suitable prey for most fishes due to their low energy content, some forage fishes may utilize this prey in the absence of more preferred prey resources during anomalously warm ocean conditions.

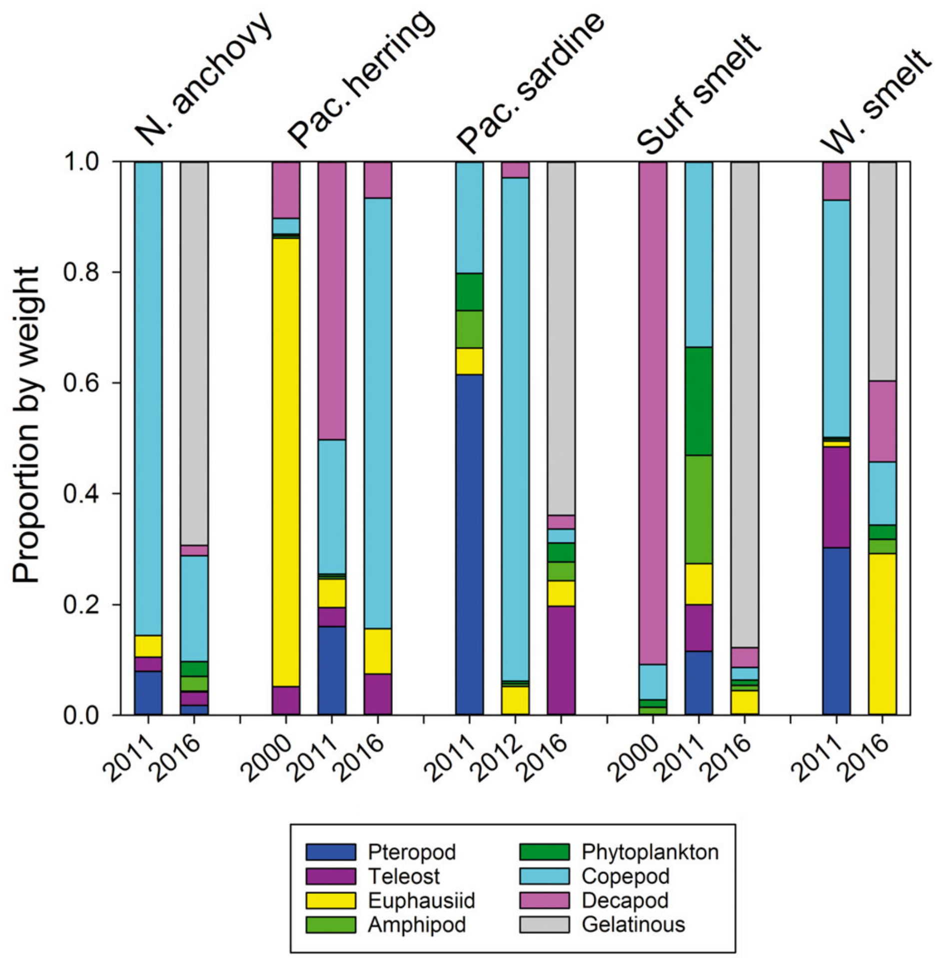


Figure 22. May diet composition by proportion wet weight of dominant forage fishes by year for the major taxonomic categories.

For more information, please contact Rick Brodeur at Rick.Brodeur@noaa.gov

f) Unclear associations between pelagic fish and jellyfish in several major marine ecosystems.

Investigators: A.F. Opdal, R.D. Brodeur, K. Cieciel, G.M. Daskalov, V. Mihneva, J.J. Ruzicka, H.M. Verheye, D.L. Aksnes.

During the last 20 years, a series of studies has suggested trends of increasing jellyfish (Cnidaria and Ctenophora) biomass in several major ecosystems worldwide. Some of these systems have been heavily fished, causing a decline among their historically dominant small pelagic fish stocks, or have experienced environmental shifts favouring jellyfish proliferation. Apparent reduction in fish abundance alongside increasing jellyfish abundance has led to hypotheses suggesting that jellyfish in these areas could be replacing small planktivorous fish through resource competition and/or through predation on early life stages of fish. In this study, we test these hypotheses using extended and published data of jellyfish, small pelagic fish and crustacean zooplankton biomass from four major ecosystems within the period of 1960 to 2014: the Southeastern Bering Sea, the Black Sea, the Northern California Current and the Northern Benguela. Except for a negative association between jellyfish and crustacean zooplankton in the Black Sea, we found no evidence of jellyfish biomass being related to the biomass of small pelagic fish nor to a common crustacean zooplankton resource. Calculations of the energy requirements of small pelagic fish and jellyfish stocks in the most recent years suggest that fish predation on crustacean zooplankton is 2–30 times higher than jellyfish predation, depending on ecosystem. However, compared with available historical data in the Southeastern Bering Sea and the Black Sea, it is evident that jellyfish have increased their share of the common resource, and that jellyfish can account for up to 30% of the combined fish-jellyfish energy consumption. We conclude that the best available time-series data do not suggest that jellyfish are outcompeting, or have replaced, small pelagic fish on a regional scale in any of the four investigated ecosystems. However, further clarification of the role of jellyfish requires higher-resolution spatial, temporal and taxonomic sampling of the pelagic community.

For more information, please contact Rick Brodeur at Rick.Brodeur@noaa.gov

g) Major shifts in macroplankton and micronekton pelagic community structure in an upwelling ecosystem related to an unprecedented marine heatwave

Investigators: R.D. Brodeur, T.D. Auth, A.J. Phillips

The community structure of pelagic zooplankton and micronekton may be a sensitive indicator of changes in environmental conditions within the California Current ecosystem. Substantial oceanographic changes in 2015 and 2016, due to the anomalously warm ocean conditions associated with a large-scale marine heatwave perturbation, resulted in onshore and northward advection of warmer and more stratified surface waters resulting in reduced upwelling. Here we quantify changes in the macrozooplankton and micronekton community composition and structure based on five highly contrasting ocean conditions. Data from fine-mesh pelagic trawl surveys conducted off Oregon and Washington during early summer of 2011 and 2013–2016 were examined for interannual changes in spatial distribution and abundance of fish and invertebrate taxa. Overall species diversity was highest in 2015 and lowest in 2011, but 2016 was similar to the other years, although the evenness was somewhat lower. The community of taxa in both 2015 and 2016 was significantly different from the previously sampled years. Crustacean plankton densities (especially Euphausiidae) were extremely low in both of these years, and the invertebrate composition became dominated mostly by gelatinous zooplankton. Fishes and cephalopods showed mixed trends overall, but some species such as age-0 Pacific hake were found in relatively high abundances mainly along the shelf break in 2015 and 2016. These results suggest dramatically different pelagic communities were present during the recent warm years with a greater contribution from offshore taxa, especially gelatinous taxa, during 2015 and 2016. The substantial reorganization of the pelagic community has the potential to lead to major alterations in trophic functioning in this normally productive ecosystem.

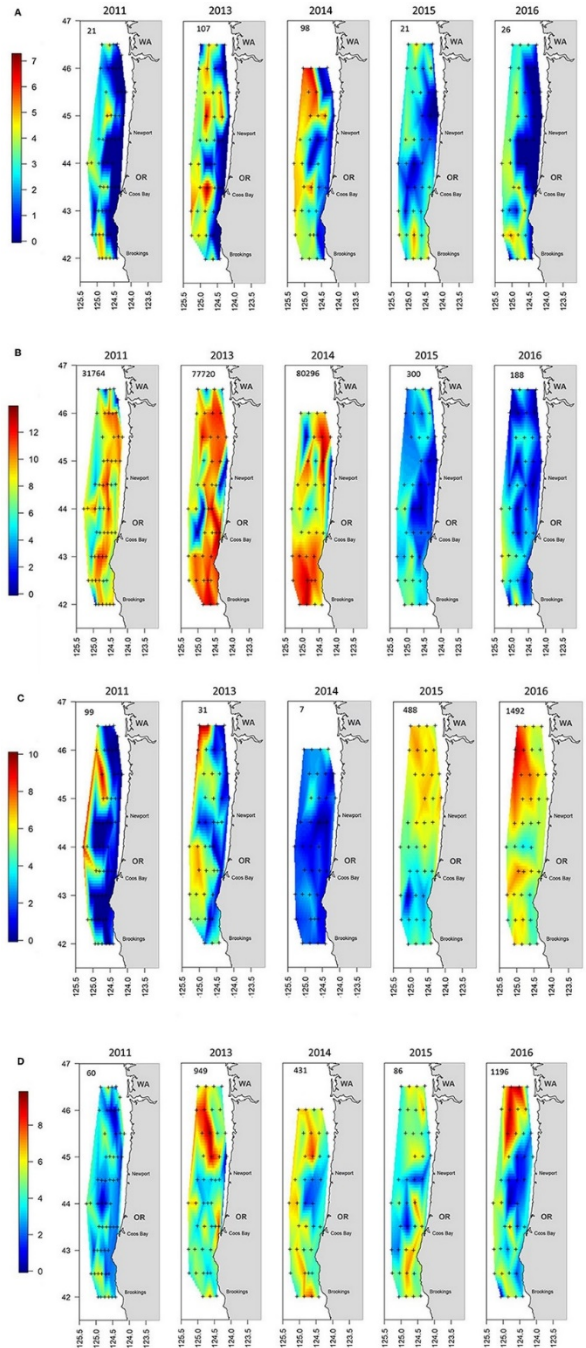


Figure 23. Distribution maps of the catch by year for the aggregated groupings of (A) Cephalopods, (B) Crustacea, (C) Gelatinous, and (D) Teleosts. The number in the upper left of each panel indicates the geometric mean catch of that grouping per haul by year. Note that the scale bar is logarithmic. The plus signs indicate locations where trawling was conducted.

For more information, please contact Rick Brodeur at Rick.Brodeur@noaa.gov

h) Distribution of pelagic thaliaceans, *Thetys vagina* and *Pyrosoma atlanticum*, during a period of mass occurrence within the California Current Large Marine Ecosystem

Investigators: R.R. Miller, J.A. Santora, T.D. Auth, K.M. Sakuma, B.K. Wells, J.C. Field, R.D. Brodeur

The spatial distribution, abundance, and size variability of two pelagic tunicate species, *Thetys vagina* and *Pyrosoma atlanticum*, were examined from midwater trawl surveys to assess the historical context and geographical aspects of a major mass occurrence event throughout the California Current Large Marine Ecosystem during 2012–19. Off central California, abundance of both species were significantly greater in 2012–19 compared to 1983–2001, and their recent persistent multiyear abundance peaks were unprecedented. Coastwide abundance and distribution of *T. vagina* during 2013–19 was patchy, with no discernible shifts in distribution or changes in mean length. From 2013–18, abundance and distribution of *P. atlanticum* demonstrated a temporal trend of increasing abundance from south to north, and in northern areas, average *P. atlanticum* colony length increased over time. In 2019, high abundances of *P. atlanticum* occurred south of Monterey Bay, but were not found in the northern California Current. We discuss how in situ and regional-scale environmental drivers may have contributed to this recent multiyear gelatinous mass occurrence, and potential consequences to forage community structure and ecosystem function.

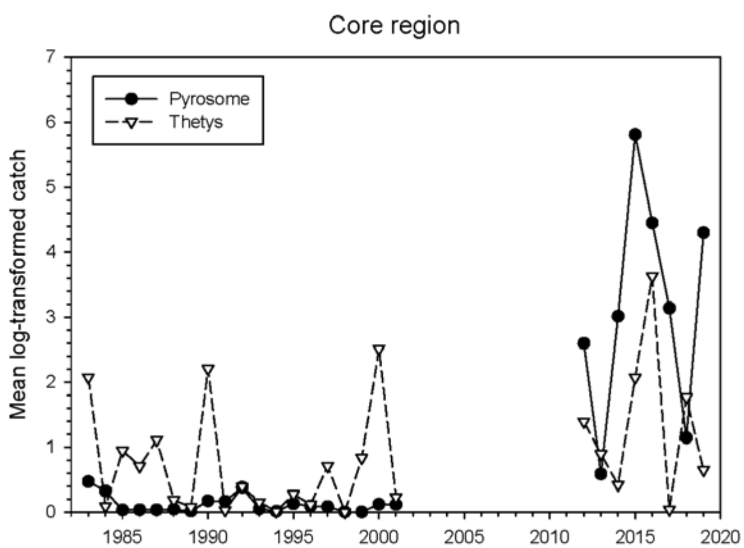


Figure 24. Time series of the annual mean log-transformed catch, ln(catch+1), for *Pyrosoma atlanticum* and *Thetys vagina* within the core region for the years 1983–2001 and 2012–19.

For more information, please contact Rick Brodeur at Rick.Brodeur@noaa.gov

i) Nekton.

Investigators: Rick Brodeur, E.A. Pakhomov

Marine nekton are the swimmers in the sea. They range in size from a few centimeters, e.g., euphausiids (krill), to the largest whales (tens of meters). Many are important in fisheries. Micronekton, the emphasis of this article, are small nekton, mainly fishes, squids, and shrimps. They inhabit all oceans and all depths. Many undertake diel vertical migrations into near-surface waters as light intensity decreases at dusk and then descend into deeper water before dawn. Some are bioluminescent, often with ventrally-oriented photophores. In addition to diel vertical migrations, we know that some micronekton also migrate horizontally over slope waters into shallow water at night. They comprise a key link between primary consumers and the higher trophic levels in all marine food webs.

For more information, please contact Rick Brodeur at Rick.Brodeur@noaa.gov

j) Spatio-temporal patterns in juvenile habitat for 13 groundfishes in the California Current Ecosystem

Investigators: Nick Tolimieri, John Wallace, Melissa Haltuch

A species' spatial distribution is one of the fundamental aspects of its ecology and is an important component of many conservation and management plans, including the designation of Essential Fish Habitat (EFH). Identifying juvenile habitats is critical for defining a species' EFH and for focusing spatial fishery management because recruitment events strongly affect population age structure and abundance. Here, we used vector autoregressive spatio-temporal models (VAST) to delineate spatial and temporal patterns in juvenile density for 13 commercially important species of groundfishes off the U.S. west coast. In particular, we identified hotspots with high juvenile density. Three qualitative patterns of distribution and abundance emerged. First, Dover sole *Microstomus pacificus*, Pacific grenadier *Coryphaenoides acrolepis*, shortspine thornyhead *Sebastolobus alascanus*, and splitnose rockfish *Sebastes diploproa* had distinct, spatially limited hotspots that were spatially consistent through time. Next, Pacific hake *Merluccius productus* and darkblotched rockfish *S. crameri* had distinct, spatially limited hotspots, but the location of these hotspots varied through time. Finally, arrowtooth flounder *Atheresthes stomias*, English sole *Parophrys vetulus*, sablefish *Anoplopoma fimbria*, Pacific grenadier *Coryphaenoides acrolepis*, lingcod *Ophiodon elongatus*, longspine thornyhead *S. altivelis*, petrale sole *Eopsetta jordani* , and Pacific sanddab *Citharichthys sordidus* had large hotspots that spanned a broad latitudinal range. These habitats represent potential, if not likely, nursery areas, the location of which will inform spatial management.

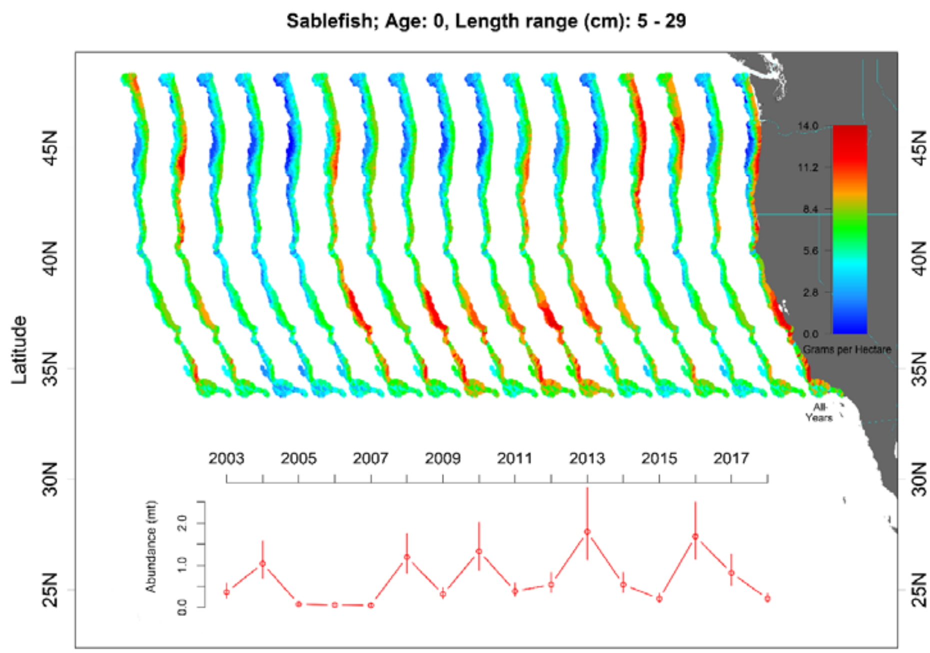


Figure 25. Spatial distribution and annual abundance index of juvenile sablefish off the west coast of the U.S.

For more information please contact Dr. Nick Tolimieri at NOAA's Northwest Fisheries Science Center, nick.tolimieri@noaa.gov.

D. Observer Program and Science

1. West Coast Observer Program

The FRAM West Coast Groundfish Observer Program (WCGOP) continued collecting fishery-dependent data during 2019 on groundfish fleets along the entire U.S. west coast. The groundfish fishery is broken down into two main categories the catch share fisheries and the non-catch share fisheries. The catch share fishery can be further broken down into the shorebased fleet and the at sea fleet. The at sea fleet includes catcher-processors (CPs) and motherships. The catch share fisheries require 100% observer and shore side monitoring. The non-catch share fisheries require observer coverage upon request and coverage is randomly assigned by fishery and port group.

Catch Shares
There are three sectors in the catch share program: shorebased, motherships (includes motherships and mother ship catcher-vessels), and catcher-processors. All vessels participating in the shorebased sector or acting as mother ship catcher-vessels (MSCV's) must carry one observer on all trips. Motherships and catcher-processors carry two observers each trip. The shorebased sector is managed through Individual Fishing Quotas (IFQ's) and includes all vessels that land catch at shore side processors. Catch shares regulations allow the shorebased sector to use trawl, longline, or pots to harvest IFQ species. The mother ship and catcher-processor sectors target Pacific hake using trawl gear and process it entirely at-sea. Motherships and catcher-processors have formed cooperatives to ensure sectors can attain Pacific hake quota without exceeding bycatch caps for overfished species or salmon.

Catch Share observers are deployed in the following catch share fisheries:

• All vessels participating in the Shore-based Individual Fishing Quota (IFQ) program including hake and non-hake groundfish trawl and fixed gear vessels
• All motherships participating in the at-sea hake fishery
• All mother ship catcher-vessels participating in the at-sea hake fishery
• All catcher-processors participating in the at-sea hake fishery

Non-catch shares
The observer program collects data in other west coast fisheries that are not part of the catch share program. The program had vessels ranging in size from skiffs to larger fixed gear vessels and depths ranging from less than 20 ft. to more than 300 ft. Due to its unique data collection circumstances in both the catch shares and non-catch shares fisheries, the program continues to stress safety and data quality.

For more information, please contact Jon McVeigh at Jon.McVeigh@noaa.gov

2. Research

a) Comparing predictions of fisheries bycatch using multiple spatiotemporal species distribution model frameworks

Investigators: Stock, B.C., E.J. Ward, T. Eguchi, J.E. Jannot, J.T. Thorson, B.E. Feist, B.X. Semmens

Spatiotemporal predictions of bycatch (i.e., catch of nontargeted species) have shown promise as dynamic ocean management tools for reducing bycatch. However, which spatiotemporal model framework to use for generating these predictions is unclear. We evaluated a relatively new method, Gaussian Markov random fields (GMRFs), with two other frameworks, generalized additive models (GAMs) and random forests. We fit geostatistical delta-models to fisheries observer bycatch data for six species with a broad range of movement patterns (e.g., highly migratory sea turtles versus sedentary rockfish) and bycatch rates (percentage of observations with nonzero catch, 0.3%–96.2%). Random forests had better interpolation performance than the GMRF and GAM models for all six species, but random forests performance was more sensitive when predicting data at the edge of the fishery (i.e., spatial extrapolation). Using random forests to identify and remove the 5% highest bycatch risk fishing events reduced the bycatch-to-target species catch ratio by 34% on average. All models considerably reduced the bycatch-to-target ratio, demonstrating the clear potential of species distribution models to support spatial fishery management.

For more information please contact Dr. Eric Ward at NOAA's Northwest Fisheries Science Center, eric.ward@noaa.gov.

b) Bycatch quotas, risk pools, and cooperation in the Pacific whiting fishery (Bycatch Quotas and Risk Pools PGTF)

Investigators: D.S. Holland, C. Martin

The United States Pacific whiting fishery uses mid-water trawl gear to target Pacific whiting off the United States west coast. The fishery is subject to sector-specific bycatch caps for Chinook salmon (*Oncorhynchus tshawytscha*) and several rockfish species (widow rockfish–*Sebastes entomelas*, canary rockfish-*Sebastes pinniger*, darkblotched rockfish–*Sebastes crameri*, Pacific Ocean Perch (POP)-*Sebastes alutus*, and yelloweye rockfish-*Sebastes ruberrimus*). Chinook bycatch can include fish from endangered populations and rockfish stocks were recovering from severe depletion though most are now rebuilt. Catch of these species is rare and uncertain, making it difficult for vessels to meet strict individual performance standards. Consequently, the industry has developed risk pools in which bycatch quota for a group of vessels is pooled, but vessels are required to follow practices that minimize bycatch risk including temporal and spatial fishing restrictions. The risk pools also require vessels to share information about bycatch hotspots enabling a cooperative approach to avoid bycatch based on real-time information. In this article we discuss the formation and structure of these risk pools, the bycatch reduction strategies they apply, and outcomes in the fishery in terms of observed bycatch avoidance behavior and utilization of target species. The analysis demonstrates the ability of these fishers to keep bycatch within aggregate limits and keep individual vessels from being tied up due to quota overages.
For more information please contact Dr. Dan Holland at NOAA's Northwest Fisheries Science Center, dan.holland@noaa.gov.

c) The utility of spatial model-based estimators of unobserved bycatch

Investigators: B.C. Stock, E.J. Ward, J.T. Thorson, J.E. Janot, B.X. Semmens

Quantifying effects of fishing on non-targeted (bycatch) species is an important management and conservation issue. Bycatch estimates are typically calculated using data collected by on-board observers, but observer programs are costly and therefore often only cover a small percentage of the fishery. The challenge is then to estimate bycatch for the unobserved fishing activity. The *status quo* for most fisheries is to assume the ratio of bycatch to effort is constant and multiply this ratio by the effort in the unobserved activity (ratio estimator). We used a dataset with 100% observer coverage, 35,440 hauls from the U.S. west coast groundfish trawl fishery, to evaluate the ratio estimator against methods that utilize fine-scale spatial information: generalized additive models (GAMs) and random forests. Applied to 15 species representing a range of bycatch rates, including spatial locations improved model predictive ability, whereas including effort-associated covariates generally did not. Random forests performed best for all species (lower root mean square error), but were slightly biased (overpredicting total bycatch). Thus, the choice of bycatch estimation method involves a tradeoff between bias and precision, and which method is optimal may depend on the species bycatch rate and how the estimates are to be used.

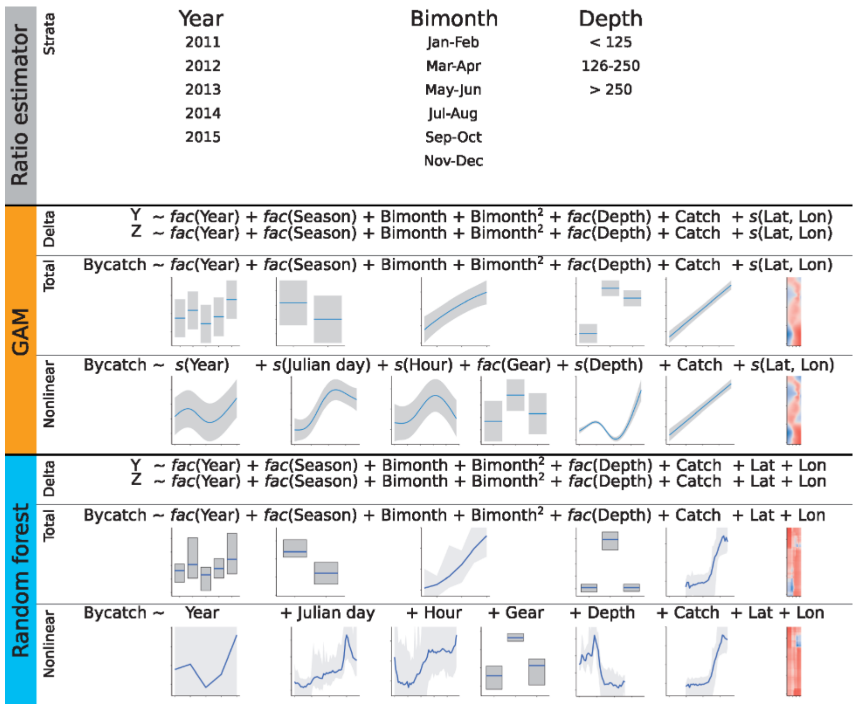


Figure 26. Summary of models fit to the West Coast Groundfish Observer Program bycatch dataset. The ratio estimator was stratified by year, bimonthly period, and depth (fathoms). The Delta and Total models were fit to the same covariates, meant to mimic the stratified ratio estimator. Covariates treated as factors are indicated by fac(). The Delta models split the bycatch data into presence/absence (Y) and positive catches (Z), then calculated bycatch as Y × Z. The Nonlinear models incorporate all available covariates using nonlinear terms, e.g. spline terms in GAMs, s(). Covariate effect plots are shown for models fit to Pacific hake. The following R packages were used in analyses: “mgcv” to fit GAMs, “visreg” to visualize GAM covariate effects, “randomForest” to fit RFs, and “forestFloor” to visualize RF covariate effects.

For more information, please contact Jason Janot at Jason.Janot@noaa.gov

d) Fishing to live or living to fish: job satisfaction and identity of west coast fishermen

Investigators: D.S. Holland, K. Norman, J.E. Abbott

Fishing is a dangerous and financially risky way to make a living, but it attracts many participants that prefer it to higher paying and safer jobs. Based on a survey of over 1400 U.S. west coast fishing vessel owners we use factor analysis and structural equation modeling to quantify distinct latent variables representing job satisfaction related to non-monetary versus monetary aspects of fishing and measures of identity and social capital associated with being a fisher. We show that these latent variables have distinct effects on (stated) fishery participation behavior and that higher non-monetary job satisfaction, social capital, and identity, are associated with a willingness to forgo higher income to be a fisher. Understanding how these factors affect and are affected by participation in fisheries could be important to increase benefits from fisheries and to ensure sustainability of management regimes that rely on indirect controls on effort to limit catch.

For more information please contact Dr. Dan Holland at NOAA's Northwest Fisheries Science Center, dan.holland@noaa.gov.

e) Joint and several liability in fishery cooperatives

Investigators: M. Bellanger, D.S. Holland, C.M. Anderson, O. Guyader, C. Macher

Cooperative-based catch share systems can be implemented such that the members of the same fishery cooperative are jointly and severally liable for not exceeding collectively assigned fishing rights. In practice, this means that a regulator can take away catch privileges from an entire cooperative that overruns its collective quota, effectively creating a penalty much larger than what could be recovered with an individual fine. Fishery cooperatives then typically implement their own internal compliance regime that includes monitoring and penalties. This article first reviews compliance practice in cooperative-based catch share systems by examining the commonalities and differences in the way compliance regimes are structured (observation and reporting requirements, penalty scheme, internal enforcement authority and indemnification mechanisms) in a number of internal agreements from fishery cooperatives in North America and in Europe. Based on our review of cooperatives and the literature on compliance, we discuss how incentives to comply may be different for an individual fisherman operating in a fishery cooperative where joint and several liability applies as compared to an individual fishing quota baseline situation without fishery cooperative. Our review suggests that, from the regulators' point of view, joint and several liability can increase the level of compliance for a given enforcement expenditure. However, the regulator cannot rely solely on cooperatives to carry out controls and must ensure that the cooperatives themselves have an interest in setting up an effective monitoring system and will enforce sanctions within the cooperative.

For more information please contact Dr. Dan Holland at NOAA's Northwest Fisheries Science Center, dan.holland@noaa.gov.

f) Catch shares drive fleet consolidation and increased targeting but not spatial effort concentration nor changes in location choice in a multispecies trawl fishery

Investigators: P.T. Kuriyama, D.S. Holland, T.A. Branch, L.A.K. Barnett, R.L. Hicks, K.E. Schnier

Catch share systems are generally expected to increase economic rents in fisheries by increasing harvest efficiency, reducing capital costs through consolidation, and increasing the value of landed catch. However, these benefits may have costs, as consolidation and the potential for associated change in spatial distribution in landings can hinder social objectives such as maintaining access for fishery-dependent communities and small owner-operators. Achievement of such fishery management objectives are determined by changes in fisher behavior, which may be complex and difficult to predict. Predicting fisher behavior is particularly challenging in multispecies fisheries, in which the mix of species is a determinant of where and when fishing effort and landings occur. We evaluate changes in overall fishing effort, species targeting, and determinants of fishing location choice in response to catch shares in the U.S. west coast Groundfish Trawl Fishery. We found reductions in total fishing effort, increased targeting of some species, and no evidence of spatial effort concentration. Key determinants of location choice (distance, expected revenue, and recently fished locations) were similar among time periods, but after catch shares there was more avoidance of areas that lacked recent fishing activity or associated information with which to develop expectations of catch and bycatch. Additionally, location choice remained constant with up to 100-fold financial penalties on bycatch species.

For more information please contact Dr. Dan Holland at NOAA's Northwest Fisheries Science Center, dan.holland@noaa.gov.

g) Observer Program Reports

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E. By-catch Reduction Engineering

1. Research

a) Use of artificial illumination to reduce Pacific halibut bycatch before trawl capture in a U.S. West Coast Groundfish Bottom Trawl

Investigator: Mark Lomeli

In the U.S. west coast groundfish bottom trawl fishery, Pacific halibut (*Hippoglossus stenolepis*) bycatch can impact some fishers' ability to fully utilize their quota shares of target groundfishes. In this study, we compared the catch efficiency for Pacific halibut and four commercially important groundfish species between an unilluminated trawl and a trawl with illumination along its wing tips and upper bridles. Results show the illuminated trawl caught significantly fewer Pacific halibut than the unilluminated trawl. This result translates to significantly fewer Pacific halibut exposed to capture-escape processes within the trawl which can cause physiological stress, fatigue, injuries and lead to unobserved and unaccounted post-release mortality. For target groundfishes, results show no significant catch efficiency effect of changing from unilluminated to illuminated trawl for lingcod (*Ophiodon elongatus*), Dover sole (*Microstomus pacificus*), and petrale sole (*Eopsetta jordani*). A significant catch efficiency effect was noted for sablefish (*Anoplopoma fimbria*) with the illuminated trawl catching fewer fish on average. Our results contribute new data on how artificial illumination can affect catches of Pacific halibut and four commercially important groundfish species. In addition, physiological parameters of Pacific halibut caught between the illuminated and unilluminated trawl are presented. While our results have obvious implications to the west coast groundfish bottom trawl fishery, our findings could have potential applications in Alaska groundfish bottom trawl fisheries, such as the eastern Bering Sea directed flatfish fishery and Pacific cod (*Gadus macrocephalus*) fishery, where Pacific halibut bycatch also occurs.

Figure 27. Images of six LED clusters placed along the selective flatfish trawl port side upper bridle and wing tip(upper left image); image of selective flatfish trawl without LED along its upper bridles and wing tips (upper right image); image of the selective flatfish trawl being deployed with LEDs along its upper bridles and wing tips (bottom images).

b) Disentangling the web of factors influencing whale bycatch in fixed gear fisheries on the U.S. west coast

Investigators: B. Feist, J. Samhouri, and in collaboration with the SWFSC and WCRO

Protection of endangered and threatened cetaceans has resulted in population recoveries and the delisting of species across the globe. While this increase in population size is desirable from a conservation perspective, it can have unintended consequences for human activities such as shipping and fishing that operate in the same ocean waters. Anomalous ocean conditions can increase the probability of whale entanglement with fishing gear by altering spatio-temporal distributions of both fisheries and cetaceans in such a way that co-occurrence increases. Entangled whale reports on the U.S. west coast increased dramatically from historical norms, ca. 2014, especially among humpback whales. Gear type can only be determined in about half of the reports, which is predominantly fixed-gear (pot- and trap-based), the majority of which originating from the highly profitable Dungeness crab fisheries. In this paper we address the question of whether changes in the spatio-temporal distributions of these fixed-gear fleets occurred coincident with the increase in entanglement sightings, and if these changes placed the fisheries in closer proximity to cetaceans. We also examine two alternate and non-mutually exclusive scenarios, including (i) changes in the spatio-temporal distribution of whales that may have resulted in overlap with fisheries activities, and (ii) increases in human observation of whale activity. We find that fishing vessel activity for the dominant pot-based fishery, Dungeness crab, was somewhat declining from 2009 to mid-2016, rather than increasing, despite increases in whale entanglement reporting that began ca. mid-2014. However, unprecedented fishing activity in the months of May and June in California (but not Washington or Oregon) were evident during the domoic acid closures of the 2015-16 Dungeness crab season, which likely led to cooccurrence of humpbacks with Dungeness fishing activities. This result is consistent with the hypothesis that increased entanglement of humpback whales that began ca. 2014 was likely a result of changes in whale spatial distributions, exacerbated by a delay in fishing effort during the 2015-16 season. Future efforts to incorporate forecasts of cetacean and fishing distributions, and oceanographic conditions, will provide information to anticipate the potential for conflicts rather than after they have already occurred.

For more information please contact Dr. Blake Feist at NOAA's Northwest Fisheries Science Center, Blake.Feist@noaa.gov.

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NMFS Southwest Fisheries Science Center

NOAA FISHERIES
NATIONAL MARINE FISHERIES SERVICE

DRAFT

Agency Report to the Technical Subcommittee of the Canada-U.S. Groundfish Committee

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Edited by Melissa Monk

With contributions from John Field, Tom Laidig, Nick Wegner, and William Watson

A. AGENCY OVERVIEW

The Southwest Fisheries Science Center (SWFSC) conducts fisheries and marine mammal research at three laboratories in California. Activities are primarily in support of the Pacific Fishery Management Council, the Endangered Species Act (ESA), the Marine Mammal Protection Act (MMPA), as well as a number of international fisheries commissions and conventions. The Science and Research Director is Kristen Koch and John Crofts assumed the role of Deputy Director on September 1, 2019. John Crofts was formerly a NOAA Corps Commander who spent most of his NOAA Corps career involved in NMFS and specifically, SWFSC science. All SWFSC divisions support the essential needs of the NMFS and the Pacific Fishery Management Council (PFMC) for groundfish, including as active members of the PFMC's Scientific and Statistical Committee (SSC), the Groundfish Management Team, and other management teams and advisory bodies.

The Center is headquartered in La Jolla, which hosts three divisions that conduct research on a wide range of Pacific and Antarctic fish, marine mammals, sea turtles, and marine habitats; the Antarctic Ecosystem Research Division (led by Dr. George Watters), the Marine Mammal and Turtle Division (division director position currently unfilled), and the Fisheries Resources Division (led by Dr. Annie Yau). The Fisheries Resources Division (FRD) conducts research on groundfish, large pelagic fishes (tunas, billfish and sharks), and small coastal pelagic fishes (anchovy, sardine and mackerel), and is the only source of groundfish research at the La Jolla facility. The Fisheries Research Division is also the primary source of federal support for the California Cooperative Oceanic Fisheries Investigations (CalCOFI) surveys that have taken place along much of the California coast since 1951. Researchers at FRD have primary responsibility for ichthyoplankton collections, studies of species abundance and distribution (including responses to climate variability), systematics, and the application of early life history information to stock assessments.

The Fisheries Ecology Division (FED) in Santa Cruz is directed by Dr. Steve Lindley, and three of the four research branches conduct studies focused on groundfish. The FED recently underwent a reorganization due to supervisor retirements and new hires. Dr. Steve Lindley is currently the acting supervisor of the Fisheries Economics team. The Molecular Ecology team (led by Dr. Carlos Garza) studies the molecular ecology and phylogeny salmonids and groundfish. Dr. John Field now oversees a larger Fisheries Assessment Group with three teams, Fisheries and Ecosystem Oceanography (led by Dr. John Field), Habitat and Groundfish Ecology (led by Dr. E.J. Dick) and Fisheries Assessment Modeling (led by Dr. Michael O'Farrell).

All of the teams within the Fisheries Assessment Group support the needs of NMFS and the Pacific Fishery Management Council, one of which is groundfish stock assessment. Specific objectives of the FED groundfish programs include: (1) collecting and developing information useful in assessing and managing groundfish stocks; (2) conducting stock assessments and improving upon stock assessment methods to provide a basis for harvest management decisions at the PFMC; (3) characterizing and mapping biotic and abiotic components of groundfish habitats, including structure-forming invertebrates; (4) disseminating information, research findings and advice to the fishery management and scientific communities; and (5) providing professional services (many of which fall into the above categories) at all levels, including inter-agency, state, national and international working groups. A scientist from Fisheries Resource Division in La Jolla currently represents the SWFSC on the Pacific Council's Groundfish Management Team, and several scientists from the Fisheries Ecology Division in Santa Cruz currently serve on the Pacific Council's Scientific and Statistical Committee.

There is also much collaboration among the three teams within the Fisheries Assessment Group. The Fisheries Assessment Modeling team primarily conducts stock assessments for both groundfish and salmon, focusing on research to advance fisheries assessment methods. The Habitat and Groundfish Ecology team utilizes a number of survey tools, e.g., visual surveys conducted with remotely operated vehicles (ROV), human-occupied submersibles, autonomous underwater vehicles (AUV), scuba, hook-and-line fishing and captive rearing, to study deep-water demersal communities and groundfish ecology. The Fisheries and Ecosystem Oceanography team within the group is responsible for leading the annual pelagic juvenile rockfish recruitment and ecosystem assessment survey along the West Coast.

The Environmental Research Division (ERD) is led by Dr. Toby Garfield and has researchers located in both Monterey and Santa Cruz. The ERD is a primary source of environmental information to fisheries researchers and managers along the west coast, and provides science-based analyses, products, and information on environmental variability to meet the agency's research and management needs. The objectives of ERD are to: (1) provide appropriate science-based environmental analyses, products, and knowledge to the SWFSC and its fishery scientists and managers; (2) enhance the stewardship of marine populations in the California Current ecosystem, and other relevant marine ecosystems, by understanding and describing environmental variability, the processes driving this variability, and its effects on the production of living marine resources, ecosystem structure, and ecosystem function; and (3) provide science-based environmental data and products for fisheries research and management to a diverse customer base of researchers, decision-makers, and the public. The ERD also contributes oceanographic expertise to the groundfish programs within the SWFSC, including planning surveys and sampling strategies, conducting analyses of oceanographic data, and cooperating in the development and testing of environmental and biological indices that can be useful in preparing stock assessments.

B. MULTISPECIES STUDIES

B1. Research on larval rockfish at the SWFSC

Contact: William Watson (william.watson@noaa.gov)
Larval Rockfish Investigators: Andrew Thompson, William Watson

During the past seven years (2013-2020), the ichthyoplankton and molecular ecology laboratories at the SWFSC, La Jolla, built species-specific larval rockfish time-series by genetically sequencing individual larvae from winter CalCOFI samples between 1998 and 2013. Results of this work are currently published in a master's thesis and two peer-reviewed scientific publications, and time-series from blue rockfish (*Sebastes mystinus*) were used by the Pacific Fisheries Management Council to inform the status of this stock.

In 2019-2020 we are continuing to analyze this data. For example, a SIO master's student (Jessica Freeman) is utilizing nonparametric multivariate and Bayesian analyses to better understand drivers of larval rockfish dynamics. In addition, a postdoctoral researcher (Noah Ben-Aderet) removed otoliths from a subset of six species collected between 1998 and 2013. He has completed measuring otolith core width as a proxy for maternal investment and outer band width as a proxy for growth rate. He is currently conducting analyses to test whether environmental conditions during parturition affect maternal investment and if maternal investment and/or environmental conditions impact rate of growth. The ultimate goal of this project is to identify mechanisms that impact rockfish recruitment and determine if larval condition can predict recruitment success.

In 2019-2020, we initiated another genetics project seeking to identify rockfishes in CalCOFI samples. Rather than sequencing individual larvae, we extracted DNA from the ethanol in which CalCOFI samples are stored. We then used metabarcoding techniques similar to those used for environmental DNA analysis to sequence DNA from all fishes in a sample. It turned out that the traditional primers used for fish metabarcoding (MiFish 12S) discriminated poorly among rockfish species. Hence, we designed rockfish-specific metabarcode primers within the cytochrome *b* gene. We metabarcoded DNA from four stations per year between 1998 and 2019 and used recently developed bioinformatics pipelines to quantify the number of DNA reads for each species in a sample. Initial results demonstrate that we are able to identify most rockfish species from ethanol preservative. The metabarcoding work is led by Zachary Gold, a Ph.D. student from UCLA. The metabarcode work will be one of the chapters of his dissertation thesis. Zack is graduating in 2020 and a manuscript on this effort should be ready for submission to a peer-reviewed journal in late 2020.

We began in 2019-2020 a collaboration with the NWFSC to explore larval rockfish dynamics before, during, and after the 2014-2016 Marine Heatwave. We obtained from Ric Brodeur and Toby Auth rockfish larvae collected annually off the Newport Hydrological Line from 2013-2019. Prior to the closure of the SWFSC due to the coronavirus pandemic, we completed tissue extractions from all larvae (approximately 1800) and sequenced and identified approximately 1000. We were on track to complete identification by the end of April, but had to postpone lab work due the closure of the Center. Once the SWFSC reopens, we should be able to complete the identifications in about a month if we can work at our pre-shutdown pace.

Finally, we continued to update larval fish identifications from historic CalCOFI surveys to current taxonomic standards. We currently have completed all surveys from July 1961 through December 2015, and samples collected during the primary rockfish reproductive seasons, winter and spring, of 2016-2019. This provides a 58-year time series of larval abundances of the rockfish species visually identifiable as larvae (*Sebastes aurora*, *S. diploproa*, *S. goodei*, *S. jordani*, *S. levis*, *S. macdonaldi*, *S. paucispinis*).

B.2 Research on Juvenile Rockfish at the SWFSC

The Rockfish Recruitment and Ecosystem Assessment survey completed its 37th survey year in June of 2010. Survey results indicated continued declines for pelagic young-of-the-year (YOY) rockfish (*Sebastes* spp.) and sanddabs (*Citharichthys* spp.), with strongly negative anomalies following near average levels in 2018 and very high abundance levels in the 2013-2017 period. YOY Pacific hake (*Merluccius productus*) were at low abundance in central California, although they were fairly abundant in the Southern California Bight. No YOY lingcod (Ophiodon elongates) were encountered in the 2019 survey. A manuscript detailing the relationship between pelagic juvenile rockfish abundance and oceanographic conditions was reported on extensively in the 2019 TSC report, and published later in 2019 (Schroeder et al., 2019. This analysis evaluated the strong relationship between high YOY rockfish abundance and greater contributions of Subarctic water to California Current source waters, which help in the interpretation of recruitment patterns and trends.

An ongoing study pivots from the temporal analysis to spatial distribution patterns of YOY rockfish, providing an analysis of the climatology of pelagic YOY rockfish distribution in years in which coastwide data are available (between 2004 and 2019), to better inform general distribution patterns by species and guild, as well as to provide guidance on the need to use coastwide data to inform recruitment indicators in stock assessments. The analysis indicates that approximately half of the variance in the time series during climatology years is shared broadly among regions, but that the other half tends to be explained by differential abundance patterns north and south of major biogeographic boundaries, such as Cape Blanco, Cape Mendocino and Point Conception. This effort follows on the heels of a somewhat similar effort for pelagic thalacians (salps and pyrosomes) reported in Miller et al. (2019), albeit for a shorter time series (2011-2019). A manuscript is in preparation and should be submitted or completed by the 2021 TSC report.

C. BY SPECIES, BY AGENCY

C1. Nearshore rockfish stock assessments

C1.a. Gopher and Black and Yellow Rockfish Complex Stock Assessment

Contact: Melissa Monk (melissa.monk@noaa.gov)

The SWFSC conducted a full stock assessment for gopher rockfish and black-and-yellow rockfish as a complex in U.S. waters off the coast of California south of Cape Mendocino (40° 10' N. latitude) using data through 2018. Gopher rockfish and black-and-yellow rockfish are genetically indistinguishable and historical catches between the two species could not be reliable separated. This was the first stock assessment to include data for black-and-yellow rockfish and the second full assessment for gopher rockfish (last assessed in 2005). Since 2000, annual total landings of catch and discards of the complex have ranged between 70-169mt, with landings (catch + discards) in 2018 totaling 92 mt. The 2019 estimated spawning output relative to unfished equilibrium spawning output is above the target of 40% of unfished spawning output at 43.82% (95% asymptotic interval: 33.57%-54.06%).

C2.b. Cowcod Stock Assessment

Contact: E.J. Dick (edward.dick@noaa.gov)

The SWFSC conducted a full stock assessment of *Sebastes levis* ("Cowcod") for the Southern California Bight (SCB), defined as U.S. waters off California and south of Point Conception (34° 27' North latitude). Waters north and south of the SCB are not considered in the assessment due to sparse data. Depletion-Based Stock Reduction Analysis was used to estimate yields for U.S. waters north of the SCB. The stock was declared overfished in 2000 and retention of cowcod was prohibited from January 2001 until January 2011. Since then, a small quota has been allocated to the trawl fishery as part of the Pacific Groundfish Trawl Rationalization Program, but retention remains prohibited in all other sectors. Reported total annual removals for cowcod over the last ten years have not exceeded 2 mt, averaging 1.3 mt per year. The 2019 stock assessment suggests the stock has increased to 57% of unfished equilibrium biomass (SB0) in 2019, with a 95% asymptotic interval (hereafter "interval") of 42% to 72%. The Pacific Fishery Management Council declared cowcod rebuilt with the acceptance of the new stock assessment.

C2. Shelf Rockfish

C2.a. Rockfish barotrauma and release device research at SWFSC La Jolla Lab

The Genetics, Physiology, and Aquaculture program at the SWFSC in La Jolla continues to evaluate the effects of barotrauma on rockfish (*Sebastes* spp.) catch and release. This work has focused on three major areas: 1. Tagging studies with acoustic transmitters to document the survival rates and sublethal effects of catch and release and barotrauma on important management species such Cowcod (*S. levis*) and Bocaccio (*S. paucispinis*) (Fig X), 2. Laboratory studies examining the sensitivity of rockfishes to hypoxia both before and immediately following laboratory induced barotrauma using hyperbaric chambers, and 3. Working with the recreational fishing community in California to measure the effectiveness and angler preference for different types of commercially available descending devices used to release rockfishes suffering from barotrauma.

Analysis of acoustic tagging work to date has shown species-specific long-term survival rates of 50.0% for Cowcod (n=46, CI= 35.7-70.5%) and 89.5% for Bocaccio (n=41, CI 80.2-99.8%). For Cowcod (which showed much lower survival rates), fish length, sea surface temperature, and dissolved oxygen levels at depth all significantly affected survival. For fish that survived, general additive models (GAMs) of post-release behavior showed that capture and barotrauma affected Cowcod and Bocaccio for up approximately 60 days post release. Dissolved oxygen also significantly affected post-release behavior. The modeled impact of dissolved oxygen on both survival rate and post-release behavior have led to on-going laboratory-based studies to examine the effects of hypoxia on Cowcod and Bocaccio behavior and physiology. Specifically, this work is examining behavioral avoidance to low oxygen using a custom-built shuttle-box system, and determining the effects of hypoxia on metabolism through respirometry trials. Better understanding how low levels of dissolved oxygen contribute to mortality and rockfish behavior will allow for refinement of the catch-and-release process and the implementation of release guidelines that maximize survival. In addition, such work can provide insight into limits on rockfish suitable habitat.

Research testing the effectiveness of descending devices released 2,275 rockfish from 32 species. While there were some significant differences between device types, all devices were effective for releasing rockfishes back to depth. Initial post-release mortality (defined as all mortality events observable from the vessel while fishing) across all devices was relatively low (7.5%) in capture depths less than 100 m. These results suggest that rockfishes should be released at least half-way to the bottom (preferably directly to the bottom) for the device to be effective in minimizing post-release mortality. Although all descending devices work, at-sea conditions, vessel type, and fish size tend to influence effectiveness and user preference of different device types. This work was recently published in *Fisheries Research* by Bellquist et al. (2019).

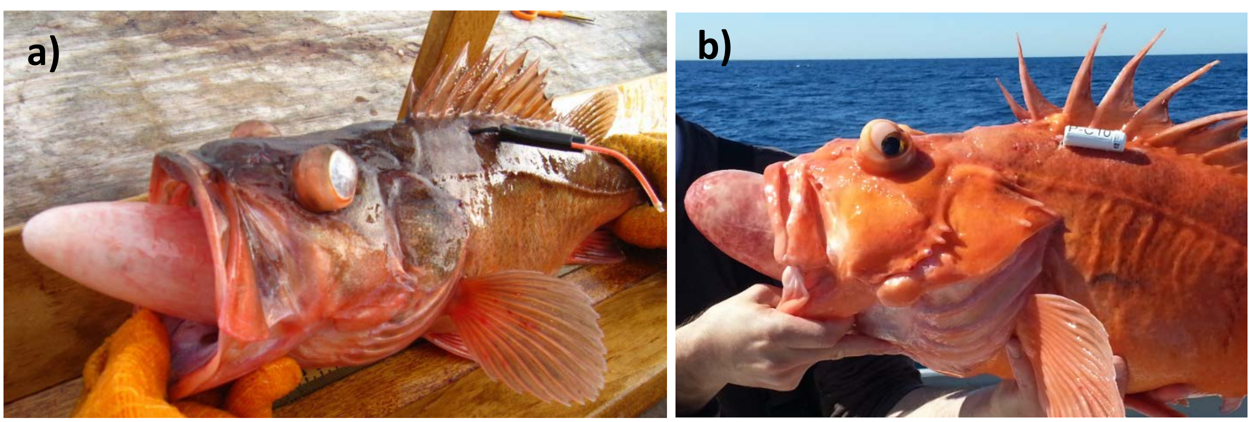

Figure X: Acoustic transmitter attachment and external barotrauma indicators for a) 47.5 cm FL Bocaccio tagged with a V9 single-anchored transmitter displaying a bloated body, everted esophagus, exophthalmia, and ocular emphysema. b) 64.0 cm Cowcod tagged with a double anchored V13 transmitter showing a bloated body, everted esophagus, exophthalmia, and the first onset of ocular emphysema (anterior-dorsal portion of eye).

D. OTHER RELATED STUDIES

D1. SWFSC FED Habitat Ecology Team 2018-19 Research on California Demersal Communities

Contact: Tom Laidig (tom.laidig@noaa.gov)
FED HET Investigators: Joe Bizzarro, Tom Laidig, Diana Watters

The SWFSC/FED Habitat Ecology Team (HET) conducts research focused on deep-water California demersal communities. Our goal is to provide sound scientific information to ensure the sustainability of marine fisheries and the effective management of marine ecosystems, with objectives to: (1) improve stock assessments, especially of rockfish species in untrawlable habitats; (2) characterize fish and habitat associations to improve EFH identification and conservation; (3) contribute to MPA design & monitoring; and (4) understand the significance of deep-sea coral (DSC) as groundfish habitat. The HET uses a variety of underwater vehicles to survey demersal fishes, macro-invertebrates (including members of DSC communities), and associated seafloor habitats off northern, central, and southern California. These surveys have resulted in habitat-specific assemblage analyses on multiple spatial scales; fishery-independent stock assessments; baseline monitoring of MPAs; documentation of marine debris on the seafloor; and predictive models of the distribution and abundance of groundfishes and deep sea corals. The following are a few examples of recent projects conducted by the HET and collaborators.

D2. Expanding Pacific Research and Exploration of Submerged Systems Campaign

Contact: Tom Laidig (tom.laidig@noaa.gov)

In 2018, a team of federal and non-federal partners initiated a new phase of collaborative ocean science off the western United States. The **EX**panding **P**acific **R**esearch and **E**xploration of **S**ubmerged **S**ystems (EXPRESS) campaign targets deepwater areas off California, Oregon, and Washington. The core focus of campaign activities is the collection of spatially explicit deepwater habitat information including multibeam, backscatter, and visual data on continental shelf, shelf edge, and slope habitats. This goal will be attained through partnerships between NOAA (NOS and NMFS), BOEM, USGS, and MBARI. From initial successes, this nascent interagency effort quickly evolved into a major field program engaging and exciting scientists and marine resource managers spanning numerous disciplines and organizations. EXPRESS members were involved in 15 research expeditions in 2019 including the 30-day deep sea coral cruise aboard the NOAA ship *Reuben Lasker* (see D3 below) and multiple west coast mapping surveys aboard the NOAA ship *Fairweather*. Six EXPRESS expeditions are currently planned for 2020.

D3. FY19 NMFS Deep-sea coral EXPRESS expedition, 1 Oct-7 Nov 2019

Contact: Tom Laidig (tom.laidig@noaa.gov)

A 30-day deep-sea coral expedition was conducted 1 Oct - 7 Nov, 2019 off the coast of Washington, Oregon, and California. The expedition was supported by NMFS' Deep Sea Coral Research and Technology Program and was jointly planned and staffed by NOAA (CINMS,

NWFSC, SWFSC), BOEM, and USGS under the EXPRESS campaign (See D2 above). Research conducted during this cruise is part of the four-year West Coast Deep Sea Coral Initiative. The goals of the expedition were to 1) Collect Essential Fish Habitat baseline information at 7 sites proposed for modification the Pacific Fishery Management Council, 2) Revisit previously surveyed sites to document if changes have occurred over time, 3) Survey areas of potential wind energy off southern Oregon and central California, 4) Collect information to validate BOEM supported cross-shelf habitat suitability models, and 5) Collect samples to help in identifying west coast corals and sponges and expand use of new technologies.
The expedition began in Willapa Canyon in southern Washington and worked its way south to the Catalina Basin. Two underwater survey vehicles were used; the NWFSC and PIFSC's autonomous underwater vehicle (AUV) and the Global Foundation for Ocean Exploration's (GFOE) remotely operated vehicle (ROV). Benthic habitats were surveyed for the presence of deep-sea corals (DSC), sponges, and fishes (Fig X, XX). Water chemistry, DSC, sponge, and geologic samples were collected for a variety of researchers.
Fifteen unique areas were sampled along the coast at depths from 133 - 1245 m. A total of 18 ROV and 24 AUV dives were completed along with almost 400 water samples for eDNA and POM studies. Thirty-five deep sea coral, 31sponge, and 14 geologic samples were collected. Over 88 fish, 32 coral, and 32 sponge taxa were identified including some potentially new species of DSC and sponges

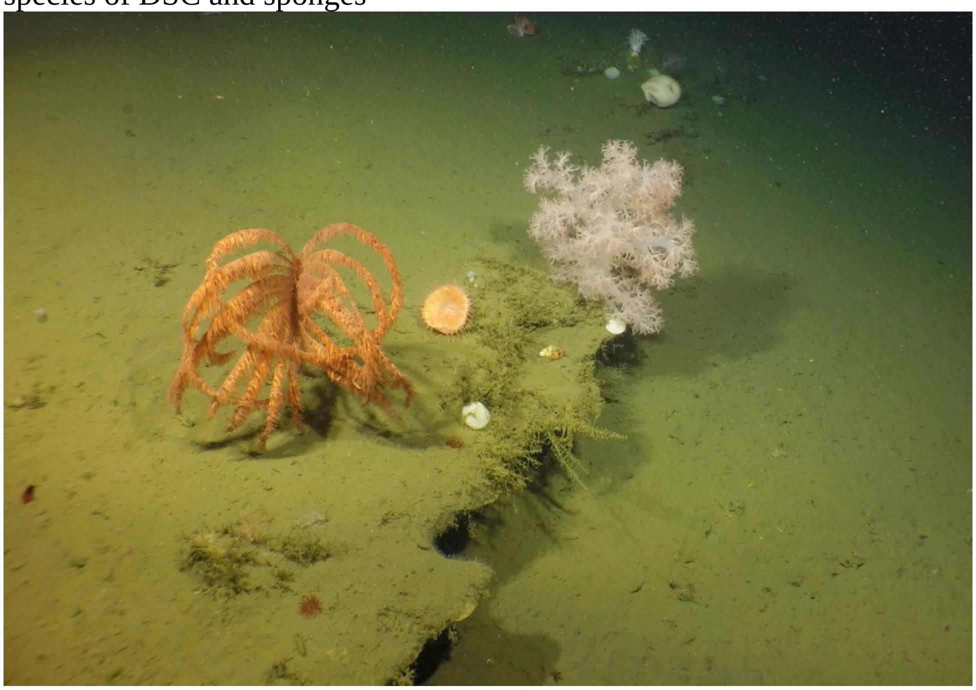

Figure X. An orange black coral (*Bathypathes* spp.) and a white soft coral (*Gersemia* spp.) at ~1100 m at Cordell Bank National Marine Sanctuary.

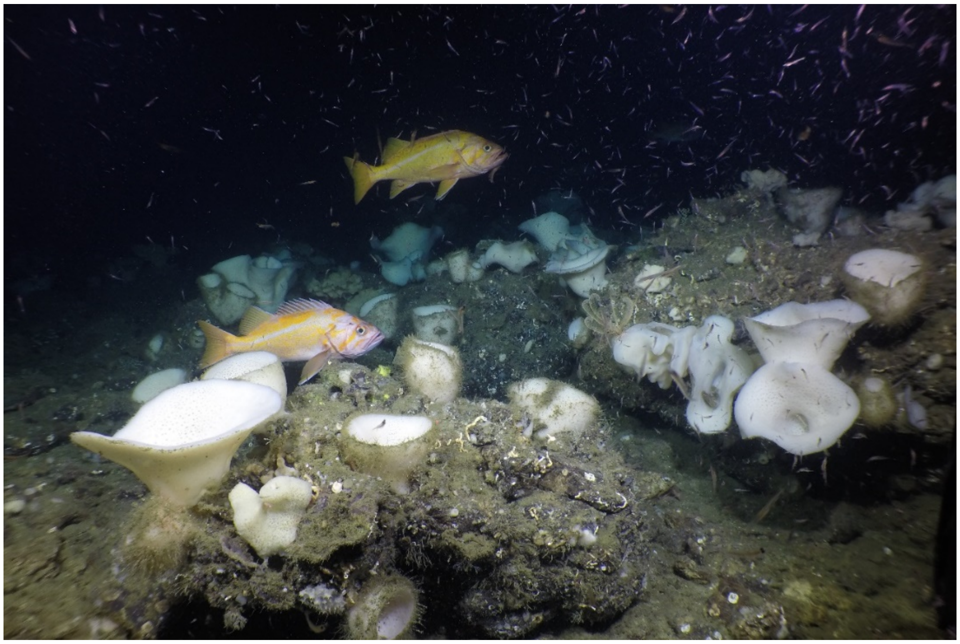
Figure XX. Two canary rockfish (*Sebastes pinniger*) within a field of sponges on Daisy Bank off central Oregon in ~140 m depth.

D4. Revise Habitat Use Database (HUD) for 5-Year Essential Fish Habitat Review
Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

During 2017, a final draft of the HUD was completed for all 117 species of groundfish identified in the current PFMC Groundfish Fishery Management Plan (FMP). The updated draft version of the HUD was then reviewed by West Coast EFH Coordinator, John Stadler, and retired NWFSC-FRAM fisheries research biologist, Waldo Wakefield. At their requests, several additions and modifications were made during 2018. A final, updated version of the HUD was be completed in May 2019. Its publicly availability through the NWFSC/FRAM Data Warehouse (https://www.nwfsc.noaa.gov/data/map) has been delayed because Todd Hay, who was integral to the QA/QC component of the project and the process of posting it on-line, left his NMFS position and no alternative plan to complete the project has yet been determined.

D5. Conduct Habitat Suitability Probability Modeling for 5-Year Essential Fish Habitat Review
Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

Support was provided to Waldo Wakefield (NWFSC, retired) and Bran Black (Oregon State University) to inform Habitat Suitability Modeling efforts for adult life stages of the 92 groundfish species that are directly managed under the PFMC Groundfish Fishery Management Plan. Using information contained in the updated HUD (see D4 above), input data were provided for latitude, depth, and habitat association inputs for Bayesian analysis. Model outputs were then displayed graphically in GIS on a scale of 0-1 that estimates the probability that any particular location (i.e., 25 m x 25 m pixel in the output map) is suitable habitat for a particular species. Modeling efforts continued throughout 2018, and were completed during May 2019.

D6. Complete Data Quality layer for Cross-Shelf Benthic Habitat Suitability Modeling Project

Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

A collaborative effort between NOS, NMFS, and BOEM personnel was initiated in 2016 to create habitat suitability models for corals and infaunal invertebrates and is ongoing. During 2017, a coastwide substrate map, initially created for the 2005 PFMC review of EFH for West Coast groundfishes, was updated to include all newly acquired seafloor induration collected since the last such effort during the 2012 EFH synthesis, and to include hard, mixed, and soft habitat types in California waters. During 2018, a data quality layer was compiled to improve the utility of the map for modeling purposes by weighing the reliability of various seafloor induration data. This updated substrate map and companion data quality layer were then used as an environmental input in coral and infauna modeling efforts. Metadata were created for the GIS products, and appropriate sections of the final report were written and submitted during the spring of 2019.

D7. Organize and Host West Coast Groundfish Food Habits Workshop
Contact: Joseph J. Bizzarro (joe.bizzarro@noaa.gov)

With support from the West Coast Region office and Office of Sustainable Fisheries, a Groundfish Food Habits Workshop was conducted at NMFS-FED in Santa Cruz during September 24-25, 2018 with over 20 participants from 4 different NMFS Science Centers, academics, CDFW biologists, and NGOs. The main goals of the Workshop were to 1) become informed of past and current research on groundfishes, as well as pelagic fishes, sea birds, and marine mammals, 2) learn how to initiate a focused food habits program from Centers that have established programs (i.e., AFSC, NEFSC), and 3) bring together SWFSC and NWFSC scientists to plan and coordinate future work. This Workshop was highly effective in achieving its goals and helped to inform the development of the SWFSC's Center for Ecosystem Science Committee. A final technical report from the Workshop was completed and submitted to all Workshop participants, the West Coast Region and Office of Sustainable Fisheries, and SWFSC-CESC on September 24, 2019.

D8. Catch estimation methods in sparsely sampled mixed stock fisheries
Contact: E.J. Dick (Edward.Dick@noaa.gov)

An ongoing project led by Nick Grunloh (UCSC/Center for Stock Assessment Research) and E.J. Dick (FED), with participation by Don Pearson (FED), John Field (FED) and Marc Mangel (UCSC/CSTAR) is focusing on the development of Bayesian hierarchical modeling approaches to be applied to historical and recent rockfish catch data and species composition samples in California fisheries, in order to improve estimates and quantify uncertainty in those estimates. Furthermore, the team has developed a Bayesian model averaging approach for inferring spatial pooling strategies across the over-stratified port sampling system. This modeling approach, along with a computationally robust system of inference and model exploration, will allow for objectively comparing alternative models for estimation of species compositions in landed catch, quantification of uncertainty in historical landings, and an improved understand the effect of the highly stratified, and sparse, sampling system on the kinds of inference possible, while simultaneously making the most from the available data. The methodology, currently a work in progress, was reviewed by a PFMC SSC methodology review panel (which included reviewers from the Center for Independent Experts) in March of 2018. The review panel provided several recommendations for additional work, and indicated that subsequent to a future review, it would be feasible to recommend that this approach for estimating the species composition of California rockfish landings be recommended as the best available science to inform stock assessments in the 2021 stock assessment cycle.

D9. Rockfish Reproductive Ecology Laboratory and Field Studies

Contact: sabrina.beyer@noaa.gov

Ongoing studies at the SWFSC Fisheries Ecology Division in partnership with the University of California Santa Cruz highlight spatiotemporal variability in reproductive output, including the production of multiple annual larval broods among California rockfishes.

A recent laboratory study of Rosy Rockfish (*Sebastes rosaceus*) documented reproductive plasticity in response to different temperature and feeding regimes affecting female body condition, with respect to maternal size. Females released zero to five larval broods annually, with larger females releasing a greater number compared with small females. Warmer water temperature decreased the time interval between brood releases, likely reflecting faster egg and larval development at warmer temperatures. However, warmer temperature did not increase the total number of broods and was likely in tradeoff with increased metabolic demand at warmer temperature. Well-fed females, in better body condition had higher fecundity as a function of both larger sized broods and a greater number of annual broods. Conversely, mature females in poor body condition at the start of the reproductive season did not reproduce, possibly evidence of skipped spawning. Reproductive plasticity in 0, 1 or more broods a year in response to the environment likely contributes to high inter-annual variation in population larval production and may affect recruitment patterns important for fisheries. Understanding the causes and consequences of reproductive plasticity will be critical for developing sustainable management strategies and to predict the response of reproductive success and fishery productivity to changing climate conditions. A manuscript of the laboratory study is undergoing NOAA internal review in preparation for submission to a scientific journal (authors: Sabrina Beyer, Suzanne Alonzo and Susan Sogard).

Field collections of Rosy Rockfish from two locations in central and southern California over the 2019-2020 reproductive season documented spatial differences in reproductive patterns. Multiple brooding was prevalent among females in the southern population collected near Anacapa Island in the Santa Barbara Channel and much less prevalent among females collected in central California in the Monterey Bay. Overall, southern females were larger in size and highly more productive through the production of multiple larval broods. The length of the parturition season was longer in Southern California. Southern females began releasing larvae in January, two months ahead of females in central California and continued to be gestating fertilized embryos into August. In Central California, females were collected with eyed-larvae over a shorter period from March through June.

A time-series of fecundity data was expanded by one additional year of collections in Central California at Cordell Bank in January 2020 to document interannual variability in reproductive effort correlated with oceanographic conditions in a range of economically important rockfishes. Samples of gravid Chilipepper (*S. goodei*), Bocaccio (*S. paucispinis*), Yellowtail (*S. flavidus*) and Widow (*S. entomelas*) rockfishes will be incorporated into a nearly 20 year time-series of fecundity data dating back to the 1980s and 1990s and spanning a range of environmental conditions in the Central region of the California Current to better understand environmental drivers of reproductive plasticity and maternal reproductive effort.

E. GROUNDFISH PUBLICATIONS OF THE SWFSC, 2019 – PRESENT

E1. Primary Literature Publications

Baetscher, D.S., Anderson, E.C., Gilbert-Horvath, E.A., Malone, D.P., Saarman, E.T., Carr, M.H., and Garza, J.C. 2019. Dispersal of a nearshore marine fish connects marine reserves and adjacent fished areas along an open coast. Molecular Ecology 28:1611-1623.

Bellquist, L., Beyer, S. Arrington, M., Maeding, J., Siddall, A., Fischer, P., Hyde, J., Wegner, N.C. 2019. Effectiveness of descending devices to mitigate the effects of barotrauma among rockfishes (*Sebastes* spp.) in California recreational fisheries. Fisheries Research 215:44-52.

Bizzarro, J.J., Gilbert-Horvath, E.A., Dick, E.J., Berger, A.M., Schmidt, K.T., Pearson, D., Petersen, C., Kautzi, L.A., Miller, R.R., Field, J.C., and Garza, J.C. 2020. Genetic identification of blue rockfish (*Sebastes mystinus*) and deacon rockfish (*S. diaconus*) to enable life history analyses for stock assessment. Fishery Bulletin 118:37-50.

Gao, J, and Munch, S.B. 2019. A function-valued trait approach to estimating the genetic basis of size at age and its potential role in fisheries-induced evolution. Evolutionary Applications 12:964-976.

Haltuch, M.A., Brooks, E.N., Brodziak, J., Devine, J.A., Johnson, K.F., Klibansky, N., Nash, R.D.M., Payne, M.R., Shertzer, K.W., Subbey, S., and Wells, B.K. 2019. Unraveling the recruitment problem: A review of environmentally-informed forecasting and management strategy evaluation. Fisheries Research 217:198-216.

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STATE OF ALASKA
GROUNDFISH FISHERIES

ASSOCIATED INVESTIGATIONS IN 2019

Prepared for the Sixty-first Annual Meeting of the Technical Subcommittee
of the Canada-United States Groundfish Committee

With contributions from:
Asia Beder, Brittany Blain-Roth, Mike Byerly, Bob Chadwick, Rhea Ehresmann,
Kathrine Howard, Lee Hulbert, Kevin McNeel, Jeff Nichols,
Wyatt Rhea-Fournier, Natura Richardson, Jan Rumble, Elisa Russ, Martin Schuster, Carole
Triem, Sarah Webster, and Carrie Worton

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ALASKA DEPARTMENT OF FISH AND GAME
DIVISION of COMMERCIAL FISHERIES & DIVISION of SPORT FISH
Capital Office Park
1255 W. 8th Street
Juneau, AK 99802-5526

TABLE OF CONTENTS

STATE OF ALASKA GROUNDFISH FISHERIES AND ASSOCIATED INVESTIGATIONS IN 2019

I. Agency Overview

A. Description of the State of Alaska commercial groundfish fishery program (Division of Commercial Fisheries)

The Alaska Department of Fish and Game (ADF&G) has jurisdiction over all commercial groundfish fisheries, except for Pacific halibut, within the internal waters of the state and to three nautical miles offshore along the outer coast. A provision in the federal Gulf of Alaska (GOA) Groundfish Fishery Management Plan (FMP) gives the State of Alaska limited management authority for demersal shelf rockfish (DSR) in federal waters east of 140° W. longitude. The North Pacific Fisheries Management Council (Council) acted in 1997 to remove black and blue (now called deacon) rockfish from the GOA FMP. In 2007, dark rockfish was removed from both the GOA and the Bering Sea and Aleutian Islands (BSAI) FMP. Thus, in these areas the state manages these species in both state and federal waters. The state also manages the lingcod resource in both state and federal waters of Alaska. The state manages some groundfish fisheries occurring in Alaska waters in parallel with NOAA Fisheries, adopting federal seasons and, in some cases, allowable gear types as specified by NOAA Fisheries. The information related in this report is from the state-managed groundfish fisheries only.

The State of Alaska is divided into three maritime regions for marine commercial fisheries management. The Southeast Region extends from the Exclusive Economic Zone (EEZ) equidistant line boundary in Dixon Entrance north and westward to 144° W. longitude and includes all of Yakutat Bay (Appendix II). The Central Region includes the Inside and Outside Districts of Prince William Sound (PWS) and Cook Inlet including the North Gulf District off Kenai Peninsula. The Westward Region includes all territorial waters of the Gulf of Alaska south and west of Cape Douglas and includes North Pacific Ocean waters adjacent to Kodiak, and the Aleutian Islands as well as all U.S. territorial waters of the Bering, Beaufort, and Chukchi Seas.

1. Southeast Region

The **Southeast Region** Commercial Fisheries groundfish staff are located in Sitka, Juneau, and Petersburg. Sitka staff is comprised of the project leader, one fishery biologist, and one full-time fishery technician. Staff in Juneau includes one full-time fishery biologist and one seasonal fishery technician, and Petersburg staff includes two fishery biologists and a seasonal fishery technician. In addition, the project provides support for port samplers in Ketchikan to allow sampling of groundfish landings. The project also receives biometric assistance from ADF&G headquarters in Juneau.

The Southeast Region's groundfish project has responsibility for research and management of all commercial groundfish resources in the territorial waters of the Eastern GOA as well as in federal waters for demersal shelf rockfish (DSR); black, deacon, and dark rockfishes; and lingcod. The project cooperates with the federal government for management of the waters of the adjacent EEZ. The project leader typically attends annual meetings of the Council’s GOA Groundfish Plan Team and produces the annual stock assessment for DSR for consideration by the Council.

Project activities center around fisheries monitoring, resource assessment, and inseason management of the groundfish resources. Inseason management decisions are based on data collected from the fisheries and resource assessment surveys. Primary tasks include fish ticket collection, editing, and data entry for both state and federally managed fisheries; dockside sampling of sablefish, lingcod, Pacific cod, and rockfish landings; and logbook collection and data entry. Three resource assessment surveys and a marking survey were conducted in 2019. The ADF&G vessel the *R/V Medeia* is home ported in Juneau and is used to conduct the annual sablefish marking survey.

2. Central Region

The **Central Region** commercial fisheries groundfish management and research staff are primarily located in Homer. The management staff in Homer consists of an area management biologist, an assistant area management biologist (serves as regional port sampling and age reading coordinator), a research analyst (processes fish tickets and manages databases), one seasonal technician, and one full-time technician who serves as the primary commercial groundfish sampler and age reader. A seasonal fishery biologist located in Cordova serves as a port sampler and provides management support, and a seasonal technician located in Seward serves as a port sampler. The area management biologist serves as a member of the Council's GOA Groundfish Plan Team. The research staff in Homer consists of a Groundfish research project lead, a fishery biologist, and a research analyst. Commercial Fisheries groundfish staff are supported by regional staff in Anchorage.

Commercial fisheries groundfish staff are responsible for the research and management of groundfish species harvested in Central Region, which includes state waters of Cook Inlet and Prince William Sound (PWS) areas, as well as federal waters for lingcod, and black, deacon, and dark rockfishes. Within Central Region, groundfish species of primary interest include sablefish, Pacific cod, walleye pollock, lingcod, rockfishes, skates, sharks, and flatfishes. Management staff collect harvest data through commercial groundfish sampling, fishermen interviews, logbooks, and onboard observing. Commercial harvest information (fish tickets) is processed in Homer for state and federal fisheries landings in Central Region ports. For some fisheries, logbooks are required, and data is collected and entered into local databases to provide additional information, including catch composition, catch per unit effort, depth, and location data. Research staff produce relative abundance estimates from bottom trawl surveys conducted in Kachemak Bay and in the inside waters of PWS. Bottom trawl surveys are conducted by ADF&G research vessels the *R/V Pandalus*, which surveys Kachemak Bay from the port of Homer, and the *R/V Solstice*, which surveys PWS from the port of Cordova.

3. Westward Region

The **Westward Region** Groundfish management and research staff are in Kodiak and Dutch Harbor. Kodiak staff is comprised of a regional groundfish management biologist, an area groundfish management biologist, an assistant area groundfish management biologist, a groundfish research project leader, an assistant groundfish research project biologist, a groundfish dockside sampling program coordinator, a groundfish dockside sampling program assistant biologist, a lead trawl survey biologist, an assistant trawl survey biologist, two seasonal fish ticket processing technicians, and several seasonal dockside sampling technicians. An area management biologist, an assistant area groundfish management biologist and a seasonal fish ticket processing technician are in the Dutch Harbor office. Seasonal dockside sampling also occurs in Chignik, Sand Point, and King Cove. The *R/V Resolution*, *R/V K-Hi-C*, and *R/V Instar* hail from Kodiak and conduct a variety of groundfish related activities in the waters around Kodiak, the south side of the Alaska Peninsula, and in the eastern Aleutian Islands.

Major groundfish activities include: fish ticket editing and entry for approximately 15,000 tickets from both state and federal fisheries; analysis of data collected on an annual multi-species trawl survey encompassing the waters adjacent to the Kodiak archipelago, Alaska Peninsula, and Eastern

Aleutians; management of black rockfish, dark rockfish, state-waters Pacific cod, lingcod, and Aleutian Island state-waters sablefish fisheries; conducting dockside interviews and biological data collections from commercial groundfish landings; and a number of research projects. In addition, the Westward Region has a member on the Council's GOA Groundfish Plan Team (Nathaniel Nichols).

4. Headquarters

a. Alaska Fisheries Information Network

The 1996 Magnuson-Stevens Act called for developing regional fishery databases coordinated between state and federal agencies. The Alaska Fisheries Information Network (AKFIN), created in 1997, accomplishes this objective. The AKFIN program provides the essential fishery catch data needed to manage Alaska's groundfish and crab resources within the legislative requirements of the Act in Section 303(a) 5. Alaska has diverse data collection needs that are similar to other states. But the extensive geographic area and complexity of fisheries management tools used in Alaska have resulted in AKFIN becoming a cooperative structure that is responsive to the needs to improve data collection. The Pacific States Marine Fisheries Commission (PSMFC) manages the AKFIN grant with the funding shared by ADF&G statewide, AKFIN contract, and the PSMFC sponsored AKFIN Support Center (AKFIN-SC) in Portland, Oregon. ADF&G has primary responsibility for the collection, editing, maintenance, analysis, and dissemination of these data and performs this responsibility in a comprehensive program.

The overall goal of ADF&G's AKFIN program is to provide accurate and timely fishery data that are essential to management, pursuant to the biological conservation, economic and social, and research and management objectives of the FMPs for groundfish and crab. The specific objectives related to the groundfish fisheries are to collect groundfish fishery landing information, including catch and biological data, from Alaskan marine waters extending from Dixon Entrance to the BSAI;

1) to determine ages for groundfish samples using age structures (as otoliths, vertebrae, and spines) arising from statewide commercial catch and resource survey sampling conducted by ADF&G;
2) to provide the support mechanisms needed to collect, store, and report commercial groundfish harvest and production data in Alaska;
3) to integrate existing fishery research data into secure and well-maintained databases with consistent structures and definitions;
4) to increase the quality and accuracy of fisheries data analysis and reporting to better meet the needs of ADF&G personnel, AKFIN partner agencies, and the public, and to make more of this information available via web-access while maintaining the department's confidentiality standards;
5) to provide GIS services for AKFIN fishery information mapping to ADF&G Division of Commercial Fisheries personnel and participate in GIS and fishery data analyses and collaboration with other AKFIN partner agencies; and
6) to provide internal oversight of the AKFIN contract between the ADF&G and the PSMFC.

Groundfish species include walleye pollock, Pacific cod, sablefish, skates, various flatfish, various rockfish, Atka mackerel, lingcod, sharks, and miscellaneous species.

The foundation of the state's AKFIN project is an extensive port sampling system for collection and editing of fish ticket data from virtually all the major ports of landing from Ketchikan to Adak and the Pribilof Islands, with major emphasis on Sitka, Homer, Kodiak, and Dutch Harbor. The port sampling program includes collection of harvest data, such as catch and effort, and the collection of biological data on the species landed. Age determination is based on samples of age structures collected from landed catches. A dockside sampling program provides for collection of accurate biological data (e.g., size, weight, sex, maturity, and age) and verifies self-reported harvest information submitted on fish tickets from shoreside deliveries of groundfish throughout coastal Alaska. In addition, the GOA Groundfish FMP and the BSAI Groundfish FMP require the collection of groundfish harvest data (fish tickets) in the North Pacific. The AKFIN program is necessary for management and for the analytical and reporting requirements of the FMPs.

The state's AKFIN program is supported by a strong commitment to development and maintenance of a computer database system designed for efficient storage and retrieval of the catch and production data on a wide area network and the internet. It supports the enhancement of the fish ticket information collection effort including regional fishery monitoring and data management; GIS database development and fishery data analysis; catch and production database development and access; the Age Determination Unit laboratory; database management and administration; fisheries data collection and reporting; and fisheries information services.

Local ADF&G personnel maintain close contact with fishers, processors, and enforcement to maintain a high quality of accuracy in the submitted fish ticket records. Groundfish landings are submitted electronically from the interagency electronic reporting system, eLandings, to the eLandings repository database. Signed copies of the fish tickets are submitted to the local office offices of ADF&G within seven days of landing. Data are reviewed, compared to other observations, edited, and verified. Once data are processed by local staff members, the fish ticket data are pulled into the ADF&G database of record; the statewide groundfish fish ticket database. Fish ticket data are immediately available to inseason management via the analysis and reporting tool, OceanAK. Verified fish ticket data are also available immediately after processing from this tool, as well.

Within the confines of confidentiality agreements, raw data are distributed to the National Marine Fishery Service (NMFS, NOAA Fisheries, both the Alaska Regional office and the Alaska Fishery Science Center), the Council, the Commercial Fisheries Entry Commission (CFEC), and the AKFIN Support Center on a regularly scheduled basis. Summary groundfish catch information is also provided to the Pacific States Fisheries Information Network (PACFIN), the State of Alaska Board of Fisheries (BOF), NOAA Fisheries, Council and the AKFIN Support Center.

The fishery information collected by the AKFIN program is not only essential for managers and scientists who must set harvest levels and conserve the fisheries resources, but it is also valuable for the fishermen and processors directly involved in the fisheries, as well as the general public. To meet those needs, the department has designed, implemented, and continues to improve database systems to store and retrieve fishery data, and continues to develop improvements to fishery information systems to provide data to other agencies and to the public.

Groundfish fishery milestones for this ongoing ADF&G AKFIN program are primarily the annual production of catch records and biological samples. In calendar year 2019, ADF&G AKFIN personnel processed 14,025 groundfish fish tickets, collected 25,821 groundfish biological samples and measured 11,776 age structures (see tables below for regional breakdown). These basic measures of ongoing production in support of groundfish marine fisheries management by

AKFIN funded ADF&G personnel are representative of the level of annual productivity by the AKFIN program since its inception in 1997 (Contact Lee Hulbert).

Groundfish Fish Tickets Processed - Calendar Year 2019

ADF&G Region	
1 - Southeast	3,287
2 - Central	2,247
4 - Westward; Kodiak, Chignik, AK Pen.	6,798
4 - Westward; BSAI	1,693
Total	14,025

Groundfish Biological Data Collection - Calendar Year 2019

ADF&G Region	AWL Samples Collected	Age Estimates Produced by Regional Personnel	Age Estimates Produced by the Age Determination Unit
1 - Southeast	7,211	n/a	5,451
2 - Central	11,291	3,093	n/a
4 - Westward	7,319	3,232	n/a
Total	25,821	6,325	5,451

b. Interagency Electronic Reporting System - eLandings (Contact Carole Triem)

ADF&G maintains a commercial harvest database, based on landing report receipts – fish tickets. These data are comprehensive for all commercial salmon, herring, shellfish, and groundfish from 1969 to present. Data are stored in an Oracle relational database and available to statewide staff via the OceanAK reporting tool. Data are transferred annually to the Commercial Fisheries Entry Commission, where additional license and value information is merged with all fish ticket records. Once completed, the data are provided to the AKFIN support center, then summarized and made available to PACFIN.

Beginning in 2001, the agencies tasked with commercial fisheries management in Alaska (ADF&G, NOAA Fisheries, IPHC) began development of consolidated landing, production, and IFQ reporting from a sole source – the Interagency Electronic Reporting System (IERS). The goal is to move all fisheries dependent data to electronic reporting systems. The web-based reporting component of this system is eLandings**.** The application for the at-sea catcher processor fleet is seaLandings. Vessels using the seaLandings application upload landing and production reports to the centralized database. tLandings was developed to address electronic reporting on-board groundfish and salmon tender vessels. The application and the landings reports are stored on a portable thumb drive and are delivered to the shoreside processor for upload to the eLandings repository database. Fisheries management agencies use a separate application, the IERS Agency Interface, to view and edit landing reports. The IERS management/development team have implemented an electronic logbook application, eLogbook, currently used by groundfish catcher processors and longline catcher vessels. The IERS has been successfully operated in Alaska's commercial fisheries since August 2005. To date, approximately 1.4 million landing reports have been submitted to the eLandings repository database. More than 99% of all groundfish landings are submitted electronically.

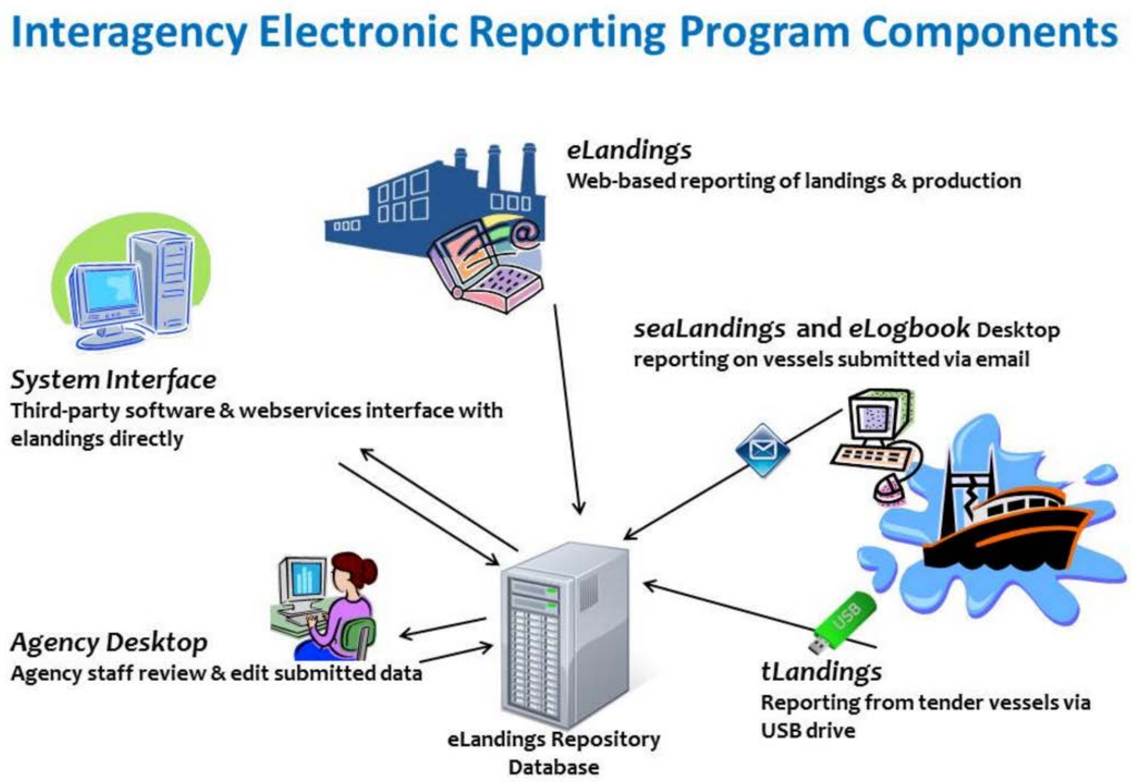


Figure 1. Data are reported by the seafood industry using eLandings web, seaLandings and tLandings. Agency staff review, edit and verify landing and production reports within the eLandings agency desktop tool. Industry can pull harvest data for their company from the database using the eLandings system interface tools.

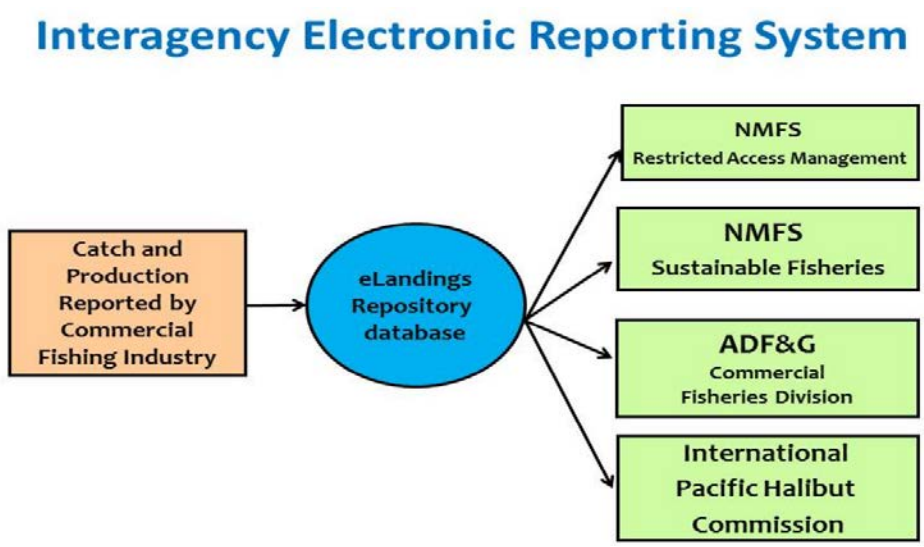


Figure 2. Interagency staff have established methods to pull data from the repository database into their databases of record. The ADF&G fish ticket records are pulled into the commercial fisheries fish ticket database once data verification has occurred.

Our approach, throughout this project, has been staged implementation which allows a small staff to successfully manage this ambitious project. Salmon fisheries are more diverse and seasonal than groundfish and crab fisheries. ADF&G will always support conventional, paper-based reporting for smaller buyers and processors. In November 2015, ADF&G adopted a regulation to require larger seafood processors to use the tLandings application for all tendered salmon. All tendered groundfish must be reported using the tLandings application, as well. During the 2019 salmon season, 93.7% percent of all salmon landings were submitted electronically.

Implementation of statewide electronic reporting of shellfish and herring fisheries is planned; however, this ambitious undertaking has been delayed. Turnover in both the Program Coordinator and various Programmer positions has contributed to the delays. Due to the complexity of the eLandings system, training a new programmer requires up to two years before he/she can act without review.

The IERS features include electronic landing and production reports, real time quota monitoring, immediate data validation, and printable (.pdf) fish ticket reports. The IERS provides processors with web-based electronic catch and production data extraction using an XML output. ADF&G personnel, funded by AKFIN, Rationalized Crab Cost Recovery funds, and IFQ Halibut/Sablefish Cost Recovery funds, participate in the IERS project on the development, implementation, and maintenance levels. During 2019, the IERS recorded 222,128 landing reports in crab, groundfish, and salmon fisheries. The IERS is extensively documented on a public and secure wiki at: https://elandings.alaska.gov/confluence/

Local ADF&G personnel in six locations throughout the state of Alaska (Petersburg, Sitka, Juneau, Homer, Kodiak and Dutch Harbor) maintain close contact with groundfish fishers, processors, and state/federal enforcement to maintain a high quality of accuracy in the submitted fish ticket records. The Interagency Electronic Reporting System – eLandings, seaLandings, tLandings, and eLogbook applications, with immediate data validation and business rules, has improved data quality and allows personnel to function at a higher level. User support is provided by ADFG and NMFS staff, who monitor the eLandings Help Desk email address. IFQ reporting support is provided by the NOAA Fisheries Data Technicians.

Landing and production data are submitted to a central database, validated and reviewed, and pulled to the individual agency databases. Landing data are available to agency personnel within seconds of submission of the report. Printable documentation of the landing report and the Individual Fishery Quota debit are created within the applications. Signed fish tickets continue to be submitted to local offices of ADF&G for additional review and comparison to other data collection documents. These documents include vessel/fisher logbooks, agency observer datasets, and dockside interviews with vessel operators.

Detailed data are distributed to the State of Alaska CFEC annually. As outlined in State of Alaska statue, 16.05.815, detailed groundfish data are available to the NOAA Fisheries-Alaska regional office from the eLandings repository database. The AKFIN Support Center receives groundfish data on a monthly schedule, which is summarized and provided to PACFIN. The CFEC merges the ADF&G fish ticket data with fisher permit and vessel permit data. This dataset is then provided to the AKFIN Support Center, which distributes the data to the professional staff of the Council, NOAA Alaska Science Center staff, and summarized data to PACFIN. Summary groundfish catch information is also posted on the ADF&G Commercial Fisheries website: http://www.cf.adfg.state.ak.us/geninfo/finfish/grndfish/grndhome.php. Summarized data are provided to the BOF, the Council, and to the State of Alaska legislature as requested.

5. Gene Conservation Laboratory

The ADF&G Gene Conservation Laboratory (GCL) is a statewide program located in Anchorage. The mission of the GCL is to protect genetic resources and provide genetic information and advice to department staff, policy makers, and the public to support management of resources.

In the past, the GCL collected genetic information on black, yelloweye, light and dark dusky rockfish, and pollock (a list of Sebastes and pollock tissue samples stored at GCL can be found in Appendix III). The GCL used traditional genetic markers, such as allozymes, mitochondria DNA, and microsatellites, to identify larval and juvenile rockfish (Seeb and Kendall 1991), to study population structure of black rockfish in the Gulf of Alaska (Seeb 2004), and to investigate spatial and temporal genetic diversity in walleye pollock from Gulf of Alaska, eastern Bering Sea, and eastern Kamchatka (Olsen et al. 2002).

In 2019, the GCL developed an operational plan with Division of Sport Fish to sample and analyze yelloweye and black rockfish from inside and outside waters of Prince William Sound, North Gulf of Alaska, and Southeast Alaska (Howard et al. 2019). The GCL used Restriction site Associated DNA Sequencing (RAD-Seq) to develop a new set of Single Nucleotide Polymorphism (SNP) genetic markers. These markers will be used to evaluate the population structure of black and yelloweye rockfish from inside and outside waters in 2020.

6. Age Determination Unit

The Mark, Tag, and Age (MTA) Laboratory's Age Determination Unit (ADU) is the statewide groundfish and invertebrate age reading program based out of Juneau, AK. The ADU is responsible for providing age data support to regional commercial fisheries programs to monitor population health, assess stock size and growth, and research species life history. The ADU also is responsible for monitoring and improving the quality of age data through precision testing of production data and continual training of age readers. During 2019, the ADU received 10,954 otolith sets from central and southeast Alaska commercial and survey sampling (representing 12 groundfish species). The ADU produced 6,418 ages and distributed 5,873 ages to region managers, including data from samples received in previous years but processed in 2019. Age data quality is assessed through precision monitoring using additional, independent estimates. A random 30% of specimens and reads with outlying fish and otolith size-at-age are selected for precision testing (data are compared to estimated ranges from growth models; otolith measurements are described below). Discrepancies between precision tests and original ages are resolved through development of independent age estimates by the disputing readers. During 2019, quality control procedures resulted in an additional 4,804 age estimates. Personnel learn to interpret seasonal banding patterns through training with experienced age readers and independent reading of preprocessed age structures. Trained personnel also continue to calibrate on preprocessed structures to insure consistency of age estimates. Training and calibration procedures resulted in an additional 2,509 age estimates. Given production, quality control, and training procedures, the ADU recorded 13,852 groundfish ages.

Correlations have been found between fish length, otolith morphometrics, and age. The ADU collects otolith measurements and uses them to identify and resolve age estimation, specimen sequence, data entry, and species identification errors. During processing, otolith length, height, and weight are recorded from a minimum of one age structure per fish (18,463 otoliths in 2019, representing 12 groundfish species). To identify possible age estimation errors, the ADU compares fish length, otolith weight, and age to estimated fish and otolith size-at-age ranges for lingcod, yelloweye rockfish, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and sablefish.

Estimated sizes-at-age were developed from Ludwig von Bertalanffy and exponential growth models, and reasonable error ranges per size were entered into a database table.

To ensure consistency of age criteria across programs, the ADU exchanges specimens and data, attends workshops, and presents research through the Committee of Age Reading Experts (CARE; Working Group of the TSC). In 2019, ADU personnel participated in age structure exchanges to address agency and TSC concerns, prepared CARE documents for the TSC meeting, and chaired, presented at, and helped organize the 2019 CARE meeting. The ADU reviewed the results of four yelloweye rockfish age structure exchanges with Washington Department of Fish and Wildlife (WDFW), Northwest Fisheries Science Center in Newport, OR (NWFSC), Fisheries and Oceans Canada (DFO), and ADF&G in Homer; and one Pacific cod exchange with the Alaska Fisheries Science Center in Seattle, WA (AFSC). The ADU also reviewed four sablefish exchanges with AFSC, NWFSC, and DFO and initiated one known-age sablefish exchange.

The ADU is funded by the State of Alaska, AKFIN, and special project support. In fiscal year 2019 and 2020, approximately 56% of funding was provided by the State of Alaska, 30% by AKFIN, and 14% from research grants. During 2019, the ADU employed 13 people (approximately 98 man months) to age, process samples, enter data, maintain sample archives, measure samples, and complete other support tasks for both groundfish and invertebrates.

B. Description of the State of Alaska sport groundfish fishery program (Division of Sport Fish)

ADF&G manages all sport groundfish fisheries within the internal waters of the state, in coastal waters out to three miles offshore, and throughout the EEZ, except for the sport halibut fishery which is managed by IPHC and NMFS. The Alaska BOF extended existing state regulations governing the sport fishery for all marine species into the waters of the EEZ off Alaska in 1998. This was done under provisions of the Magnuson-Stevens Fishery Conservation and Management Act that stipulate that states may regulate fisheries that are not regulated under a federal FMP or other applicable federal regulations. No sport fisheries are included in the GOA FMP.

Most management and research efforts are directed at halibut, rockfish, lingcod, and sablefish; the primary bottomfish species targeted by the sport fishery. Statewide data collection programs include an annual mail survey (Statewide Harvest Survey, SWHS) that estimates overall harvest (in number of fish) of halibut, rockfishes (all species combined), lingcod, Pacific cod, sablefish, and sharks (all species combined), and a mandatory logbook to assess harvest of selected species including halibut, rockfish (pelagic, yelloweye, or other nonpelagic), lingcod, sablefish, and salmon shark in the charter boat fishery.

The lack of stock assessment information for state-managed species has prevented development of abundance-based fishery objectives. As a result, management is based on building a conservative regulatory framework specifying bag and possession limits, seasons, and methods and means. Stock status is evaluated by examining time series data on age, size, and sex composition. The lack of stock assessments, coupled with increasing effort and harvest in several groundfish sport fisheries, accentuate the need for developing comprehensive management plans and harvest strategies that include the sport and commercial sectors.

Regional programs with varying objectives address estimation of sport fishery statistics including harvest and release magnitude and biological characteristics such as species, age, size, and sex composition. Research was funded through state general funds and the Federal Aid in Sport Fish Restoration Act. There are essentially two maritime regions for marine sport fishery management in Alaska.

1. Southeast Region

The **Southeast Region** extends from the EEZ boundary in Dixon Entrance north and westward to Cape Suckling, at approximately 144° W. longitude. Regional staff in Juneau coordinate a data collection program for halibut and groundfish in conjunction with a regionwide salmon harvest studies project. The regional research coordinator, project leader, and the project research analyst are based in Juneau. The project biometrician is stationed in Anchorage. Beginning in 2014, the area management biologists in Yakutat, Juneau, Sitka, Petersburg/Wrangell, Ketchikan, and Craig are responsible for the onsite daily supervision of the field technicians. A total of 25-30 technicians work at the major ports in the Southeast region, where they interview anglers and charter operators and collect data from sport harvests of halibut and groundfish while also collecting data on sport harvests of salmon.

Biological data collected included lengths of halibut, rockfish, lingcod, and sablefish, sex of lingcod, sex and age of black rockfish at Sitka, genetic information of black and yelloweye rockfish, the sport fishery sector (charter or unguided), statistical areas fished, and other basic data. Otoliths were collected from black rockfish landed at Sitka for estimation of age composition in 2016–2019. Genetic information was collected from black and yelloweye rockfish in 2019. Data summaries were provided to the Alaska BOF, other ADF&G staff, the public, and a variety of other agencies such as the Council, IPHC, and NOAA Fisheries.

The Regional Management Coordinator and Area Management Biologists in Yakutat, Haines/Skagway, Sitka, Juneau, Petersburg/Wrangell, Craig, and Ketchikan are responsible for groundfish management in those local areas. The demersal shelf rockfish and lingcod sport fisheries are managed under the direction of the Demersal Shelf Rockfish Delegation of Authority and Provisions for Management (5 AAC 47.065) and the Lingcod Delegation of Authority and Provisions for Management (5 AAC 47.060) for allocations set by the Alaska BOF.

2. Southcentral Region

The **Southcentral Region** includes state and federal waters from Cape Suckling to Cape Newenham, including PWS, Cook Inlet, Kodiak, the Alaska Peninsula, the Aleutian Islands, and Bristol Bay. The Southcentral Region groundfish staff consists of two regional management biologists as well as area management biologists and assistants for the following areas: (1) PWS and the North Gulf areas, (2) Lower Cook Inlet, and (3) Kodiak, Alaska Peninsula, and the Aleutian Islands. In addition, a region-wide harvest assessment project is based in the Homer office, consisting of a project leader, project assistant, and six technicians. Seasonal technicians collected data from the sport harvest at six major ports in the region.

Ongoing assessment of sport harvest and fishery characteristics at major ports throughout the region includes interviews of anglers and charter boat operators and sampling of the sport harvest. Data collected included length, age, and sex of halibut, rockfishes, lingcod, and sharks; sablefish, Pacific cod, and other infrequently harvested sport bottomfish species may also be sampled opportunistically. All non-halibut age reading was done in Homer, and the staff members are active participants in CARE. Halibut otoliths were forwarded to the IPHC for age reading.

Southcentral Region staff is responsible for management of groundfish fisheries, except halibut, in state and federal waters. In addition, staff provide sport halibut harvest statistics to the IPHC and the Council, assist in development and analysis of the statewide charter logbook program and SWHS, provide information to the Alaska BOF, advisory committees, and local fishing groups, draft and review proposals for sport groundfish regulations, and disseminate information to the public.

II. Surveys

Fishery surveys, where applicable, are addressed in research sections by species.

III. Marine Reserves

Nothing to report for 2019.

IV. Groundfish Research, Assessment, and Management

A. Hagfish

1. Research

In 2016, the **Southeast Region** began an opportunistic survey for *Eptatretus stoutii* and *E. deani* during the annual shrimp pot surveys to gather information on distribution and life history information including: size at maturity, fecundity, sex ratio, length, and weight frequencies. Survey sampling continued in 2017 and stations were expanded to Clarence Strait based bycatch occurrence of hagfish during the sablefish longline survey. Samples were collected in Ernest Sound and Behm Canal using longlined 20-L bucket traps dispersed 5.5 m apart with each trap consisting of 9.5 mm escape holes, 1 kg weight, and a 102 mm entry funnel and destruct device. Each set was sampled for count-by-weight (number of hagfish and weight per trap) and a sub-sample of 5 hagfish per trap or 125 per set were frozen and sampled for biological information in the lab. To date 634 hagfish have been sampled with the largest length recordings for *E. deani* at 770 mm for females and 620 mm for males (Contact Rhea Ehresmann).

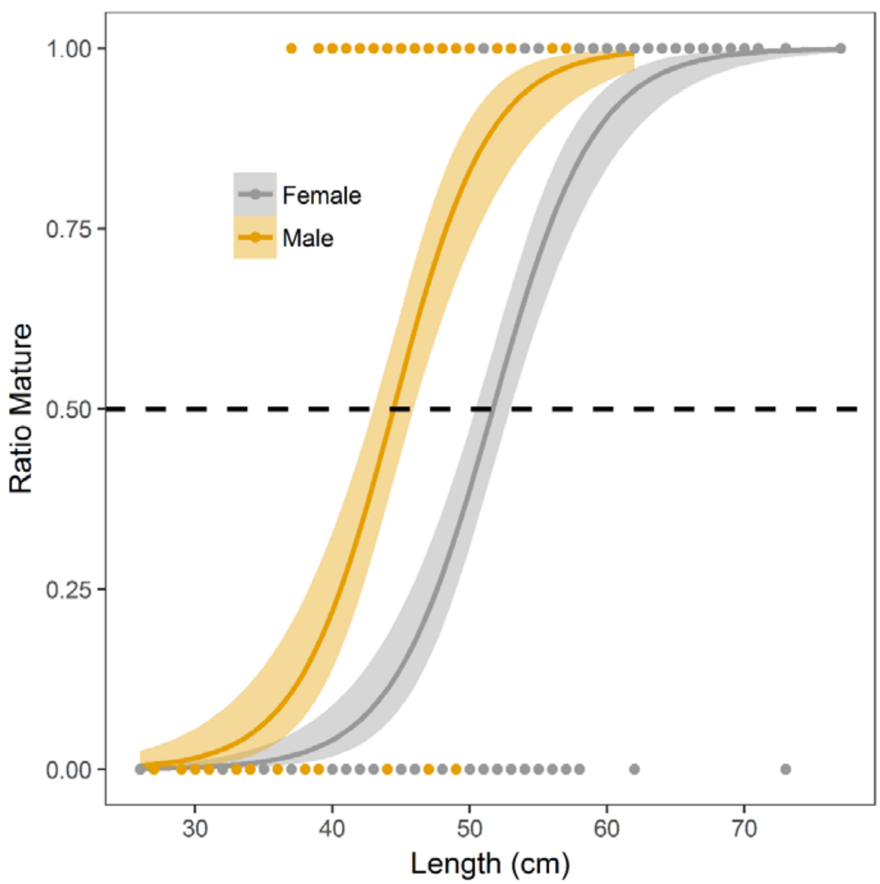


Figure 3. Preliminary size at 50% maturity with 95% confidence intervals for male (44.4 cm, n=182) and female (51.6 mm, n=269) *E. deani* in southern Southeast Alaska.

2. Assessment

There are no stock assessments for hagfish.

3. Management

A commissioner's permit is required before a directed fishery may be prosecuted for hagfish. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes. Gear is restricted to 3,000 gallons in volume using any combination of gear types included Korean style traps, buckets, and barrels per vessel. In 2018 six hagfish management areas were created within the Southeast Region. In 2019, one commissioner's permit was issued for directed fishing of hagfish in the **Southeast Region**. There has been an increase in interest in this fishery with several fishermen requesting information late in 2019 with the anticipation of obtaining permits in 2020.

4. Fisheries

The developing directed fishery for hagfish in the Southeast region has a total guideline harvest level (GHL) of 120,000 lbs. In 2019 a total of 110,146 pounds of hagfish were harvested in the directed fishery. The primary species caught is *E. deani* and a market has been developing for Alaskan hagfish where they are sold for food. Currently in the **Westward**, **Central**, and **Southeast Regions** hagfish are allowed up to 20% as bycatch in aggregate with other groundfish during directed fisheries for groundfish.

B. Dogfish and other sharks

1. Research

The **Division of Sport Fish—Southcentral Region** collected harvest and fishery information on sharks through the groundfish harvest assessment program although no specific research objectives were identified. Interviews were conducted representing 2,687 boat-trips and 13,117 angler-days of effort targeting groundfish species in 2019. Interviewed anglers caught seven salmon sharks but kept only two, caught two sleeper sharks and did not retain any, and caught 2,666 spiny dogfish and kept 10. Biological data were obtained from one salmon shark and two spiny dogfish (Contact Martin Schuster).

2. Assessment

There are no stock assessments for dogfish or sharks.

3. Management

Directed fisheries for spiny dogfish in the Central and Southeast Regions are allowed under terms of a commissioner's permit. The commercial bycatch allowance in the **Southeast Region** is 35% round weight of the target species in longline and power or hand troll fisheries. Full retention of dogfish bycatch is permitted in the salmon set net fishery in Yakutat. In the **Central Region**, bycatch had historically been set at 20% of the round weight of the target species on board a vessel, the maximum allowable retention amount in regulation; however, from 2014 through 2019, allowable bycatch levels of all shark species in aggregate (includes spiny dogfish) were set at 15% by emergency order (EO).

The practice of "finning" is prohibited; all sharks retained must be sold or utilized and have fins, head, and tail attached at the time of landing. "Utilize" means use of the flesh of the shark for human consumption, for reduction to meal for production of food for animals or fish, for bait or for scientific, display, or educational purposes.

Sport fishing for sharks is allowed under the statewide Sport Shark Fishery Management Plan adopted by the BOF in 1998. The plan recognizes the lack of stock assessment information, the potential for rapid growth of the fishery, and the potential for overharvest, and sets a statewide daily bag limit of one shark and a season limit of two sharks of any species except spiny dogfish which have a daily bag limit of five. Sport demand for sharks continued to be low in 2019.

4. Fisheries

No applications for commissioner's permits were received in 2019, and no permits have been issued in **Central Region** since 2006. During 2019, commercial harvest of spiny dogfish as bycatch was low in both Cook Inlet Area (.002 mt) and PWS (0.383 mt).

Estimates of the 2019 sport harvest of sharks are not yet available, but harvest in 2018 was estimated at 60 sharks of all species in Southeast Alaska and 328 sharks in Southcentral Alaska. The precision of these estimates was relatively low; the Southeast estimate had a CV of 45% and the Southcentral estimate had a CV of 31%. The statewide charter logbook program also required reporting of the number of salmon sharks kept in the charter fishery. In 2018, 6 salmon sharks were harvested by charter anglers in Southeast and 8 were harvested in Southcentral. Charter anglers are believed to account for most of the sport salmon shark harvest.

C. Skates

1. Research

A population abundance index from the PWS bottom trawl survey is generated for three skate species each year of that survey. The survey occurs in Eastern PWS and the time series begins in 1999 for big and longnose skates and 2001 for Bering skate. Though a survey was conducted in 2019, estimates are presented through 2018. Aleutian skates are also captured in the survey, but their occurrence is too low to estimate abundance. Bering skate catch per unit effort (CPUE) has had an increasing trend from 2007 to 2017. CPUE was slightly down in 2018 but approximately at the long-term survey average. Big skate CPUE in 2018 was similar to the previous two surveys being at time-series highs. Longnose skate CPUE fell to a survey low in 2017 but came up slightly in 2018 but remained below the long-term average (Contact Wyatt Rhea-Fournier).

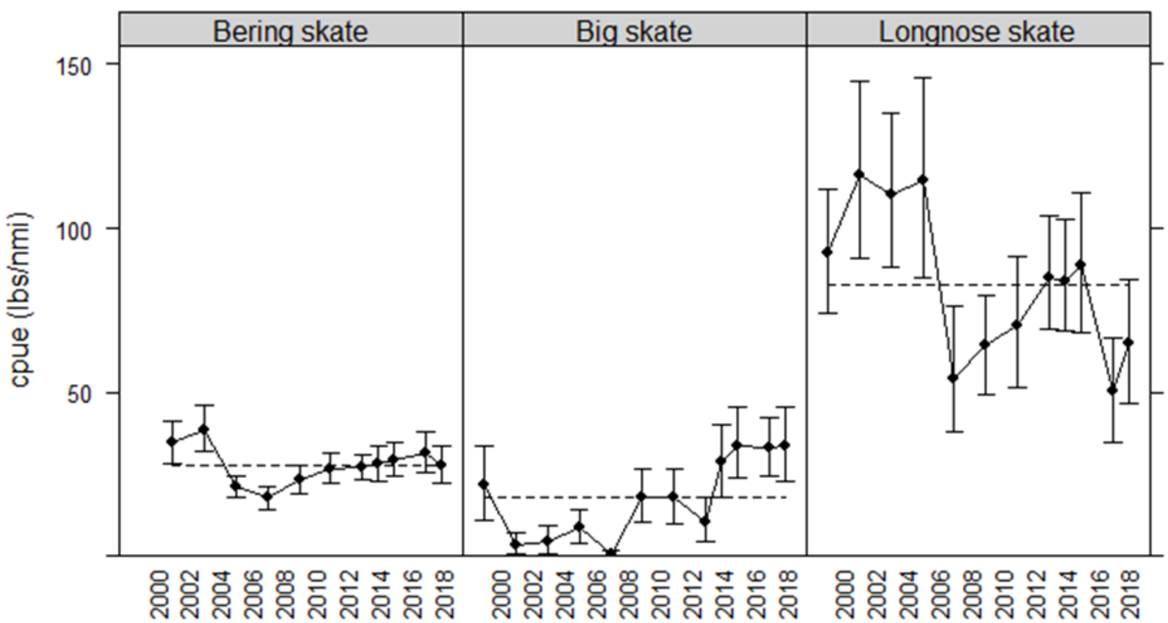


Figure 4. PWS trawl survey CPUE estimates for skates with 90% confidence intervals. Dotted line represents the long-term survey average.

2. Assessment

There are no stock assessments for skates.

3. Management

A commissioner's permit is required before a directed commercial fishery may be prosecuted for skates. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

Currently in the **Central Region**, skates are harvested commercially as bycatch up to 5% of target species; this allowable bycatch level is set by EO to align with the NMFS maximum retainable allowance (MRA) for skates in the GOA.

A directed fishery in PWS for big and longnose skates was prosecuted under the authority of a commissioner's permit in 2009 and 2010. However, the fishery was deemed unsustainable, and no permits were issued thereafter. The permit stipulated seasons, district, gear, and included a logbook requirement.

In the Cook Inlet Area, combined big and longnose skate harvest as bycatch was 6.2 mt in 2019, up slightly from 2018, after a steady decline since 2011. In PWS, skate harvest was 5.7 mt in 2019, less than half the 2018 harvest and the lowest level since 2008. Due to bycatch limits being set as a percentage of the targeted species, harvest levels of the target species may affect the amount of bycatch harvested.

Over the last ten years, in **Southeast Region**, skate landings in internal waters of Northern Southeast Inside (NSEI) and Southern Southeast Inside (SSEI) fluctuated with a low harvest in 2011 of 1.5 mt and a high in 2014 of 18.2 mt. In 2019, a total of 6.3 mt of skates were landed. Skate harvest fluctuates with current market value.

D. Pacific cod

1. Research

Commercial landings in the **Southeast Region**, **Central Region**, and the **Westward Region** are sampled for length, weight, age, sex, and stage of maturity. Catch rate and biological information are gathered from fish ticket records, port sampling programs, a tagging program, and during stock assessment surveys for other species. A mandatory logbook program was initiated in 1997 for the state waters of Southeast Alaska.

Pacific cod are captured in Central Region Tanner crab bottom trawl surveys. A population abundance index from the PWS bottom trawl survey is generated each year with the coefficient of variation (CV) ranging from 0.16 to 0.54 and averaging 0.28. The survey occurs in Eastern PWS and the Pacific cod time series begins in 1991. Estimated CPUE dropped substantially in 2017 and remained low with 2018 being the second lowest in the time series.

In the Central Region, skipper interviews and biological sampling of commercial Pacific cod deliveries from Cook Inlet and PWS areas during 2019 occurred in Homer, Seward, Whittier, and Cordova. Sample data collected included date and location of harvest, species, length, weight, sex, and gonad condition. Otoliths were collected from approximately 20% of sampled fish. Data are provided to NMFS for use in stock assessment (Contact Elisa Russ).

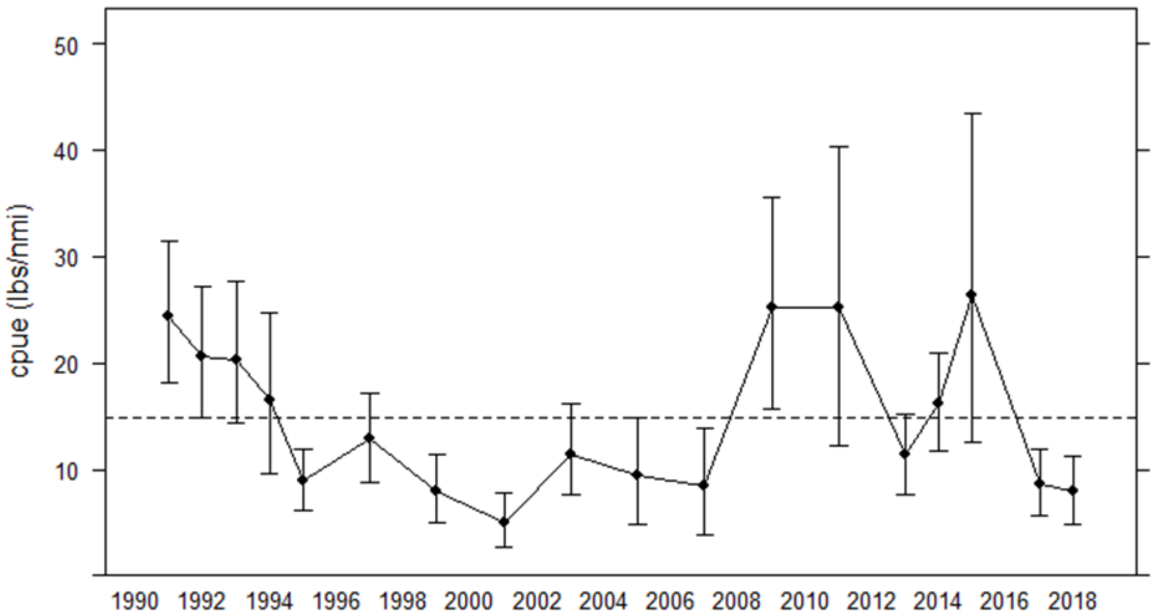


Figure 5. PWS trawl survey CPUE estimates for Pacific cod with 90% confidence intervals. Dotted line represents the long-term survey average.

2. Assessment

No stock assessment programs were active for Pacific cod during 2019.

3. Management

The internal waters of **Southeast Alaska** are comprised of two areas, NSEI Subdistrict and SSEI Subdistrict. The GHR was based on average historic harvest levels rather than on a biomass-based acceptable biological catch (ABC) estimate. This fishery has the most participation in the winter months, and inseason management actions such as small area closures are implemented to spread out the fleet and reduce the risk of localized depletion. Pacific cod in state waters along the outer coast are managed in conjunction with the Total Allowable Catch (TAC) levels set by the federal government for the adjacent EEZ.

In the GOA, Pacific cod Management Plans are established for fisheries in five groundfish areas: **Prince William Sound**, **Cook Inlet**, **Kodiak**, **Chignik** and **South Alaska Peninsula**. Included within the plans are season, gear and harvest specifications. Initially the state-waters fisheries were restricted to pot or jig gear to minimize halibut bycatch and avoid the need to require onboard observers in the fishery. However, in PWS the use of longline gear has been permitted since 2009 in response to the very low levels of effort and harvest by pot and jig gear and high level of interest from the longline gear group. Guideline harvest levels are further allocated by gear type.

Annual GHLs are based on the estimate of ABC of Pacific cod as established by the Council. Current GHLs are set at 25% of the Central Gulf ABC, apportioned between the Kodiak, Chignik, and Cook Inlet Areas, 25% of the Eastern Gulf ABC for the PWS Area, and 30% of the Western Gulf Pacific cod ABC for the South Alaska Peninsula Area. Most CGOA state-waters fisheries open after the respective gear sector closure in the federal Pacific cod A season, generally late winter through early spring. A 58-foot overall length (OAL) vessel size limit is in place for the Chignik and South Alaska Peninsula Areas and the Cook Inlet and Kodiak Areas. A harvest cap for vessels larger than 58 ft limits harvest to a maximum of 25% of the overall GHL. If the GHL is not fully harvested, the fishery management plans allow removal of area exclusivity, vessel size restrictions, and gear limits later in the season to increase harvest to promote achievement of GHL.

In the **Bering Sea/Aleutian Islands area**, a Pacific cod Management Plan for a nonexclusive Aleutian Islands District, west of 170° W longitude, state-waters fishery has been adopted. Included within the plan are season, gear and harvest specifications. The fishery GHL is set by regulation at 27% of the Aleutian Islands ABC for Pacific cod.

Currently, on January 1, the Aleutian Islands state-waters Pacific cod season opens in the Adak Section, between 175° W long and 178° W long, to vessels 60 feet OAL or less using trawl, pot, and jig gear, and vessels 58 feet OAL or less using longline gear. The state waters of the Aleutian Islands Subdistrict, west of 170° W long, open 4 days after the closure of the federal Bering Sea-Aleutian Islands A season for catcher-vessel trawl fishery is closed, or 4 days after the federal Aleutian Islands Subarea non-CDQ season is closed, or March 15, whichever is earliest. When waters west of 170° W long are open, trawl vessels may not be greater than 100 feet OAL, pot vessels may not be greater than 125 feet OAL, and vessels using mechanical jig or longline gear not greater than 58 feet OAL.

A state-waters Pacific cod fishery management plan has also been adopted in waters of the Bering Sea near Dutch Harbor. The **Dutch Harbor Subdistrict** Pacific cod season is open to vessels 58 feet or less OAL using pot gear, with a limit of 60 pots. The fishery GHL is set at 8 percent of the Bering Sea ABC for Pacific cod. The season opens seven days after the federal Bering Sea–Aleutian Islands pot/longline sector's season closure, and may close and re-open as needed to coordinate with federal fishery openings. Additionally, there is a Pacific cod season open to vessels 58 feet or less OAL using jig gear. The fishery GHL is set at 100,000 pounds which is subtracted from the overall Bering Sea ABC for Pacific cod. The season opens May 1.

There is no bag, possession, or size limit for Pacific cod in the sport fisheries in Alaska, and the season is open year-round. Sport harvest of Pacific cod is estimated through the SWHS. The **Division of Sport Fish—Southcentral Region** creel sampling program also collects data on cod catch by stat area (on a vessel-trip basis) through dockside interviews, and lengths of sport-caught Pacific cod, though this is a secondary objective and there are no sample size targets. Interviewed anglers caught 842 Pacific cod in 2019, of which 542 were retained. Biological data were collected from 56 Pacific cod in Southcentral Region. No information is collected in the Southeast Region creel survey program on the Pacific cod sport fishery.

4. Fisheries

Most of the Pacific cod harvested in **Southeast Alaska** are taken by longline gear in the NSEI Subdistrict during the winter months. Prior to 1993 much of the cod taken in Southeast Alaska commercial fisheries was utilized as bait in fisheries for other species. In recent years in Southeast Alaska the Pacific cod harvest has been largely sold for human consumption. A total of 105 mt of Pacific cod were harvested in Southeast state-managed (internal waters) fisheries during 2019 with 82 mt harvested from the directed fishery.

For **Central Region** Pacific cod fisheries, the dominant gear type has been pot gear in Cook Inlet Area and longline gear in PWS fisheries. In the **Cook Inlet**, **Kodiak**, **Chignik**, and **South Alaska Peninsula** state-waters Pacific cod fisheries, pot gear vessels harvest 92% of the total catch and the remaining 8% is harvested by jig gear. In the **Dutch Harbor Subdistrict** state-waters Pacific cod fishery, pot and jig gear are legal gear types however each gear has a separate allocation. In the **Aleutian Islands Subdistrict** state-waters fishery, trawl, jig, longline, and pot are all legal gear types. Both pot and trawl vessels participated in 2019; however, harvest by gear type is confidential due to the number of processors.

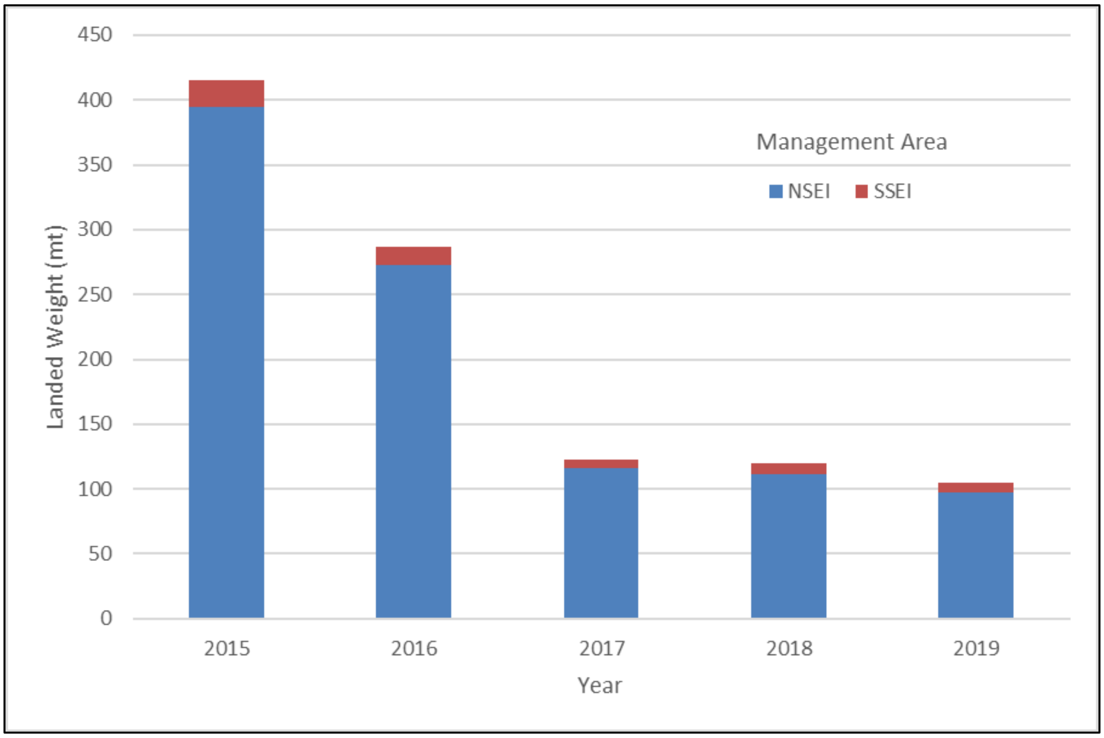


Figure 6. Annual harvest of Pacific cod in the Northern Southeast Inside (NSEI) and Southern Southeast Inside (SSEI) management areas in Southeast Alaska from 2015–2019 for the directed and bycatch fisheries.

In **Central Region**, the Cook Inlet Area state-waters fishery GHL is based on 3.75% of the federal CGOA Pacific cod ABC and the PWS GHL is based on 25% of the EGOA ABC. The 2019 GHLs for the state-waters Pacific cod seasons in the Cook Inlet and PWS areas of the Central Region were 288 mt and 425 mt, respectively, both down 6% from 2018, after a decrease of approximately 80% from 2017 to 2018 following a sharp decline in abundance observed in the NMFS survey. Pacific cod harvest in 2019 from the state-waters seasons was 260 mt from Cook Inlet Area and 185 mt from PWS. Pacific cod harvest during the 2019 parallel seasons was 200 mt from Cook Inlet Area and 34 mt from PWS, both down significantly from 2018. In Cook Inlet Area and PWS, parallel fisheries were open concurrently with federal "A" and "B" seasons for each respective gear type. In Cook Inlet Area, the GHL is allocated 85% to pot gear and 15% to jig gear; pot vessels achieved their allocation; however, jig vessels only harvest 3% of their allocation. For PWS, the GHL is allocated 85% to longline gear and 15% to jig and pot gear combined; longline vessels harvested just over 50% of their allocation; there was no effort by pot or jig gear in 2019.

In the **Westward Region**, the Kodiak Area state-waters Pacific cod GHL is based on 12.5% of the annual CGOA Pacific cod ABC, the Chignik Area GHL is based on 8.75% of the annual CGOA ABC, and the South Alaska Peninsula Area GHL is based on 30% of the WGOA Pacific cod ABC. Legal gear is limited to pot and jig gear during state-waters Pacific cod fisheries in these three areas. The 2019 Pacific cod GHLs were 958 mt in the Kodiak Area, 671 mt in the Chignik Area and 2,290 mt in the South Alaska Peninsula Area. Total state-waters Pacific cod catch in the Kodiak, Chignik and South Alaska Peninsula was 961 mt, 630 mt and 2,302 mt respectively. Pot gear vessels took more than 92% of the total 2019 catch in the state-waters Pacific cod fisheries. In the Aleutian Islands District state-waters Pacific cod GHL is based on 31% of the annual AI Pacific cod ABC. Legal gear is limited to nonpelagic trawl, pots, longline and jig gear during state-waters the Pacific cod fishery. The 2019 total state-waters Pacific cod catch for the Aleutian Islands Subdistrict was 6,198 mt. The **Dutch Harbor Subdistrict** state-waters Pacific cod 2019 GHL for pot gear is based on 8% of the annual Bering Sea Pacific cod ABC. In 2019, the total state-waters catch for the Dutch Harbor Subdistrict pot gear fishery was 14,671 mt. The Dutch Harbor Subdistrict state-waters Pacific cod GHL for jig gear is 45 mt, which is subtracted from the annual Bering Sea Pacific cod ABC. The 2019 harvest for this fishery is confidential due to limited participation.

Estimates of the 2019 sport harvest of Pacific cod are not yet available from the SWHS, but the 2018 estimates were 7,426 fish in **Southeast** and 7,531 fish in **Southcentral Alaska**. The estimated annual harvests for the recent five-year period (2014-2018) averaged about 13,535 fish in **Southeast** Alaska and 25,906 fish in **Southcentral** Alaska. Statewide Pacific cod harvest peaked at over 60,000 fish in 2014 and in 2018 was at the lowest level since 2003.

E. Walleye Pollock

1. Research

In the **Central Region** skipper interviews and biological sampling of PWS commercial trawl pollock deliveries during 2019 occurred in Kodiak. Sample data collected included date and location of harvest, species, length, weight, sex, and gonad condition. Otoliths were collected from approximately half of sampled fish and aged by Homer staff (Contact Elisa Russ).

Beginning in 1998, spatial patterns of genetic variation were investigated in six populations of walleye pollock from three regions: North America – Gulf of Alaska; North America – Bering Sea; Asia – East Kamchatka. The annual stability of the genetic signal was measured in replicate samples from three of the North American populations. Allozyme and mtDNA markers provided concordant estimates of spatial and temporal genetic variation. These data show significant genetic variation between North American and Asian pollock as well as evidence that spawning aggregations in the Gulf of Alaska, such as PWS, are genetically distinct and may merit consideration as distinct stocks. These data also provide evidence of inter-annual genetic variation in two of three North American populations. Gene diversity values show this inter-annual variation is of similar magnitude to the spatial variation among North American populations, suggesting the rate and direction of gene flow among some spawning aggregations is highly variable. This study was published in 2002 in the Fishery Bulletin (Olsen et al. 2002) (Contact Bill Templin).

There are no bag, possession, or size limits for pollock in the sport fisheries in Alaska. Harvest of pollock is not explicitly estimated by the SWHS and no pollock harvest information is collected in charter logbooks or creel surveys in Southcentral or Southeast Alaska.

Pollock are captured in Central Region Tanner crab bottom trawl surveys. A population abundance index from the PWS bottom trawl survey is generated each year of that survey with CV ranging from 0.15 to 0.67 and averaging 0.26. The survey occurs in Eastern PWS and the pollock series begins in 1994. Estimated CPUE was down in 2017 to a survey low but increased slightly in 2018.

2. Assessment

No stock assessment work was conducted by the department on pollock in 2019.

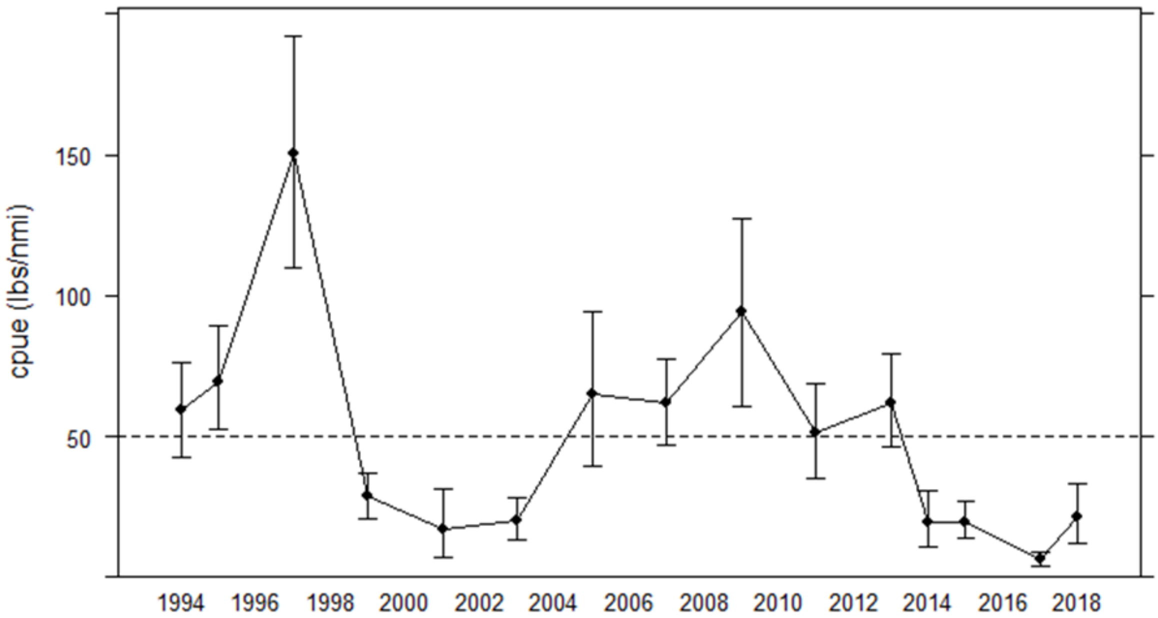


Figure 7. PWS trawl survey CPUE estimates for Walleye pollock with 90% confidence intervals. Dotted line represents the long-term survey average.

3. Management

Prince William Sound Area pollock pelagic trawl fishery regulations include a January 13 registration deadline, logbooks, catch reporting, check-in and check-out provisions, and accommodation of a department observer upon request. The PWS Inside District is divided into three sections for pollock management: Port Bainbridge, Knight Island, and Hinchinbrook, with the harvest from any section limited to a maximum of 60% of the GHL. Additionally, the fishery is managed under a 5% maximum bycatch allowance that is further divided into five species or species groups. In addition, the Rockfish Management Plan allows only 0.5% rockfish bycatch during this pollock fishery. In 2013, new management measures were implemented to set the PWS pollock GHL at 2.5% of the federal Gulf of Alaska ABC. For **Cook Inlet Area,** directed fishing for pollock is managed under a “Miscellaneous Groundfish” commissioner’s permit. Initiated in December 2014, a commissioner’s permit fishery for pollock using seine gear was prosecuted through 2016. In **Central Region**, pollock is also retained as bycatch to other directed groundfish fisheries, primarily Pacific cod (Contact Jan Rumble).

4. Fisheries

The 2019 PWS pollock pelagic trawl fishery opened January 20 and closed February 13. There were 25 landings made by 22 vessels with a total harvest of 2,966 mt, or 99% of the 2,988 mt GHL; interest in the fishery was high because of low Pacific cod abundance and corresponding harvest levels. Rockfish bycatch during the fishery totaled 4.4 mt, well below the 15 mt allowed as bycatch to the pollock harvested. In the Cook Inlet Area, no seine pollock commissioner’s permits were issued in 2019. Pollock was harvested in Central Region as bycatch to other groundfish fisheries at low levels; in 2019, 1.2 mt was harvested in Cook Inlet Area and 0.6 mt in PWS. In Southeast, one Commissioner’s permit was issued to fish for pollock in 2019 but no fishing occurred (Contact Rhea Ehresmann).

F. Pacific Whiting (hake)

1. Research

There was no research conducted on Pacific whiting (hake) in 2019.

2. Assessment

There are no stock assessments for Pacific whiting (hake).

3. Management

A commissioner's permit is required in **Central Region** and **Southeast Region** before a directed fishery may be prosecuted for Pacific Whiting (hake). This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for Pacific whiting (hake) in 2019. Currently in **Central Region** and **Southeast Region** Pacific whiting (hake) are grouped with the other groundfish assemblage and are allowed up to 20% as bycatch in aggregate during directed fisheries for groundfish.

G. Grenadiers

1. Research

There was no research conducted on grenadiers in 2019.

2. Assessment

There are no stock assessments for grenadiers.

3. Management

A commissioner's permit is required in **Central Region** and **Southeast Region** before a directed fishery may be prosecuted for grenadiers. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for grenadiers in 2019. Currently in the **Central Region** and **Southeast Region** grenadiers are considered part of the other groundfish assemblage and are allowed up to 20% as bycatch in aggregate during directed fisheries for groundfish.

H. Rockfishes

Commercial rockfish fisheries are managed under three assemblages: DSR, pelagic shelf rockfish (PSR), and slope rockfish. DSR include the following species: yelloweye, quillback, China, copper, rosethorn, canary, and tiger. PSR include black, deacon, dusky, dark, yellowtail, and widow. Slope rockfish contain all other *Sebastes* species. Thornyhead, *Sebastolobus* species, are defined separately; in Central Region, thornyhead rockfish harvest is combined with slope rockfish for reporting.

1. Research

In the **Southeast Region** biological samples of rockfish are collected from the directed commercial DSR fishery; sampling effort was expanded in 2008 to include the sampling of DSR caught as bycatch in the IFQ halibut fishery. The sampling of the halibut fishery was started in part to obtain more samples in years that the directed fishery was not opened. Fishery data are also collected from the logbook program, which is mandatory for all groundfish fisheries. The logbook program is designed to obtain detailed information regarding specific harvest location. In 2019, length, weight and age structures were collected from 553 yelloweye rockfish caught in the directed and 771 caught in the halibut commercial longline fisheries. Skipper interviews and port sampling of commercial rockfish deliveries in **Central Region** during 2019 occurred in Homer, Seward, Whittier, Kodiak, and Cordova. Efforts throughout the year were directed at the sampling of rockfish delivered as bycatch to other groundfish and halibut fisheries, primarily DSR and slope species. The directed jig fishery in the Cook Inlet Area that targets PSR begins July 1 and historically has been the focus of rockfish sampling during the last half of the year. Sample data collected included date and location of harvest, species, length, weight, sex, gonad condition, and otoliths. Homer staff determine ages of PSR and DSR otoliths; otoliths from slope and thornyhead rockfish species were sent to the ADF&G Age Determination Unit in Juneau. In 2018, a new project was initiated to study genetic variation between outside waters of North Gulf, outside waters of PWS, and inside waters of PWS for both yelloweye and black rockfish; tissue samples were collected in 2018 and 2019 with genetic analysis to follow. Additionally, ovaries were collected from both species of rockfish for maturity and fecundity studies. An age structure exchange was also conducted on yelloweye rockfish between commercial and sport age reading staff in Homer. The genetics and gonad collections, and age structure exchange, were conducted as collaborative interdivisional research as part of the ADF&G Statewide Rockfish Initiative (SRI) initiated in 2017 (Contact Elisa Russ).

Funding for **Central Region** DSR and lingcod ROV surveys ended in 2016 and surveys have not been conducted since then. Rockfishes are captured in Central Region bottom trawl surveys for Tanner crab. All rockfish are sampled for length, weight, sex, and age structures. Rougheye/blackspotted rockfish composed >90% of the rockfish catch by weight in all years. A population abundance index from the PWS bottom trawl survey is estimated for rougheye/blackspotted rockfish each year of that survey with CV estimates ranging from 0.16 to 0.40 and averaging 0.25. The survey occurs in Eastern PWS and the time series begins in 1991. Estimated CPUE in 2017 was the lowest in the time series but increased slightly in 2018. (Contact Mike Byerly or Wyatt Rhea-Fournier).

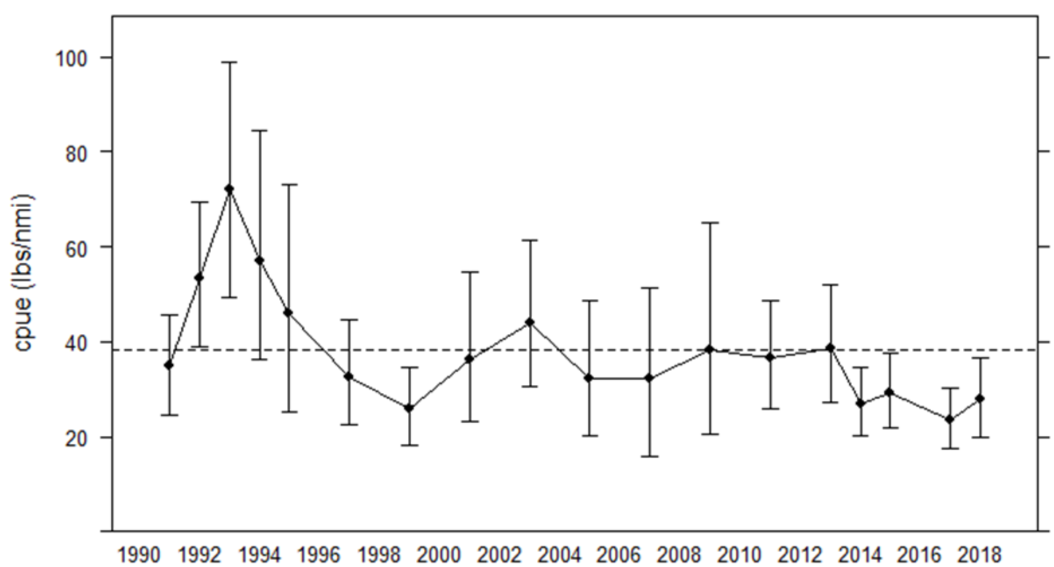


Figure 8. PWS trawl survey CPUE estimates for rougheye/blackspotted rockfish with 90% confidence intervals. Dotted line represents the long-term survey average.

The **Westward Region** continued port sampling of several commercial rockfish species in 2019. Rockfish sampling concentrated on black and dark rockfish with opportunistic sampling of other miscellaneous *Sebastes* species. Skippers were interviewed for information on effort, location, and bycatch. Length, weight, gonadal maturity, and otolith samples were collected (Contact Sonya El Mejjati). Staff from the Kodiak office have completed aging black rockfish otoliths through the 2019 season.

The **Westward Region** also continued to conduct hydroacoustic surveys of black and dark rockfish in the Northeast, Afognak, Eastside, and Southeast districts of the Kodiak Management Area in 2019 to generate biomass estimates for both black and dark rockfish. Surveys of Northeast, Afognak, Eastside, and Southeast districts in the Kodiak Management Area will continue in 2020 (Contact Carrie Worton).

The **Division of Sport Fish—Southeast Region** continued to collect catch and harvest data from rockfish as part of a marine harvest onsite survey program with rockfish harvests tabulated back to 1978 in some ports. Rockfish objectives included estimation of: 1) species composition, 2) length composition and average weight, as derived from a length-weight regression relationship, 3) age and sex composition of black rockfish at Sitka, 4) genetic composition of black and yelloweye rockfish from inside and outside ports, and 5) biomass of total sport removals (harvest and release mortality). Primary species harvested in Southeast Alaska included yelloweye, black, copper, silvergray, and quillback rockfish. A total sample size of 10,623 rockfish was obtained from the sport harvests at Ketchikan, Craig, Wrangell, Petersburg, Juneau, Sitka, Gustavus, Elfin Cove, and Yakutat in 2019 (Contact Mike Jaenicke). The **Division of Sport Fish—Southcentral Region** continued collection of harvest and fishery information on rockfish as part of the harvest assessment program. Rockfish objectives included estimation of 1) species composition, 2) age, sex, and length composition of primary species, and 3) the spatial distribution of rockfish harvest and groundfish effort by port. The 2019 total sample size from the sport harvests at Seward, Valdez, Whittier, Kodiak, Central Cook Inlet, and Homer was 4,847 rockfish (Contact Martin Schuster). The Division of Sport Fish conducted research in PWS on the ability of 6 species of rockfish to resubmerge unassisted when released at the surface. This study is ongoing. Results will be published as an ADF&G Fishery Data Series report towards the end of 2021 (Contact Brittany Blain-Roth or Jay Baumer). In addition, a University of Alaska, Fairbanks Graduate Student/ADF&G Biologist collected life history information on yelloweye rockfish to improve estimates of maturity, fecundity and skip-spawning between Prince William Sound and Northern Gulf of Alaska. The project results are expected to be completed towards the end of 2020 (Contact Brittany Blain-Roth or Donald Arthur). Similar data are currently being collected from black rockfish in the same area.

The **Age Determination Unit** continued the North Pacific Research Board funded project 1803: Reconstructing reproductive histories of yelloweye rockfish through opercular hormone profiles. ADF&G personnel sampled opercula and otoliths from female yelloweye rockfish along with black rockfish and other representative species. Ages were estimated using otoliths and corresponding bands were identified on opercula. Sampled opercula material was sent to Baylor University to analyze progesterone, cortisol, and ecdysteroid concentrations. Lifetime reproductive and stress hormone profiles were constructed for 13 female yelloweye rockfish and individual profiles were used to estimate age of sexual maturity and annual spawning frequency. Preliminary results suggest the onset of sexual maturity for female yelloweye rockfish is between 8 and 20 years and mean spawning frequency could be as low as 40%. Also, there was little evidence supporting reproductive senescence in female yelloweye rockfish. Yelloweye and black rockfish operculum samples paired with blood and ovary samples are being processed to validate results (Contact Dion Oxman).

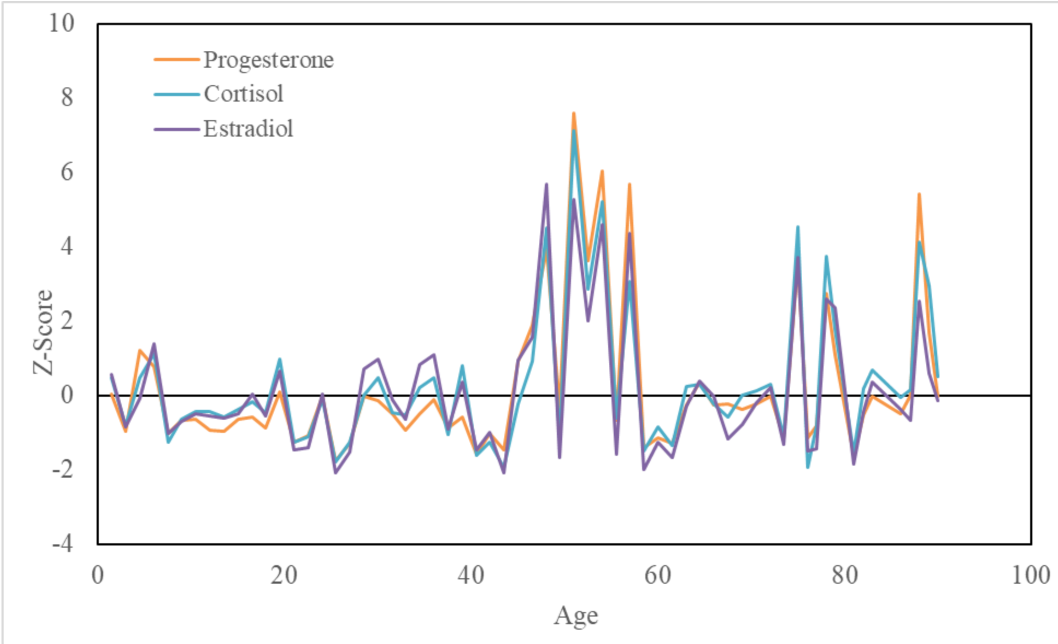


Figure 9. Normalized progesterone, cortisol, and estradiol concentrations recovered from annual growth increments within the operculum of a 90-year old female yelloweye rockfish via immunoassay extraction. Hormone concentrations were normalized based on concentrations prior to the first peak, assuming this were estimates of non-reproductive levels.

2. Assessment

The **Southeast Region** performs multi-year stock assessments for DSR in the Southeast District. Biomass is estimated by management area as the product of yelloweye rockfish density determined from line transect surveys, the area of rocky habitat within the 100-fathom contour no deeper than 180 m, and the average weight of yelloweye rockfish. Yelloweye rockfish density for the stock assessment is based on the most recent estimate by management area. Yelloweye rockfish densities for each area are multiplied by the current year's average commercial fishery weight of yelloweye rockfish specific to that management area. Allowable biological catch for SEO is set by multiplying the lower bound of the 90% confidence interval of total biomass for yelloweye rockfish by the natural mortality rate (M = 0.02). In the past, the yelloweye biomass estimate was expanded to the entire DSR assemblage by multiplying the proportion of other DSR species in the commercial catch (2.0 to 4.0%). However, starting in 2015, the non-yelloweye DSR biomass estimate has been calculated from catch data from 2010–2014 recreational, commercial, and subsistence fisheries and added to the yelloweye ABC to obtain a total for the entire DSR assemblage. There is no stock assessment information available for DSR in NSEI and SSEI management areas, and surveys for non-DSR species (e.g. black rockfish) have not been conducted since 2002.

Prior to 2012, line transect surveys were conducted using a manned submersible. Since 2012, visual surveys have been conducted using a remotely operated vehicle (ROV). The last submersible surveys were conducted in 2009 in Eastern Yakutat (EYKT), 2005 in Southern Southeast Outside (SSEO) Subdistrict, 2007 in Central Southeast Outside (CSEO) Subdistrict, and 2001 in Northern Southeast Outside (NSEO) Subdistrict. Density estimates were derived from each of these surveys except for the NSEO management area where data were too limited to obtain a valid density estimate. Density estimates by area for the most recent submersible surveys ranged from 765 to 1,755 yelloweye rockfish per km^2 with CV estimates of 12 to 33%.

The ROV surveys were most recently performed in collaboration with Central Region staff in 2019 in EYKT and in 2018 in SSEO, NSEO and CSEO. The most recent density estimates for EYKT in 2019 was 1,562 yelloweye rockfish per km^2 (CV = 25%), SSEO in 2018 was 1,624 yelloweye rockfish per km^2 (CV = 25%), CSEO in 2018 was 897 yelloweye rockfish per km^2 (CV = 14%), and NSEO in 2018 was 544 yelloweye rockfish per km^2 (CV = 18%). In addition, fish lengths for yelloweye rockfish, lingcod, black rockfish, and halibut are measured from ROV video data using stereo camera imaging software (SeaGIS, Ltd) (Contact Rhea Ehresmann).

Central Region conducts ROV surveys along the northern Gulf of Alaska coast from the Kenai Peninsula to PWS to monitor the local abundance of DSR in selected index sites; however, assessment surveys have not been conducted in recent years (Contact Mike Byerly or Wyatt Rhea-Fournier).

In the **Westward Region** rockfish surveys using hydroacoustic equipment were deployed to assess black and dark rockfish stocks in the Kodiak Management Area. Surveyed areas included the Northeast, Afognak, Eastside, and Southeast districts of the Kodiak Management Area (Contact Carrie Worton).

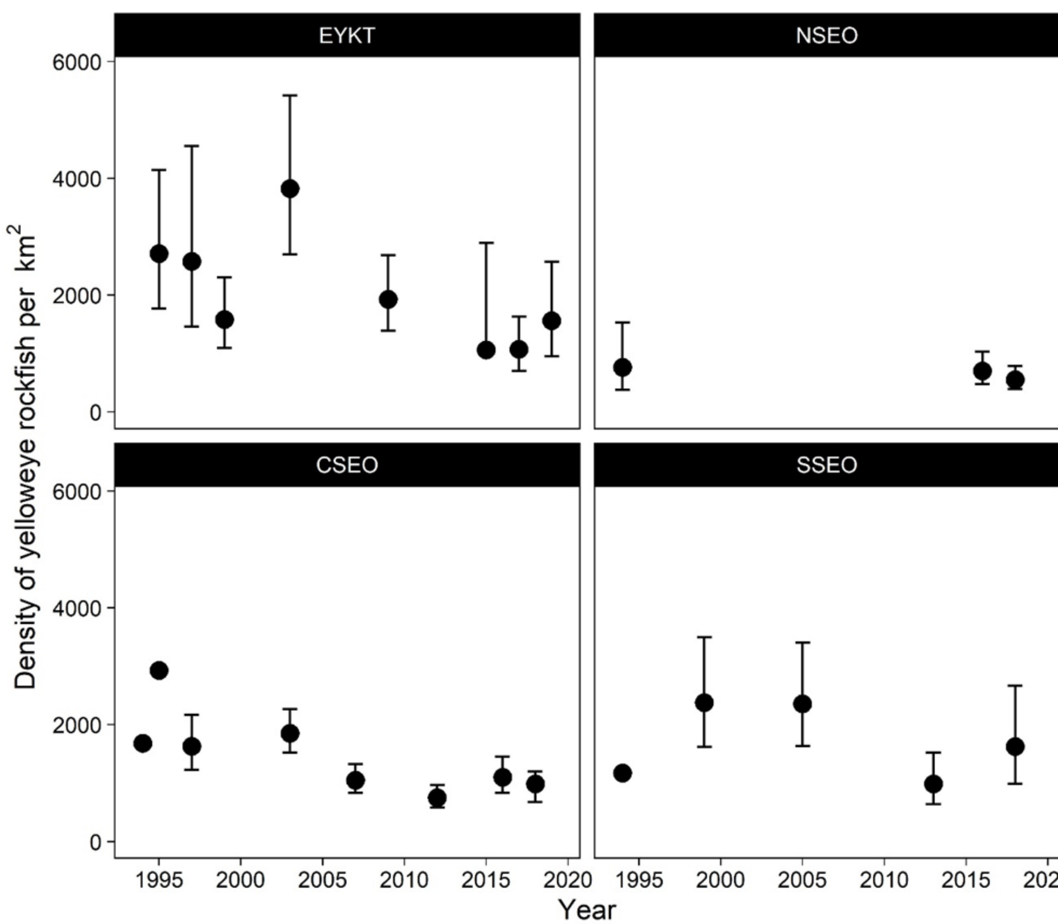


Figure 10. Density estimates of yelloweye rockfish with 90% confidence intervals in the Eastern Gulf of Alaska management areas.

3. Management

Management of DSR in the **Southeast Region** is based upon a combination of total allowable catch (TAC), guideline harvest range (GHR), seasons, gear restrictions, and trip and bycatch limits. Directed commercial harvest of DSR is restricted to hook-and-line gear. Directed fishing quotas are set for Southeast Outside management areas (NSEO, CSEO, SSEO, and EYKT) based on the stock assessment. Directed fishery quotas for the two internal water management areas (NSEI and SSEI) are set at 25 mt annually. Regulations adopted in 1994 included logbook requirements and 5-day trip limits of 6,000 pounds sold per vessel in all areas except EYKT where the trip limit was 12,000 pounds. New regulations adopted in 2018 further restricted trip limit rules by prohibiting additional fish to taken or allowed on board a vessel until the trip limit period expired. The EYKT trip limit amount was also reduced to 8,000 pounds.

The directed DSR fishery season in SEO occurs in the winter, prior to the start of the commercial halibut IFQ season. The SEO TAC for DSR is set after decrementing estimated subsistence harvest, the remainder is allocated 84% to the commercial sector and 16% to the sport sector. The 2019 ABC for DSR was 261 mt, which resulted in a TAC of 254 mt with allocations of 194 mt to commercial fisheries and 41 mt to sport fisheries. Estimated subsistence harvest for 2019 was 7 mt. A significant portion of the total commercial harvest is taken as bycatch during the halibut fishery. Each year DSR bycatch is estimated and decremented from the commercial TAC prior to the determining whether an area has enough quota remaining to prosecute a directed fishery.

Management of the commercial black rockfish fishery in the Southeast Region is based upon a combination of GHLs and gear restrictions. Directed fishery GHLs are set by management area and range from 11 mt in EYKT and IBS to 57 mt in SSEOC with a total GHL of 147 mt for the Eastern Gulf of Alaska Area. A series of open and closed areas was also created for managers to better understand the effects of directed fishing on black rockfish stocks. Halibut and groundfish fishermen are required to retain and report all black rockfish caught (Contact Rhea Ehresmann).

In **Central Region**, commercial rockfish fisheries in Cook Inlet and PWS areas are managed under their respective regulatory Rockfish Management Plans. Plan elements include a fishery GHL of 68 mt for each area and 5-day trip limits of approximately 0.5 mt in the Cook Inlet District, 1.8 mt in the North Gulf District, and 1.4 mt in PWS. Rockfish regulations underwent significant change beginning in 1996 when the BOF formalized the GHL into a harvest cap for all rockfish species in Cook Inlet and PWS areas and adopted a 5% rockfish bycatch limit for jig gear during the state-waters Pacific cod season. In 1998, the BOF adopted a directed rockfish season opening of July 1 for the Cook Inlet Area and restricted legal gear to jigs to target PSR species. At the spring 2000 BOF meeting, the BOF closed directed rockfish fishing in PWS and established a bycatch-only fishery with mandatory full retention of all incidentally harvested rockfish. In November 2004, the BOF also adopted a full retention requirement for rockfish in the Cook Inlet Area and restricted the directed harvest to PSR. Rockfish bycatch levels were also set at 20% during the sablefish fishery, 5% during the state-waters Pacific cod season and 10% during other directed fisheries. In 2010, the BOF adjusted rockfish bycatch levels for Cook Inlet to 10% during halibut and directed groundfish, other than rockfish, and 20% nonpelagic rockfish during the directed PSR fishery. In addition, logbooks are required during the Cook Inlet Area directed jig fishery. In 2014, the BOF adopted regulations to adjust rockfish bycatch levels during the parallel Pacific cod season in PWS to 5%, for consistency with the PWS state-waters season; in addition, a 0.05% rockfish bycatch limit was established for the PWS pollock pelagic trawl fishery. Proceeds from rockfish landed in excess of allowable bycatch and harvest levels are surrendered to the State of Alaska (Contact Jan Rumble).

The **Westward Region** has conservatively managed black rockfish since 1997, when management control was transferred to the State. Area GHLs were set at 75% of the average production from 1978–1995 and sections were created to further distribute effort and thereby lessen the potential for localized depletion. Since 1997, section GHLs have been reduced in some areas that have received large amounts of effort.

In the Kodiak Area, vessels may not possess or land more than 2.3 mt of black rockfish in a 5-day period. Additionally, vessel operators are required to register for a single groundfish district fishery at a time. Registration requirements also exist for the Chignik and South Alaska Peninsula areas. In the Kodiak Area, fishers may retain up to 20% of black rockfish by weight caught incidentally during other fisheries, and in the Chignik and South Alaska Peninsula Area black rockfish may be retained up to 5% by weight. In the Aleutian Islands District of the Bering-Sea Aleutian Islands Area, fishers may retain up to 20% of black rockfish and 20% for dark rockfish caught in the Bering Sea–Aleutian Islands area incidentally during other fisheries. A voluntary logbook program was initiated in 2000 in the hope of obtaining CPUE estimates as well as more detailed harvest locations; the logbook program was made mandatory in 2005 (Contact Nathaniel Nichols).

In 2019, the Kodiak Area black rockfish GHL was 55 mt allocated across five districts. GHLs were attained in four sections of the Kodiak Area for a total harvest of 50 mt. The Chignik and South Alaska Peninsula area GHLs were 45 mt and 34 mt respectively. In the South Alaska Peninsula Area, the 2019 black rockfish harvest was 7.3 mt and no black rockfish harvest occurred in the Chignik Area. The Aleutian Islands GHL for black rockfish was 41 mt allocated across three sections. No vessels made directed black rockfish landings in the Aleutian Islands Area; all harvest was incidental retention. In 2019, less than 1 mt of black and 7.6 mt of dark rockfish were harvested incidental to other groundfish species.

Sport fisheries are managed primarily under two assemblages: pelagic, defined the same as for commercial fisheries, and nonpelagic, which includes all other species of the genus *Sebastes*. For the 2019 season, the **Southeast Alaska** region's sport bag and possession limit for pelagic rockfish was five fish per day, 10 in possession.

The sport fishery in Southeast outside waters is allocated a portion of the TAC (16%) for demersal shelf rockfish. The nonpelagic rockfish regulations were set as follows:

<u>All Southeast Alaska Waters</u>: 1) nonpelagic resident bag and possession limit was one rockfish of any species; 2) nonresident bag limit was one fish, with an annual limit of one yelloweye rockfish.

<u>Southeast Alaska Outside Waters</u>: 1) Retention of nonpelagic rockfish was prohibited in all Southeast Outside waters from July 25 through August 31, 2019; 2) All anglers fishing from a vessel in Southeast Outside waters during this period were required to have a functional deep water release mechanism on board and release nonpelagic rockfish at the depth of capture or at least 100 feet using the deep water release mechanism.

For the entire Southeast Alaska region, charter operators and crewmembers were not allowed to retain nonpelagic rockfish while clients were on board the vessel. All anglers fishing from charter vessels were required to release nonpelagic rockfish to the depth of capture or at least 100 feet, whichever is shallower, using a deep-water release device. Charter vessels were required to have at least one functional deep-water release device on board and available for inspection (Contact Bob Chadwick).

As in Southeast Alaska, sport rockfish regulations in **Southcentral Alaska** largely rely on bag limits for regulating effort and are more restrictive for nonpelagic species to account for their lower natural mortality rates. The open season for rockfish was year-round in all areas. In 2019, the bag limit in Cook Inlet was five rockfish daily, only one of which could be a nonpelagic species (DSR or slope species); the possession limit was two bag limits. The bag limit in PWS was four rockfish per day, with a possession limit of eight rockfish only one of which could be a nonpelagic species. The bag limit in the North Gulf Coast area was four rockfish per day, only one of which could be a nonpelagic species; the possession limit was two bag limits. The bag limit for Chiniak and Marmot Bay areas off Kodiak was three rockfish, no more than two of which could be nonpelagic and one of which could be a yelloweye. The bag limit in the remainder of Kodiak was five rockfish, no more than two of which could be nonpelagic species, and no more than one of the nonpelagic species could be a yelloweye. The bag limit in the Alaska Peninsula and Aleutian Islands was 10 rockfish per day. For all areas off Kodiak, the Alaska Peninsula, and the Aleutian Islands, the possession limit was two bag limits.

Beginning in 2020, all vessels sport fishing in saltwater of Alaska must have a functioning deepwater release mechanism (DRM) on board, and all rockfish not harvested must be released at depth of capture, or at a depth of 100 feet. In 2017 the department began an interdivisional process to develop comprehensive harvest strategies for groundfish, beginning with black and yelloweye rockfish using information from all fisheries. Commercial and sport fisheries are currently managed separately, and several areas of the state lack annual harvest targets for the sport fishery. There was agreement on the need to develop harvest strategies that applied to all removals and an integrated approach to management, to set harvest guidelines and control rules. The department is committed to developing abundance-based goals where assessment is possible and simpler strategies where information is lacking. The initial focus on black and yelloweye rockfish is to address immediate management needs and serve as models for other groundfish species.

4. Fisheries

Directed fisheries for DSR and black rockfish occurred in Southeast in 2019. The directed fishery for DSR in SEO opened in SSEO only. EYKT, NSEO, and CSEO sections did not open to directed fishing because the portion of the TAC allocated to those areas was not large enough to support manageable fisheries. In addition, a new management strategy was implemented in 2016, which alternates the directed commercial fishery opening for DSR by management area if the allocated TAC is deemed sustainable. For example, CSEO was the only management area open in 2018 and will not reopen until at least 2022 and SSEO was the only management area open in 2019 and will not reopen until at least 2023, if the estimated biomass is sufficient for a fishery. This strategy allows for a minimum three-year recovery period after a management area was opened to the directed fishery. Directed fishing for DSR was also opened in internal waters. The 2019 harvest of DSR by directed fisheries in SSEO was 45.5 mt and internal waters harvest was 20.6 mt. In addition, DSR was taken as bycatch with 97.6 mt harvested in SEO and 26.3 mt in internal waters. Harvest in the directed black rockfish fishery in Southeast Outside District (SEO) was 2.1 mt and black rockfish bycatch harvest in all groundfish, halibut, and salmon troll fisheries in SEO was 5.2 mt. Slope, PSR, and thornyhead rockfish were also taken as bycatch in internal waters with 66.1 mt harvested in 2019.

For **Central Region** commercial rockfish fisheries, both the Cook Inlet and PWS areas have a rockfish GHL of 68 mt, which includes both directed and bycatch harvest. In the Cook Inlet Area in 2019, the total rockfish harvest was 30.0 mt, up slightly from 2018. In Cook Inlet Area, PSR harvest comprised just over half of the total harvest, with the majority coming from the directed fishery; remaining harvest was DSR and slope rockfish bycatch to other groundfish fisheries. In PWS, rockfish are only harvested as bycatch, as there is no directed fishery. The harvest of 32.6 mt in 2019 increased about 20% from 2018, although still well below the GHL. The majority of rockfish bycatch in PWS was caught by longline gear (85%) followed by trawl gear (13%) with the minimal remaining harvested by jig gear.

Sport harvest (guided and unguided) is estimated primarily through the SWHS (all species combined). Charter vessel logbooks provide reported harvest for the guided sector in three categories - pelagic, yelloweye, other nonpelagic. Additionally, species-specific data are available only from creel surveys.

Harvest reporting areas for these programs are different than commercial reporting areas, making direct comparisons difficult. However, efforts are currently underway to estimate sport harvest for rockfish, by species, in the same geographic report areas as used in commercial fisheries.

Sport rockfish harvest is typically estimated in numbers of fish. Estimates of the 2019 harvest are not yet available from the SWHS, but the 2018 estimates for all species combined were 163,822 fish in Southeast and 145,296 fish in Southcentral Alaska. The average annual harvest estimates for the recent five-year period (2014-2018) were 173,581 rockfish in Southeast Alaska and 146,852 fish in Southcentral Alaska. Rockfish harvest in the sport fishery has increased substantially in recent years, likely in response to more restrictive limits for other sport caught fish.

I. Thornyhead rockfish

1. Research

There was no research conducted on thornyhead rockfish in 2019.

2. Assessment

There are no stock assessments for thornyhead rockfish.

3. Management

A commissioner's permit is required before a directed fishery may be prosecuted for thornyhead rockfish. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for thornyhead rockfish in 2019. In **Central Region** thornyhead rockfish are retained as bycatch up to 10% in aggregate with other rockfish during a halibut or directed groundfish fishery, with exceptions occurring in PWS for the bycatch allowance for the directed sablefish fishery (20%), Pacific cod (5%), and directed pollock trawl fishery (0.05%). For directed drift or set gillnet fisheries for salmon or herring up to 10% of thornyhead rockfish and other rockfish in aggregate may be retained. Proceeds from bycatch overages are forfeited to ADF&G.

In **Southeast Region**, thornyheads were retained as bycatch, based on the round weight of the target species, of up to 5% in aggregate with other rockfish for halibut fishing and in the directed lingcod fishery; 15% in aggregate with other rockfish for the directed DSR, directed black rockfish, and state-managed sablefish fisheries; and 20% in aggregate with shortraker and rougheye rockfishes in the directed Pacific cod fishery. For pot gear only, 5% thornyhead bycatch was permitted in the sablefish and Pacific cod fisheries. Any bycatch overages that occurred in state waters were forfeited to ADF&G.

J. Sablefish

1. Research

In 2019, sablefish longline surveys were conducted for both the NSEI and SSEI areas in the **Southeast Region**. These surveys are designed to measure trends in relative abundance and biological characteristics of the sablefish population. Biological data collected in these surveys include length, weight, sex and maturity stage. Otoliths are collected and sent to the ADF&G age determination unit in Juneau for age reading. The cost of these surveys is offset by the sale of the fish landed; however, in 2019 six commercial fishermen participated in the surveys and were allowed to sell their Personal Quota Share (PQS); thus, reducing the impact on the quota by for fish harvested and sold by the state. The department plans to allow permit holders to harvest their PQS aboard future NSEI longline surveys. A mark-recapture survey has been conducted using longlined pots since 2000 with this survey performed using the state vessel the *R/V Medeia* since 2012. In May and June 2019, 10,790 sablefish were marked and released in NSEI over the course of the tagging survey. In addition to marking, 574 length-weight-girth samples were collected throughout the survey as part of an escape ring study. Over the 21-day survey, 17 longlined pot sets were made. Sablefish were targeted by statistical area in proportion to the commercial catch using logbook data from the three previous years. The mark-recapture results serve as the basis of our NSEI stock assessment. A tagging survey is scheduled for 2020 and will include a continuation of the escape ring study conducted in 2019 (Contact Rhea Ehresmann).

In **Central Region**, ADF&G conducted longline surveys for sablefish from 1996 through 2006 in PWS. Longline survey effort was extended into the North Gulf District in 1999, 2000 and 2002. All longline surveys were discontinued due to lack of funding, and with the goal of transitioning to a pot longline survey, particularly in PWS. Between 1999 and 2005, sablefish were opportunistically tagged in PWS on ADF&G trawl surveys. Sablefish tagging surveys were conducted in PWS in 2011, 2013, and 2015 using pot longline gear. There were 1,203, 318, and 26 fish tagged in 2011, 2013, and 2015, respectively. CPUE was very low in 2013 with an average of 0.11 fish per pot. To date, 329 fish have been recaptured from the 2011 survey and 56 were captured from the 2013 survey and 5 from the 2015 survey. Of all tagged releases, 57% have been recaptured within PWS and 29% outside in the GOA with the remainder of unknown location. There have been no PWS sablefish tagging surveys since 2015.

Sablefish are captured in Central Region Tanner crab bottom trawl surveys. A population abundance index from the PWS bottom trawl survey is generated each year of that survey with the catch composed of predominantly 1 and 2-yr old fish. Precision in the estimates is generally poor with CV values ranging from 0.17 to 0.86 and averaging 0.42. The survey occurs in Eastern PWS and the sablefish series begins in 1994. Estimated CPUE declined sharply in 2007 and has remained very low though results from the 2018 survey showed a slight increase (Contact Wyatt Rhea-Fournier).

Skipper interviews and biological sampling occurred in Cordova, Whittier, and Seward for the PWS commercial fishery and in Seward and Homer for the Cook Inlet Area fishery. Data collected included date and location of harvest, length, weight, sex, gonad condition, and otoliths. Otoliths were sent to the Age Determination Unit. Logbooks are required for both fisheries and provide catch and effort data by date and location (Contact Elisa Russ).

The Division of Sport Fish—Southeast Region collects catch, harvest, and biological data from sablefish as part of a marine harvest survey program. Ports sampled in 2019 included Juneau, Sitka, Craig, Petersburg/Wrangell, Gustavus, Elfin Cove, Yakutat, and Ketchikan. Length data were collected from 372 sablefish in 2019, primarily from the ports of Sitka, Ketchikan, Elfin Cove, and Juneau (Contact Mike Jaenicke).

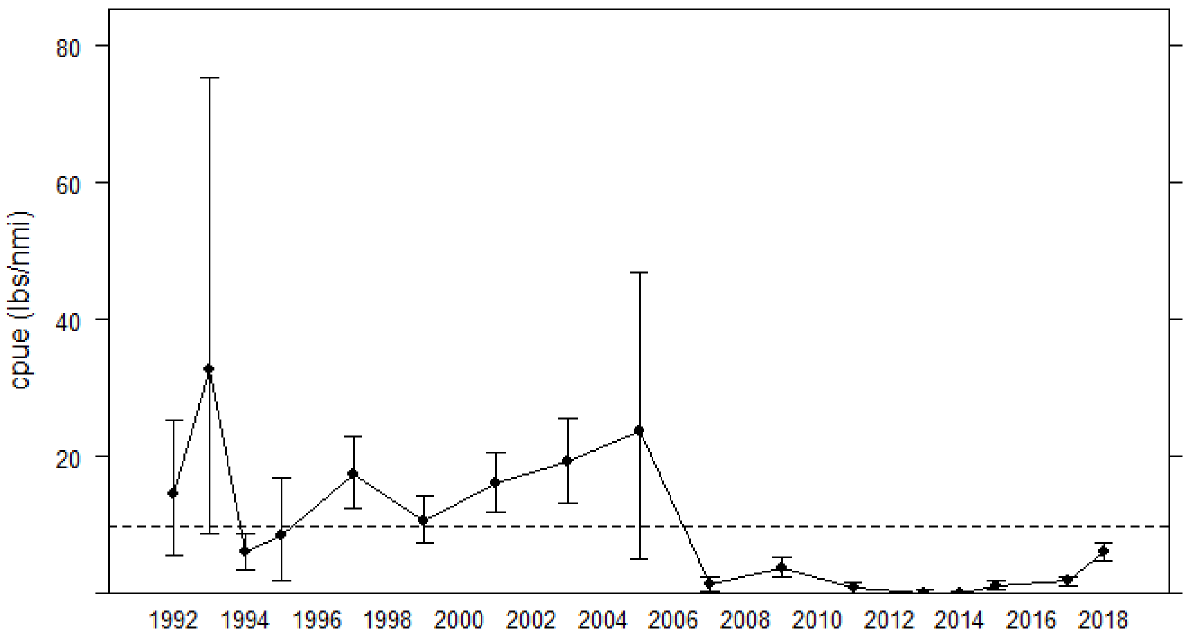


Figure 11. PWS trawl survey CPUE estimates for sablefish with 90% confidence intervals. Dotted line represents the long-term survey average.

The **Age Determination Unit** worked with the AFSC, Auke Bay Laboratories to investigate the use of age-0 lapillar and sagittal otoliths to infer daily growth in juvenile sablefish in the Gulf of Alaska. Otoliths from rhinoceros auklet bill-load samples from 1978 to present, survey samples, and samples from laboratory reared juvenile sablefish were removed and prepared. The external and internal structure of otoliths collected from bill-load samples were significantly damaged due to storage and were not useful for modeling size nor daily growth. Focus was shifted to samples included in growth trials conducted at Auke Bay Laboratories. Otolith size and daily increment width was measured using image analysis. The relationships between lapillar and sagittal otolith increment width, comparison of total increment count on both structures, otolith size to fish size, temperature and feeding ration were modeled. Evaluations of survey and laboratory reared juvenile sablefish found close agreement in daily age between otoliths, strong linear relationships between otolith size and fish size, and peak otolith increment width in both structures between 14 and 18°C and at maximum feed rations. These findings support current and previous studies, and investigators plan to publish methods and findings (Contact Kevin McNeel).

2. Assessment

In the **Southeast Region**, the department is using mark-recapture methods with external tags and fin clips to estimate abundance and exploitation rates for sablefish in the NSEI Subdistrict. Sablefish are captured with pot gear in May or June, marked with a tag and a fin clip then released. Tags are recovered from the fishery and fish are counted at the processing plants and observed for fin-clips. The 2019 recommended ABC of 480 mt for the NSEI fishery was calculated by applying the 2018 fishery mortality at age (based on a harvest rate of 6.35% using the F50% biological reference point (BRP)) to the 2019 forecast of total biomass at age and summing across all ages. The 2019 ABC was a 9.6% increase from the 2018 ABC (438 mt), which was also based on the

F50% BRP (the harvest rate was 6.35% for 2018). Since 2009 BRPs have become more conservative, i.e. F45% in 2009 and F50% since 2010. In addition to the mark-recapture work, an annual longline survey is conducted in NSEI to provide biological data as well as relative abundance information. In SSEI only an annual longline survey is conducted to provide biological data as well as relative abundance information. Unlike NSEI, the department does not currently estimate the absolute abundance of SSEI sablefish. There appears to be substantial movement of sablefish in and out of the SSEI area, which violates the assumption of a closed population; consequently, Peterson mark-recapture estimates of abundance or exploitation rates are not possible for this fishery. Instead, the SSEI sablefish population is managed based on relative abundance trends from survey and fishery CPUE data, as well as with survey and fishery biological data that are used to describe the age and size structure of the population and detect recruitment events (Contact Rhea Ehresmann).

3. Management

There are three separate internal water areas in Alaska which have state-managed limited-entry commercial sablefish fisheries. The NSEI and SSEI (**Southeast Region**) and the PWS Inside District (**Central Region**) each have separate seasons and GHLs. In the Cook Inlet Area, there is a state-managed open access sablefish fishery with a separate GHL.

In the Southeast Region both the SSEI and NSEI sablefish fisheries have been managed under a license limitation program since 1984. In 1994 the BOF adopted regulations implementing an equal share quota system where the annual GHL was divided equally between permit holders and the season was extended to allow for a more orderly fishery. In 1997 the BOF adopted this equal share system as a permanent management measure for both the NSEI and SSEI sablefish fisheries. In 2019 there were 78 eligible permit holders in NSEI and 22 permit holders in SSEI.

In 2017, the CFEC approved a public petition for SSEI longline permit holders to fish pot gear due to whale depredation and rockfish bycatch issues, thus making the permit a longline/pot permit. SSEI has 19 longline/pot permits and 3 pot permits; the NSEI fishery is restricted to longline gear only. In 2018, the BOF amended SSEI sablefish longline and pot seasons to a concurrent season occurring from June 1 to November 15, adopted new regulations to require commercial sablefish pots to have two 4-inch circular escape rings and allowed for the possession of live sablefish for delivery as a live product.

During the February 2009 BOF meeting, the BOF made no changes affecting the regulation of commercial sablefish fisheries; however, bag and possession limits were established for the sablefish sport fishery. At the 2012 BOF meeting, a regulation was passed to require personal use and subsistence sablefish household fishing permits. Bag (50 fish per permit), vessel (200 fish per vessel) and hook (350 per permit) limits were adopted for personal use sablefish fishing at the 2015 BOF meeting. In 2018, the BOF approved the use of pots in the personal use sablefish fishery with a limit of two pots per person, 8 pots per vessel.

The NSEI quota was set at 417 mt and the SSEI quota was set at 268 mt for 2019.

There is no open-access sablefish fishery in the Southeast Outside District as there are limited areas that are deep enough to support sablefish populations inside state waters. In some areas of the Gulf, the state opens the fishery concurrent with the EEZ opening. These fisheries, which occur in Cook Inlet Area’s North Gulf District and the Aleutian Island District, are open access in state waters, as the state cannot legally implement IFQ management at this time. The fishery GHLs are based on historic catch averages and closed once these have been reached.

In the **Central Region** the Cook Inlet Area sablefish GHL is set using a historic baseline harvest level adjusted annually by the relative change to the ABC in the federal CGOA. In 2004, the BOF adopted a sablefish fishery-specific registration, logbook requirement, and 48-hour trip limit of 1.8 mt in the Cook Inlet Area. For PWS, a limited-entry program that included gear restrictions and established vessel size classes was adopted in 1996. Between 1996 and 2014, the PWS fishery GHL was set at 110 mt, which is the midpoint of the harvest range set by a habitat-based estimate. Tagging studies conducted by the NMFS and ADF&G indicate that sablefish populations throughout the GOA including PWS are likely mixed. Therefore, the GHL was adjusted by applying the relative change each year in the NMFS GOA sablefish ABC, which is derived from NMFS stock assessment surveys. The GHL was adjusted beginning in 2015 by applying the relative change in the GOA-wide ABC for sablefish back to 1994; this adjustment continued in 2019. PWS fishery management developed through access limitation and in 2003 into a shared quota system wherein permit holders are allocated shares of the GHL. Shares are equal within each of four vessel size classes but differ between size classes. In 2009, the BOF adopted regulations which included a registration deadline, logbooks, and catch reporting requirements; new season dates of April 15–August 31 were also adopted. The new season opening date, one month later than in previous years, was adopted to reduce the opportunity for orca depredation on hooked sablefish which predominately occurred prior to May 1.

The sole **Westward Region** sablefish fishery occurs in the Aleutian Islands. The GHL for the Aleutian Islands is set at 5% of the combined Bering Sea Aleutian Islands TAC. The state GHL can be adjusted according to recent state-waters harvest history when necessary. From 1995 to 2000 the fishery opened concurrently with the EEZ IFQ sablefish fishery. In 2001 the BOF changed the opening date of the state-waters fishery to May 15 to provide small vessel operators an opportunity to take advantage of potentially better weather conditions. From 1995 to 2000 all legal groundfish gear types were permissible during the fishery. Effective in 2001, longline, pot, jig and hand troll became the only legal gear types. Vessels participating in the fishery are required to register and fill out logbooks provided by ADF&G. In 2013, the BOF changed the season opening and closing dates reverting them back to coincide with the federal IFQ season.

The Southeast Alaska **sport fishery** for sablefish was regulated for the first time in 2009. Sport limits in 2019 were four fish of any size per day, four in possession, with an annual limit of eight fish applied to nonresidents. Creel surveys in Southeast Alaska in 2019 sampled 372 sablefish, reflecting the low harvest relative to other species. The sablefish sport fishery in Southcentral Alaska has no bag, possession, or size limits. Interviewed anglers retained 155 of 286 sablefish caught in 2019. Port sampling of sablefish is opportunistic in Southcentral Alaska and is not a primary objective of the program; port samplers in Southcentral Alaska measured only 17 sablefish from the sport harvest, again reflecting the relatively low harvests.

4. Fisheries

In the Southeast Region, the 2019 NSEI sablefish fishery opened August 15 and closed November 15. The 78 permit holders landed a total of 411 mt of sablefish. The fishery is managed by equal quota share; each permit holder was allowed 5.4 mt. The 2019 SSEI sablefish fishery season allowed longline/pot gear permits to fish from June 1–November 15. In SSEI, 19 permits were designated to be fished with longline/pot gear and 3 permits for pot gear only. The 22 permit holders landed a total of 266 mt of sablefish, each with an equal quota share of 12.2 mt (Contact Rhea Ehresmann).

In the **Central Region,** the 2019 Cook Inlet Area sablefish fishery opened at noon July 15 with a GHL of 28.1 mt and closed by regulation on December 31. Three longline vessels participated and harvested only 33% of the GHL; all harvest occurred in the North Gulf District. Harvest and effort have been steadily decreasing in the Cook Inlet Area fishery and 2019 marked the lowest harvest since 1990. The 2019 PWS sablefish fishery opened April 15 with a GHL of 60.8 mt and closed by regulation on August 31. PWS sablefish harvest totaled 42.5 mt, steadily increasing since the 7.7 mt historical low in 2015, although still not achieving the GHL. Longline gear was used to harvest 59% of the total and 39% was harvested with pot gear; pot effort has been increasing in recent years in response to excessive orca depredation on sablefish in PWS (Contact Jan Rumble).

Within the **Westward Region**, only the Aleutian Islands have sufficient habitat to support mature sablefish populations of enough magnitude to permit commercial fishing. All other sections within the region are closed by regulation to avoid the potential for localized depletion from the small amounts of habitat within the jurisdiction of the state. Bycatch from the areas closed to directed fishing is limited to 1%. The 2019 Aleutian Island fishery opened concurrent with the IFQ season, on March 15 with pot, longline, jig and hand troll gear allowed. The GHL was set at 174.8 mt for the state-waters fishery. The harvest from the 2019 Aleutian Islands sablefish fishery was 48.8 mt. The season remained open until the November 14closure date (Contact Asia Beder).

The most recent sablefish sport harvest estimates from the SWHS are for 2018. The estimated harvest was 20,431 fish in Southeast Alaska and 5,824 fish in Southcentral Alaska. SWHS estimates are suspected to be biased due to misidentification and misreporting. Sablefish are not commonly taken by anglers in most areas of the state, and relatively high catches were reported from some areas where sablefish are rarely or never observed by creel survey crews. Charter logbooks indicated guided harvests of 11,778 sablefish in Southeast Alaska and 846 sablefish in Southcentral Alaska in 2018 (Contact Bob Chadwick, Jason Dye).

K. Lingcod

1. Research

In the **Southeast Region**, dockside sampling of lingcod caught in the commercial fishery continued in 2019 in Sitka with 1,172 fish sampled for biological data. Otoliths were sent to the ADU in Juneau for age determination (Contact Rhea Ehresmann). In the **Central Region**, skipper interviews and port sampling were conducted in Cordova, Seward, and Homer. Data obtained included date and location of harvest, length, weight, sex and age structures. Otoliths were sent to the ADU in Juneau for age determination. Gonad condition was generally not determined as nearly all fish were delivered gutted, however, evidence of sex (vent/papilla) was required by EO to remain intact on lingcod by having fishermen cut 1 inch forward of the vent when gutting fish (Contact Elisa Russ). Funding for Central Region lingcod ROV surveys ended in 2016 and no surveys have been conducted in recent years (Contact Mike Byerly).

The Division of Sport Fish—Southeast Region continued to collect catch, harvest, and biological data from lingcod as part of a marine harvest survey program with lingcod harvests tabulated back to 1987 in some ports. Data collected in the program include statistics on effort, catch, and harvest of lingcod taken by Southeast Alaska sport anglers. Ports sampled in 2019 included Juneau, Sitka, Craig, Petersburg/Wrangell, Gustavus, Elfin Cove, Yakutat, and Ketchikan. Length and sex data were collected from 1,685 lingcod in 2019, primarily from the ports of Sitka, Ketchikan, Craig, Gustavus, Elfin Cove, and Yakutat (Contact Mike Jaenicke).

The **Division of Sport Fish—Southcentral Region** continued collection of harvest and fishery information on lingcod through the groundfish harvest assessment program. Lingcod objectives include estimation of 1) the age, sex, and length composition of lingcod harvests by ports and 2) the geographic distribution of harvest by each fleet. The program sampled 502 lingcod from the sport harvest at Seward, Valdez, Whittier, Kodiak, and Homer in 2019. These ports accounted for most of the sport lingcod harvest in Southcentral Alaska (Contact Martin Schuster).

2. Assessment

There is no stock assessment for lingcod in the **Southeast Region**.

Central Region conducts ROV surveys along the northern Gulf of Alaska coast from the Kenai Peninsula to PWS for to estimate local abundance and biomass of lingcod concurrently with DSR. No surveys were conducted in 2019 (Contact Mike Byerly or Wyatt Rhea-Fournier).

3. Management

Management of commercial lingcod fisheries in **Southeast Alaska** is based upon a combination of GHRs, season, and gear restrictions. Regulations include a winter closure for all users, except longliners, between December 1 and May 15 to protect nest-guarding males. GHLs were reduced in 2000 in all areas and allocations were made between directed commercial fishery, sport fishery, longline fisheries, and salmon troll fisheries. The 27-inch minimum commercial size limit remains in effect and fishermen are requested to keep a portion of their lingcod with the head on and proof of gender to facilitate biological sampling of the commercial catch. Vessel registration is required, and trip limits are utilized by ADF&G staff when needed for the fleet to stay within their allocations. The directed fishery is limited to jig or dinglebar troll gear. In 2003 the Alaska BOF established a super-exclusive directed fishery registration for lingcod permit holders fishing in the IBS Subdistrict.

The **Central Region** has directed commercial fisheries for lingcod in Cook Inlet and PWS areas. Regulations for the commercial lingcod fishery include open season dates of July 1 to December 31 and a minimum size requirement of 35 inches (89 cm) overall or 28 inches (71 cm) from the front of the dorsal fin to the tip of the tail. The directed lingcod fishery in the Cook Inlet Area is limited to jig gear only. Guideline harvest levels are 24 mt for Cook Inlet Area and 3.3 mt in the Inside District of PWS and 11.5 mt for the PWS Outside District. Resurrection Bay, near Seward, is closed to commercial harvest of lingcod. In 2009, a new BOF regulation permitted retention of lingcod at a 20% bycatch level in PWS waters following closure of the directed season. Cook Inlet Area also allows 20% bycatch levels for lingcod; however, no bycatch may be retained after the GHL is achieved.

In **Southeast Alaska**, sport harvests of lingcod are incorporated into a regionwide lingcod management plan. This plan reduced GHLs for all fisheries (combined) in seven management areas and allocated a portion of the GHL for each area to the sport fishery. Since 2000, harvest limit reductions, size limits, and mid-season closures have been implemented by emergency order in various management areas to ensure sport harvests do not exceed allocations. The sport fishery lingcod season for 2019 was May 16–November 30. Charter vessel operators and crew members were prohibited from retaining lingcod while guiding clients. For resident anglers, the limits regionwide were one fish per day and two in possession, with no size limit. Additional restrictions were put into place for nonresidents to keep harvest from exceeding allocations specified by the Alaska BOF:

(1) In the Northern Southeast area, nonresidents were allowed one fish daily or in possession, the fish must be 30–35 inches in length or at least 55 inches or greater in length, and the annual limit was two fish, of which one must be 30–35 inches in length and one must be at least 55 inches in length;

(2) In the Southern Southeast area, nonresidents were allowed one fish daily or in possession, the fish must be 30–45 inches in length or at least 55 inches or greater in length, and the

annual limit was two fish, of which one must be 30–45 inches in length and one must be at least 55 inches in length.

Notwithstanding the limits for each area, the nonresident annual limit in the combined waters of Southeast Alaska was four fish of which only one may be 55 inches or greater in length. In addition, the Pinnacles area near Sitka has been closed to sport fishing year-round for all groundfish since 1997 (Contact Bob Chadwick).

A suite of regulations was established in 1993 for sport lingcod fisheries in **Southcentral Alaska** considering the lack of quantitative stock assessment information. Resurrection Bay remained closed to lingcod fishing year-round to rebuild and protect the population, although there is no formal rebuilding plan. The season was closed region-wide from January 1 through June 30 to protect spawning and nest guarding lingcod. Daily bag limits in 2019 were two fish in Cook Inlet and Kachemak Bay, and one fish in North Gulf Coast and Prince William Sound areas. All areas except Kodiak had a minimum size limit of 35 inches to protect spawning females (Contact Jason Dye or Matt Miller).

4. Fisheries

Lingcod are the target of a "dinglebar" troll fishery in **Southeast Alaska**. Dinglebar troll gear is power troll gear modified to fish for groundfish. Additionally, lingcod are landed as significant bycatch in the DSR longline, halibut longline, and salmon troll fisheries. The directed fishery landed 129 mt of lingcod in 2019. An additional 57 mt was landed as bycatch in halibut and other groundfish fisheries and 6 mt in the salmon troll fishery.

Central Region commercial lingcod harvests have primarily occurred in the North Gulf District of the Cook Inlet Area and PWS. The 2019 lingcod GHL was 23.8 mt in Cook Inlet Area, and the fishery closed December 9 when the GHL was achieved; increases in lingcod effort and harvest in recent years began in 2017 with similar harvest levels in both 2017 and 2018. In PWS, lingcod harvest in 2019 was 12.0 mt in PWS, down slightly from 2018. Approximately 85% of the lingcod harvest from Cook Inlet Area was from the directed lingcod jig fishery and the remainder was harvested as bycatch primarily on longline gear. In PWS, 78% of lingcod harvest was with longline gear and 20% with jig gear, with only 3.7 mt or 30% of total harvest from the directed fishery. (Contact Jan Rumble).

In the **Westward Region**, no directed lingcod effort occurred during 2019. All lingcod were harvested incidental to other federal and state managed groundfish fisheries. The 2019 harvest totaled 18 mt in the Kodiak Area and <1 mt in the Chignik, South Alaska Peninsula, and Aleutian Islands – Bering Sea areas combined.

Sport lingcod harvest estimates from the SWHS for 2018 (the most recent year available) were 15,031 lingcod in Southeast Alaska and 13,645 lingcod in Southcentral Alaska. The average estimated annual harvest for the recent five-year period (2014-2018) was 12,975 fish in Southeast Alaska and 14,356 fish in Southcentral Alaska.

L. Atka Mackerel

1. Research

There was no research on Atka mackerel during 2019.

2. Assessment

There are no state stock assessments for Atka mackerel.

3. Management

A commissioner's permit is required in **Central Region** and **Southeast Region** before a directed fishery may be prosecuted for Atka mackerel. This permit may restrict depth, dates, area, and gear, establish minimum size limits, and require logbooks and/or observers, or any other condition determined to be necessary for conservation and management purposes.

4. Fisheries

There was no directed fishery for Atka mackerel in 2019. Currently in the **Central Region** and **Southeast Region** Atka mackerel are considered part of the other groundfish assemblage and are allowed up to 20% as bycatch in aggregate in directed fisheries for groundfish.

M. Flatfish

1. Research

There was no research on flatfish during 2019.

2. Assessment

There are no stock assessments for flatfish.

3. Management

Trawl fisheries for flatfish are allowed in four small areas in the internal waters of **Southeast Alaska** under a special permit issued by the department. The permits are generally issued for no more than a month at a time and specify the area fished and other requirements. Trawl gear is limited to beam trawls, and mandatory logbooks are required, observers can be required, and there is a 20,000-pound weekly trip limit.

Within **Central Region** flatfish may be harvested in a targeted fishery only under the authority of an ADF&G commissioner's permit. The permit may stipulate fishing depth, seasons, areas, allowable sizes of harvested fish, gear, logbooks, and other condition determined to be necessary for conservation or management purposes.

There are no bag, possession, or size limits for flatfish (excluding Pacific halibut) in the sport fisheries in Alaska. Harvest of flatfish besides Pacific halibut are not explicitly estimated by the SWHS and no information is collected in the creel surveys and port sampling of the sport fisheries in Southcentral or Southeast Alaska. Flatfish are occasionally taken incidentally to other species and in small shore fisheries, but the sport harvest is believed to be negligible.

4. Fisheries

No effort has occurred in the **Southeast** fishery in recent years. Since 2000, only one vessel has applied for a commissioner's permit to participate in this fishery; this vessel made a single flatfish landing in 2014. Due to limited participation, harvest information is confidential for this landing. The Southeast flatfish trawl areas are also the sites of a shrimp beam trawl fishery. In the past, most of the Southeast harvest was starry flounder. In state waters of the **Westward Region**, the State of Alaska adopts most NOAA Fisheries regulations and the flatfish fishery is managed under a parallel management structure. In **Central Region** during 2019, one commissioner's permit to catch flatfish was issued in the Cook Inlet Area and none in PWS. The purpose of the Cook Inlet Area permit was to test the viability of pot gear; however, there was limited success.

N. Pacific Halibut and IPHC Activities

The sport halibut fishery is monitored by the **Division of Sport Fish**. Data on sport fishery effort and harvest are collected through port sampling in Southeast and Southcentral Alaska, the SWHS, and charter vessel logbooks. Estimates of harvest and related information are provided annually to the IPHC for use in the annual stock assessment, and to the North Pacific Fishery Management Council (Council). The Council's Scientific and Statistical Committee has periodically reviewed the state's estimation and projection methods. ADF&G provides an analysis each year that is used by the Council to recommend regulatory changes for the charter fishery to keep its harvest within allocations specified in the Catch Sharing Plan for Guided Sport and Commercial Fisheries in Alaska. The Council's recommendations are incorporated by the IPHC as annual management measures for the charter fishery. Estimates of sport harvest and associated analyses are posted on the North Pacific Fishery Management Council's web page at http://www.npfmc.org (Contact Sarah Webster).

O. Other groundfish species

In 1997 the BOF approved a new policy that would strictly limit the development of fisheries for other groundfish species in **Southeast**. Fishermen are required to apply for a permit for miscellaneous groundfish if they wish to participate in a directed fishery for species that do not already have regulations in place. Permits do not have to be issued if there are management and conservation concerns. The state also has a regulation that requires that the bycatch rate of groundfish be set annually for each fishery by emergency order unless otherwise specified in regulation.

V. Ecosystem Studies – N/A

VI. Other Related Studies

Staff in the **Central Region** currently house all data in an MS Access database format. Queries are complete for calculating CPUE, abundance, and biomass estimates from most surveys. All data are additionally captured in GIS for spatial analysis.

ADF&G manages state groundfish fisheries under regulations set triennially by the BOF.

ADF&G announces the open and closed fishing periods consistent with the established regulations and has authority to close fisheries at any time for justifiable conservation reasons. The department also cooperates with NOAA Fisheries in regulating fisheries in offshore waters.

A. User Pay/Test Fish Programs

The department receives receipt authority from the state legislature that allows us to conduct stock assessment surveys by recovering costs through sale of fish taken during the surveys. Receipt authority varies by region. In **Southeast Alaska** several projects are funded through test fish funds, notably the sablefish longline assessments and mark-recapture work, the herring fishery, and some salmon assessments.

VII. Publications

Beder, A., and J. Shaishnikoff. 2019. Annual management report for groundfish fisheries in the Bering Sea-Aleutian Islands Management Area, 2018. Alaska Department of Fish and Game, Fishery Management Report No. 19-18, Anchorage.

Beder, A. 2019. Fishery management plan for the Aleutian Islands Subdistrict state-waters and parallel Pacific cod seasons, 2020. Alaska Department of Fish and Game, Fishery Management Report No. 19-31, Anchorage.

Beder, A. 2019. Fishery management plan for the Dutch Harbor Subdistrict state-waters and parallel Pacific cod seasons, 2020. Alaska Department of Fish and Game, Fishery Management Report No. 19-32, Anchorage.

Bevaart, K., and N. Richardson. 2019. Fishery management plan for the South Alaska Peninsula Area state-waters Pacific cod season, 2019. Alaska Department of Fish and Game, Fishery Management Report No. 19-02, Anchorage.

Howard, K. G., S. Campen, F. R. Bowers, R. E. Chadwick, J. W. Erickson, J. J. Hasbrouck, T. R. McKinley, J. Nichols, N. Nichols, A. Olson, J. Rumble, T. T. Taube, and B. Williams. 2019. ADF&G Statewide Rockfish Initiative: Strategic plan 2017-2020. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report 5J19-05, Anchorage.

Howard, K. G., Habicht, C., Russ, E., Olson, A., Nichols, J., & Schuster, M. (2019). Operational Plan: Genetic Sampling of Yelloweye and Black Rockfish from Inside and Outside Waters of Prince William Sound, North Gulf of Alaska, and Southeast Alaska.

Howard, K. G., C. Worton, E. Russ, J. Nichols, A. Olson, K. Wood, M. Schuster, K. Reppert, T. Tydingco, M. Byerly, and S. Campen. 2019. Alaska Department of Fish and Game statewide rockfish initiative. Alaska Department of Fish and Game, Special Publication No. 19-09, Anchorage.

Olson, A. and J. Sullivan. 2019. 2019 Southern Southeast Inside Subdistrict Sablefish Fishery Management Plan. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 1J19-06, Douglas.

Richardson, N., and K. Bevaart. 2019. Fishery management plan for the Chignik Area state-waters Pacific cod season, 2019. Alaska Department of Fish and Game, Fishery Management Report No. 19-01, Anchorage.

Rumble, J., E. Russ, and C. Russ. 2019. Cook Inlet Area groundfish management report, 2016–2018. Alaska Department of Fish and Game, Fishery Management Report No. 19-24, Anchorage.

Sullivan, J., A. Olson, and B. Williams. 2019. 2018 Northern Southeast Inside Subdistrict Sablefish Fishery Stock Assessment and 2019 Management Plan. Alaska Department of Fish and Game, Division of Commercial Fisheries, Regional Information Report No. 5J19-03, Douglas.

Wood, K., A. Olson, B. Williams, and M. Jaenicke. 2019. Assessment of the Demersal Shelf Rockfish Stock Complex in the Southeast Outside Subdistrict of the Gulf of Alaska. Stock Assessment and Fishery Evaluation Reports for 2020 Fisheries. North Pacific Groundfish Stock Assessments, GOA.

A. Statistical Area Charts

Digital groundfish and shellfish statistical area charts are available and can be viewed or downloaded at:
http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryGroundfish.groundfishmaps
(Contact Lee Hulbert).

B. Websites

ADF&G Home Page: http://www.adfg.alaska.gov

Commercial Fishing home page:
http://www.adfg.alaska.gov/index.cfm?adfg=fishingCommercial.main

Sport Fisheries home page: http://www.adfg.alaska.gov/index.cfm?adfg=fishingSport.main

News Releases: http://www.adfg.alaska.gov/index.cfm?adfg=newsreleases.main

Rockfish Conservation page:
http://www.adfg.alaska.gov/index.cfm?adfg=fishingSportFishingInfo.rockfishconservation

Age Determination Unit Home Page: http://mtalab.adfg.alaska.gov/ADU/

Region I, Southeast Region, Groundfish Home Page:
http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyareasoutheast.groundfish

Gene Conservation Laboratory Home Page:
http://www.adfg.alaska.gov/index.cfm?adfg=fishinggeneconservationlab.main

Region II, Central Region, Groundfish Pages:
http://www.adfg.alaska.gov/index.cfm?adfg=fishingcommercialbyarea.southcentral

Westward Region, Groundfish Pages:
http://www.adfg.alaska.gov/index.cfm?adfg=commercialbyfisherygroundfish.groundfishareas

ADF&G Groundfish Overview Page:
http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryGroundfish.main

Commercial Fisheries Entry Commission: http://www.cfec.state.ak.us/

State of Alaska home page: http://www.alaska.gov

Demersal shelf rockfish stock assessment document:
https://www.afsc.noaa.gov/REFM/Docs/2017/GOAdsr.pdf

Groundfish charts:
http://www.adfg.alaska.gov/index.cfm?adfg=CommercialByFisheryGroundfish.groundfishmaps

VIII. References

Olsen, J. B., Merkouris, S. E., & Seeb, J. E. (2002). An examination of spatial and temporal genetic variation in walleye pollock (Theragra chalcogramma) using allozyme, mitochondrial DNA, and microsatellite data. Fishery Bulletin, 100(4), 752-764.

Seeb, L. W., & Kendall, A. W. (1991). Allozyme polymorphisms permit the identification of larval and juvenile rockfishes of the genus Sebastes. Environmental Biology of Fishes, 30(1-2), 191-201.

Seeb, L. W. (2004). Genetic Markers Distinguish Populations of Black Rockfish in the Gulf of Alaska. of North Pacific Rockfishes: Ecological Genetics and Stock Structure, 57.

APPENDICES

Appendix I. Alaska Department of Fish and Game staff (updated 04/15/2020)

COMMERCIAL FISHERIES DIVISION

HEADQUARTERS

Chief, Computer Services Phillip Witt P.O. Box 115526 Juneau, AK 99811 (907) 465-4753	Age Determination Unit Supervisor Kevin McNeel P.O. Box 115526 Juneau, AK 99811 (907) 465-3054	eLandings Program Coordinator II Carole Triem P.O. Box 115526 Juneau, AK 99811 (907) 465-6157
AKFIN Program Coordinator Lee Hulbert P.O. Box 115526 Juneau, AK 99811 (907) 465-6109	Fishery Biologist I Chris Hinds P.O. Box 115526 Juneau, AK 99811 (907) 465-1174	SE Groundfish Project Biometrician Jane Sullivan P.O. Box 115526 Juneau, AK 99811 (907) 465-6129

SOUTHEASTERN REGION

Groundfish/Shellfish Coordinator Andrew Olson 802 3rd ST Douglas, AK 99824 (907) 465-4259	Groundfish Project Leader Rhea Ehresmann 304 Lake St. Rm. 103 Sitka, AK 99835 (907) 747-6688	Fishery Biologist II Vacant 304 Lake St. Rm. 103 Sitka, AK 99835 (907) 747-6688
Fishery Biologist II Kellii Wood P.O. Box 667 Petersburg, AK 99833 (907) 772-5222	Fishery Biologist II Aaron Baldwin 802 3rd ST Douglas, AK 99824 (907) 465-3896	Fishery Biologist I Erica Ebert P.O. Box 667 Petersburg, AK 99833 (907) 772-5223
Fishery Technician IV Mariah Leeseberg 304 Lake St. Rm. 103 Sitka, AK 99835 (907) 747-6688	Fishery Technician III Madison Bargas 802 3rd ST Douglas, AK 99824 (907) 465-6135	Fishery Technician IV Elisa Teodori P.O. Box 667 Petersburg, AK 99833 (907) 772-5233

CENTRAL REGION

Groundfish/Shellfish Research Project Leader Wyatt Rhea-Fournier 3298 Douglas Place Homer, AK 99603-7942 (907) 235-8191	Area Management Biologist Jan Rumble 3298 Douglas Place Homer, AK 99603-7942 (907) 235-8191	Groundfish Sampling/Ageing Mgr.; Asst. Area Management Biologist Elisa Russ 3298 Douglas Place, Homer AK 99603-7942 (907) 235-8191
Fish Ticket Processing/Data Analyst Chris Russ 3298 Douglas Place, Homer, AK 99603-7942 (907) 235-8191	Groundfish/Shellfish Research Biologist Mike Byerly 3298 Douglas Place Homer, AK 99603-7942 (907) 235-8191	GIS Analyst Josh Mumm 3298 Douglas Place Homer, AK 99603-7942 (907) 235-8191
Fishery Biologist I Karen Swartzbart 401 Railroad Avenue Cordova, 99574 (907) 424-3235		

WESTWARD REGION

Shellfish/Groundfish Program Coordinator Mark Stichert 351 Research Ct Kodiak, AK 99615-6399 (907) 486-1842	Area Management Biologist Nathaniel Nichols 351 Research Kodiak AK 99615-6399 (907) 486-1845	Groundfish Research Biologist Carrie Worton 351 Research Ct Kodiak AK 99615-6399 (907) 486-1849
Groundfish Sampling Coordinator Sonya El Mejjati 351 Research Ct Kodiak, AK 99615-6399 (907) 486-1846	Assistant Area Management Biologist Natura Richardson 351 Research Ct Kodiak, AK 99615 (907) 486-1840	Area Management Biologist Miranda Westphal P.O. Box 920587 Dutch Harbor, AK 99692 (907) 581-1239
Assistant Groundfish Research Biologist Philip Tschersich 351 Research Ct Kodiak, AK 99615-6399 (907) 486-1871	Assistant Area Management Biologist Asia Beder P.O. Box 920587 Dutch Harbor, AK 99692 (907) 581-1239	Lead Trawl Survey Biologist Kally Spalinger 351 Research Ct Kodiak, AK 99615-6399 (907) 486-1840

SPORT FISH DIVISION

STATEWIDE

Deputy Director Tom Taube P.O. Box 115526 Juneau, AK 99811-5526 (907) 465-6187	Statewide Bottomfish Coordinator Sarah Webster 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2212	Logbook Program Coordinator Bob Powers 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2299
Statewide Harvest Survey Coord. Bill Romberg 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2366	Fisheries Scientist Dr. Kathrine Howard 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2141	

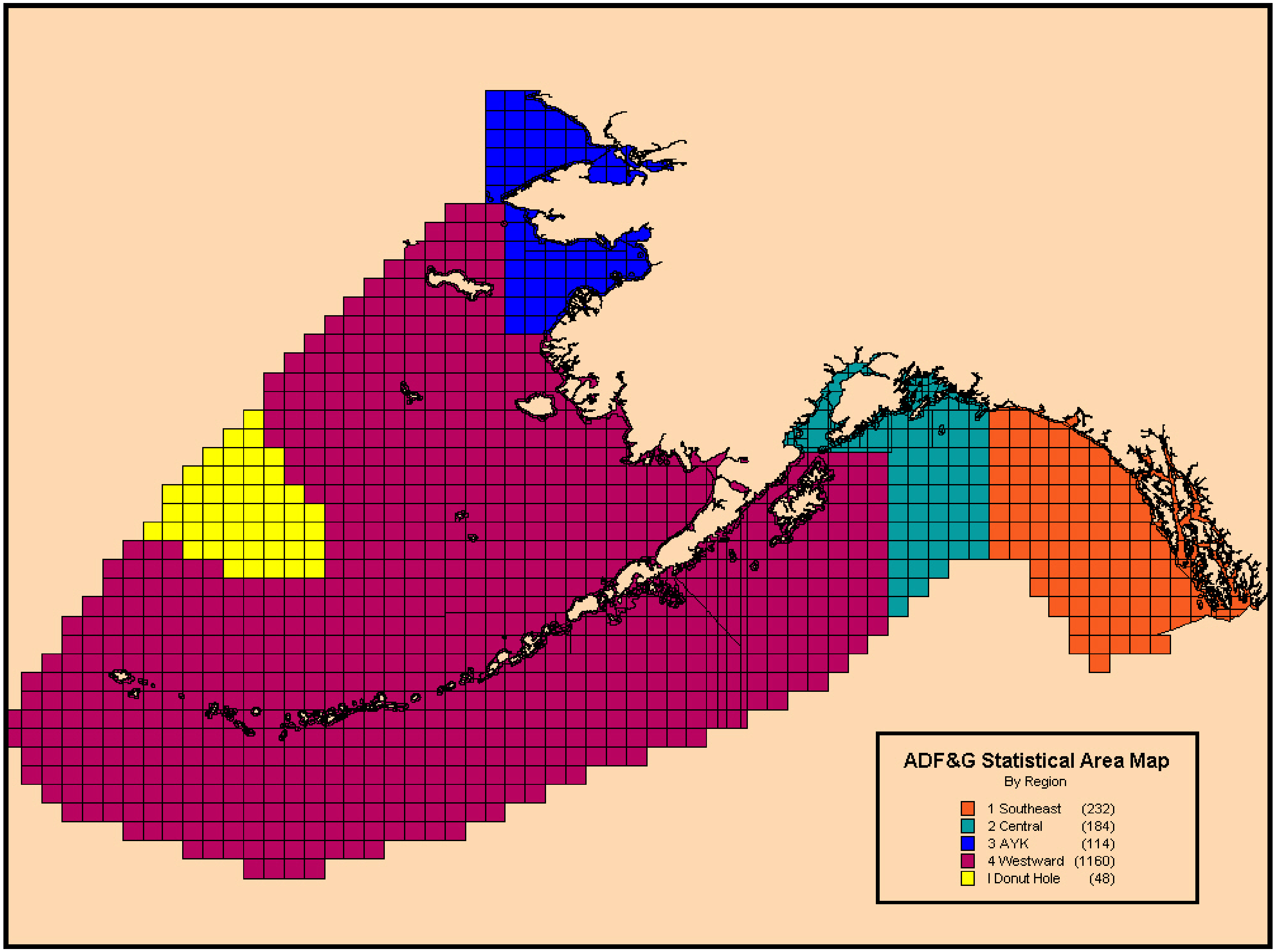
SOUTHEAST REGION

Project Leader, Mar. Harv. Studies Michael Jaenicke P.O. Box 110024 Juneau, AK 99811-0024 (907) 465-4301	Regional Management Biologist Robert Chadwick 304 Lake St., Room 103 Sitka, AK 99835-7563 (907) 747-5551	Regional Research Biologist Jeff Nichols P.O. Box 110024 Juneau, AK 99811-0024 (907) 465-4398
Yakutat Area Management Biologist Jason Pawluk P.O. Box 49 Yakutat, AK 99689-0049 (907) 784-3222	Haines/Skagway Area Mgmt. Biol. Richard Chapell P.O. Box 330 Haines, AK 99827-0330 (907) 766-3638	Juneau Area Mgmt. Biol. Daniel Teske P.O. Box 110024 Juneau, AK 99811-0024 (907) 465-8152
Sitka Area Management Biologist Troy Tydingco 304 Lake St., Room 103 Sitka, AK 99835-7563 (907) 747-5355	Petersburg/Wrangell Area Mgmt. Biol. Patrick Fowler P.O. Box 667 Petersburg, AK 99833-0667 (907) 772-5231	Prince of Wales Area Mgmt. Biol. Craig Schwanke P.O. Box 682 Craig, AK 99921 (907) 826-2498
Ketchikan Area Mgmt. Biologist Kelly Piazza 2030 Sea Level Drive, Suite 205 Ketchikan, AK 99901 (907) 225-2859	Biometrician – Div. Sport Fish-RTS Jiaqi Huang 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2327	

SOUTHCENTRAL REGION

Halibut/Groundfish Project Leaders Martin Schuster, Marian Ford 3298 Douglas Place Homer, AK 99603 (907) 235-8191	Regional Management Biologists Jason Dye, Matthew Miller 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2218	Regional Research Biologist Tim McKinley 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2218
Lower Cook Inlet Mgmt. Biol. Mike Booz 3298 Douglas Place Homer, Alaska 99603-8027 (907) 235-8191	PWS and North Gulf Mgmt. Biol. Jay Baumer, Brittany Blain-Roth 333 Raspberry Road Anchorage, AK 99518-1599 (907) 267-2218	Kodiak, Alaska Pen., and Aleutian Islands Management Biologist Tyler Polum 211 Mission Road Kodiak, AK 99615-6399 (907) 486-1880
Biometrician Adam Reimer Division of Sport Fish-RTS 43961 Kalifornsky Beach Road, Suite B Soldotna, AK 99669-8276 (907) 262-9368	Biometrician Jiaqi Huang Division of Sport Fish-RTS 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2327	Biometrician Ben Buzzee Division of Sport Fish-RTS 333 Raspberry Road Anchorage, AK 99518-1565 (907) 267-2388

Appendix II. Map Depicting State of Alaska Commercial Fishery Management Regions.



Appendix III. Tissue samples of *Sebastes* species and pollock collected for genetic analyses and stored at Alaska Department Fish and Game, Gene Conservation Laboratory, Anchorage. Species, sampling location, year collected, sample size, and tissue type are given.

Species	Location	Year	Sample size	Tissues
Yelloweye rockfish, *Sebastes ruberrimus*				
	Gravina, Danger, Herring	1991	27	muscle, liver, eye
	Knight Is./Naked Islands area	1998	100	fin
	Flamingo Inlet	1998	46	fin, larvae
	Tasu Sound	1998	50	fin
	Topknot	1998	49	fin
	Triangle Island	1998	63	fin, larvae
	Sitka	1998	49	fin
	Kachemak Bay	1999	58	fin
	Kodiak Island	1999	115	fin
	Resurrection Bay	1999	100	fin
	Fairweather Grounds	1999	100	fin
	SE Stat Areas 355601, 365701 (CSEO)	1999	100	fin
	Whittier	2000	97	fin
	Whittier	2000	50	fin
	Port Gravina	2008	61	fin
	Prince William Sound - inside	2018	71	fin
	Prince William Sound Marine	2018	121	fin
	Eastern North Gulf Coast	2019	51	fin
	Kodiak	2019	10	fin
	North Gulf Coast	2019	123	fin
	Prince William Sound	2019	110	fin
	Prince William Sound	2019	175	fin
	Sitka, Craig	2019	467	fin
	Sitka, Craig, Petersburg	2019	396	fin
Black rockfish, *S. melanops*				
	Kodiak Island	1996	2	muscle, liver, heart, eye
	Ugak Bay, Kodiak Island	1997	100	muscle, liver, heart, eye
	Resurrection Bay - South tip Hive Island	1997	82	muscle, liver, heart, eye, fin
	Carpa Island	1998	40	fin
	Eastside Kodiak Is.: Ugak and Chiniak Bays	1998	100	fin
	Southwest side Kodiak Island	1998	86	fin
	Westside Kodiak Island	1998	114	fin
	North of Fox Island	1998	24	fin
	Washington - Pacific Northwest	1998	20	fin
	Sitka	1998	50	fin
	Castle Rock near Sand Point	1999	60	fin
	Akutan	1999	100	fin
	Oregon - Pacific Northwest	1999	50	muscle, liver, heart
	SE Stat Areas 355631, 365701 (CSEO)	1999	83	fin
	Sitka Sound Tagging study	1999	200	fin
	Dutch Harbor	2000	6	fin
	Chignik	2000	100	fin
	Valdez	2000	13	fin
	Whittier	2000	16	fin
	Valdez	2001	50	fin
	Whittier	2001	93	fin
	Yakutat Bay	2003	130	fin
	Eastern North Gulf Coast	2019	34	fin
	Gustavas to Ketchikan	2019	719	fin

Kachemak Bay	2019	50	fin
North Gulf Coast	2019	125	fin
Prince William Sound	2019	319	fin
Sitka, Craig	2019	31	fin
Dusky rockfish, *S. ciliatus*			
Kodiak Island	1997	50	muscle, liver, heart, eye
Resurrection Bay	1998	3	fin
Eastside Kodiak Is.: Ugak, Chiniak, Ocean Bays	1998	100	muscle, liver, heart, eye
Sitka Black RF Tagging study	1999	15	muscle, liver, heart, eye
Sitka	2000	23	liver, fin
Sitka	2000	23	fin
Harris Bay - Outer Kenai Peninsula	2002	37	muscle
North Gulf Coast - Outer Kenai Peninsula	2003	45	fin
Walleye pollock, *Gadus chalcogrammus*			
Exact location unknown; see comments	1997	402	fin
Bogoslof Island	1997	120	muscle, liver, heart
Middleton Island	1997	100	fin
NE Montague/E Stockdale	1997	100	fin
Orca Bay, PWS	1997	100	fin
Port Bainbridge	1997	100	fin
Shelikof Strait	1997	104	muscle, liver, heart, eye, fin
Bogoslof Island	1998	100	muscle
Eastern Bering Sea	1998	40	muscle, liver, heart
Middleton Island	1998	100	muscle, liver, heart
Port Bainbridge	1998	100	muscle, liver, heart
Resurrection Bay	1998	120	fin
Shelikof Strait	1998	100	muscle, liver, heart
PWS Montague	1999	300	heart
Eastern PWS	1999	94	heart
Kronotsky Bay, E. Coast Kamtchatka	1999	96	muscle, liver, heart, eye, fin
Avacha Bay	1999	100	unknown
Bogoslof Island	2000	100	muscle, liver, heart
Middleton Island	2000	100	muscle, liver, heart
Prince William Sound	2000	100	muscle, liver, heart
Shelikof Strait	2000	100	muscle, liver, heart

California Department of Fish and Wildlife
Agency Report
to the
Technical Subcommittee
of the
Canada-United States Groundfish Committee

April 2020

Prepared by

John Budrick
Andre Klein
Traci Larinto
Melissa Mandrup
Melanie Parker
Michael Prall
Travis Tanaka
Amanda VanDiggelen

Contents

I. Agency Overview

Within the California Department of Fish and Wildlife (CDFW), the Marine Region is responsible for protecting and managing California's marine resources under the authority of laws and regulations created by the State Legislature, the California Fish and Game Commission (CFGC) and the Pacific Fishery Management Council (PFMC). The Marine Region is unique in the CDFW because of its dual responsibility for both policy and operational issues within the State's marine jurisdiction (0 – 3 miles). It was created to improve marine resources management by incorporating fisheries and habitat programs, environmental review and water quality monitoring into a single organizational unit. In addition, it was specifically designed to be more effective, inclusive, comprehensive and collaborative in marine management activities.

The Marine Region has adopted a management approach that takes a broad perspective relative to resource issues and problems. This ecosystem approach considers the values of entire biological communities and habitats, as well as the needs of the public, while ensuring a healthy marine environment. The Marine Region employs approximately 140 permanent and 100 seasonal staff that provide technical expertise and policy recommendations to the CDFW, CFGC, PFMC, and other agencies or entities involved with the management, protection, and utilization of finfish, shellfish, invertebrates, and plants in California's ocean waters. Groundfish project staff are tasked with managing groundfish and providing policy recommendations to the CDFW, CFGC, and PFMC. Other staff work indirectly on groundfish, such as our California Recreational Fisheries Survey staff that sample our recreational fisheries and our Marine Protected Areas Project and their remotely operated vehicle (ROV) work that benefits groundfish. Additionally, Pacific States Marine Fisheries Commission (PSMFC) staff sample the state's commercial groundfish fishery. The Marine Region's annual Year in Review provides summary of all its programs, including groundfish.

Contributed by Traci Larinto (Traci.Larinto@wildlife.ca.gov)

II. Surveys

ROV Visual Survey and Analysis for MPA and Fishery Data Needs

Scientists from CDFW's Groundfish and MPA Management Projects continued analysis of ROV survey data collected from 2014 to 2016 to develop methods for estimating fish density and total expanded biomass for select species using design and model-based approaches. In January 2020, these methods were evaluated for use in stock assessments by the PFMC's Scientific and Statistical Committee (SSC). An evaluation of the methods was performed by a committee formed by the SSC and two independent reviewers from the Center of Independent Experts. In February, the reviewers met in person and received presentations from CDFW. In addition, ROV methods developed by the Oregon Department of Fish and Wildlife were evaluated and presented in parallel with CDFW's. The proceedings of the evaluations is being prepared for approval by the full SSC at the June 2020 PFMC meeting.

Preliminary results of modeling Gopher Rockfish (*Sebastes carnatus*) as a test case, indicate that depth, latitude and seafloor terrain attributes provide a suitable model fit. Seafloor mapping data was used as a basis for expansion of modeled Gopher Rockfish abundance and biomass. The estimates derived from the model-based approach are comparable to design-based estimates derived from the same data. Following full SSC approval, CDFW will develop similar models with the 2014-2016 statewide survey data to inform upcoming stock assessments of Brown, Copper and Vermilion rockfish in 2021. ROV data collected in 2020 and 2021, as part of long-term MPA monitoring, will also be incorporated into the models where feasible. The projected estimates of density and biomass from these models may also be used to measure MPA performance. Future surveys may provide a time series to examine long term trends in abundance to inform fishery and MPA management.

Contributed by Michael Prall (michael.prall@wildlife.ca.gov) and John Budrick (John.Budrick@wildlife.ca.gov)

III. Reserves

Marine Protected Areas Research and Monitoring

Completed in 2012, California's marine protected area (MPA) Network spans the entire California Coast including offshore islands and is comprised of 124 MPAs. The Network is adaptively managed through the MPA Management Program, which is comprised of four focal areas: outreach and education, research and monitoring, enforcement and compliance, and policy and permitting.

A key component of the research and monitoring focal area is the Statewide MPA Monitoring Program. The Program takes a two-phased approach to monitoring: Phase 1, regional baseline monitoring, which concluded in 2018, and Phase 2, statewide long-term monitoring, which is ongoing.

To manage Phase 2, the State developed a MPA Monitoring Action Plan, which prioritizes key measures and metrics, habitats, sites, species, human uses, and management questions to target for long-term monitoring. In 2019, seven projects were funded to monitor six habitats and human uses. Monitoring activities will span 2019-2020 and reports will be submitted in 2021.

In 2022, the first comprehensive review of the MPA Management Program including an evaluation of the MPA network performance will take place. Monitoring data from Phase 1 and Phase 2 will analyzed using a before-after, control-impact approach to measure the networks performance since 2012.

In October 2019, the MPAs around the Northern Channel Islands earned the prestigious international Blue Park Award for meeting the highest science-based standards for marine life protection and management. The Northern Channel Islands are some of the oldest in California's comprehensive statewide network.

To receive updates about the MPA Management Program, click here; archived MPA stories are available here.

Contributed by Amanda Van Diggelen (Amanda.VanDiggelen@wildlife.ca.gov)

IV. Review of Agency Groundfish Research, Assessment and Management

A. Hagfish

There are two species of hagfish that reside off California, Pacific Hagfish (*Eptatretus stoutii*) and Black Hagfish (*E. deani*). Of the two, the Pacific Hagfish (hagfish) is the preferred species for California's primarily export-only fishery. Using traps, fishermen land hagfish in live condition. The hagfish are usually maintained dockside until packaged for live export to South Korea where they are sold live for human food. Considered scavengers, hagfish are found over deep, muddy habitat.

1. Assessment
Little is known about the status or biomass of hagfish stocks. Since 2007, CDFW's Northern and Central California Finfish Research and Management Project has been monitoring the fishery and documenting changes in the average weight and spawning status of landed hagfish through dockside sampling. Sampling activity began with the emergence of the fishery in Moss Landing (2007), ending there in 2008 due to market changes, occurred in southern California from 2009 to 2011, and began in Morro Bay in 2010 and Eureka in 2012. The Moss Landing fishery reemerged in 2016 with one vessel making landings of hagfish taken with barrel traps, and sampling resumed. Due to the physical impossibility of accurately measuring hagfish in a live condition, staff employs a count-per-pound method to monitor changes in average weight of retained hagfish. Randomly selected hagfish from sampled landings are examined to determine spawning status by sex and length frequency. For the period of 2010-2018, landings have fluctuated between 360 and 976 metric tons (0.8 and 2.1 million pounds) annually with an average of 688 mt (1.5 million pounds). The annual ex-vessel value for this period ranged from $565,000 to $1.84 million with an average of $1.21 million. In 2019 there were 576 metric tons (1.3 million pounds) landed with an ex-vessel value of $1.10 million. Fishing effort and export demand is market driven by the South Korean economy and fishing activities of Washington and Oregon fishermen. California fishermen fishing effort can be influenced by the price and availably of bait, fuel costs, and other fisheries that may be available to hagfish fishermen.

2. Management
The commercial hagfish fishery is open access; only a commercial fishing license and a general trap permit are required. Hagfish may be taken in 19-liter (5-gallon) bucket traps, Korean traps, or barrel traps with dimensions up to 1.14 m (45 in.) long and 0.64 m (25 in.) outside diameter. The maximum number of traps allowed per vessel is 200 bucket, 500 Korean, or 25 barrel traps. Fishermen must choose one trap type and may not combine hagfish trap types or have non-hagfish traps onboard when fishing with a chosen hagfish trap. To assist in enforcing vessel trap limits, the vessel commercial registration number must be on the trap buoy. There is no limit on the number

of groundlines for bucket or Korean traps; however, barrel traps may be attached to no more than three groundlines. All traps must have a CDFW approved destructive device and all holes, except for the entrance, in any hagfish trap must have a minimum diameter of 14.2 millimeters (9/16 in.). When in possession of hagfish, no other finfish species may be possessed on board. Currently logbooks are not required for this fishery. There are no annual quotas or minimum size limits.

Contributed by Travis Tanaka (Travis.Tanaka@wildlife.ca.gov)

B. Groundfish, all species combined

1. Research off California
Scientific Collecting Permits are issued by CDFW to take, collect, capture, mark, or salvage, for scientific, educational, and non-commercial propagation purposes. Permits are generally issued for three years, except that student permits are for one year. While a complete report of groundfish-related research activities isn't available for this report, the permits fall into four broad categories: 1) public display in aquariums and interpretive centers; 2) environmental monitoring; 3) life history studies that include age and growth, hormone assays and genetics for population structure; and, 4) studies related to changing environmental conditions such as ocean acidification and hypoxia.

   Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

2. CDFW Research
In 2019, Marine Region continued its ongoing research on Yelloweye Rockfish (*Sebastes ruberrimus*). The population off the West Coast was designated as an overfished stock in the early 2000s. Commercial and recreational regulations were implemented to minimize gear interactions in combination with a prohibition on retention (or limited retention in designated fishing sectors) and area closures. As a result, there has been limited opportunity to collect biological information for studying age and growth parameters that are crucial components of stock assessment modeling.

   In coordination with the California Recreational Fisheries Survey Program (CRFS) CDFW collected 75 Yelloweye Rockfish from the recreational fishing sector in 2019. Length, weight, sex, and otoliths were collected from specimens. Fish ranged in length from 188-585 mm in total length (7.4-23.0 in.), and were approximately 45 percent male, 52 percent female, and 3 percent unknown. Data from these fish will be used to inform future stock assessments on Yelloweye Rockfish.

   CDFW continued its statewide collection of carcasses of Lingcod (*Ophiodon elongatus*) along with several recreationally important species of rockfish during 2019 to inform upcoming stock assessments for those species. Carcasses were primarily collected from Commercial Passenger Fishing Vessels (CPFVs) after the fish had been filleted by deckhands. The carcasses were returned to CDFW offices where length, sex and otoliths were collected. Over 50 Lingcod carcasses and 800 rockfish carcasses were collected in 2019. Collection activities will continue in 2020.

Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

3. Yellowtail Rockfish
Starting in 2013, the PFMC recommended issuance of an Exempted Fishing Permit (EFP) to commercial fishermen to study a method of commercial jig fishing to determine whether it is possible to target Yellowtail Rockfish (*Sebastes flavidus*) inside the Rockfish Conservation Areas (RCA) while avoiding overfished rockfish species (e.g. Canary (*S. pinniger*), Yelloweye, and Bocaccio rockfishes (*S. paucispinis*)). The goal of this study is to determine if targeting species in the midwater column can provide additional fishing opportunities for the commercial fishery in the RCAs while avoiding overfished stocks that are more likely to reside on the bottom. Data from trips taken between 2013 and 2019 indicate that the gear is successfully targeting healthy stocks such as Yellowtail and Widow (*S. entomelas*) rockfishes, and now Canary Rockfish, while avoiding overfished species. Canary Rockfish and Bocaccio have since been rebuild, Canary rockfish in 2016 and Bocaccio in 2019, and are currently allowed to be retained and sold under this EFP. Prior to the rebuilding of Canary Rockfish and Bocaccio catch of these species was minimal, and catch of Yelloweye Rockfish continues to be minimal.

   In 2015, the geographic extent of the EFP was expanded to Point Conception and additional vessels were added to allow for additional data collection in more southerly areas. In 2019, the PFMC recommended this item be considered for future regulation implementation.

   Contributed by Melissa Mandrup (Melissa.Mandrup@wildlife.ca.gov)

3. Assessment
The CDFW did not independently conduct any stock assessments in 2019 for groundfish species but did contribute to STAT teams for Gopher/Black-and-Yellow Rockfish (*Sebastes chrysomelas*) complex and for Cowcod (*S. levis*). CDFW was involved in the formal STAR panel review process of several full stock assessments conducted in 2019, including Cowcod, Gopher/Black-and-Yellow Rockfish complex, Sablefish (*Anoplopoma fimbria*), cabezon (Scorpaenichthys mamoratus), and Big (*Raja binoculata*) and Longnose Skate (*R. inornata*). The new stock assessment for Cowcod determined that the stock has rebuilt however, the new stock assessment is highly uncertain, and the stock had been overfished for two decades according to the previous four prior assessments.

   Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

4. Management

Groundfish management is a complex issue and is conducted by the PFMC with input by CDFW as well as the states of Oregon and Washington and the treaty tribes, and guided by the federal Pacific Coast Groundfish Fishery Management Plan. With the exception of some nearshore species, harvest guidelines, fishery sector allocations, commercial trip limits and recreational management measures (e.g., bag limits, season limits, RCAs) are recommended by the PFMC and implemented by National Marine Fisheries Service (NMFS).

5. Commercial Fishery Monitoring

CDFW has collected commercial fisheries statistics since 1916 using paper fish tickets. Beginning July 1, 2019, CDFW began requiring the submission of electronic fish tickets via PSMFC's E-Tix system instead of the paper fish tickets. Once landed an electronic fish ticket needs to be completed immediately. If that is not possible, a paper dock ticket must be completed and the electronic fish ticket submitted within 3 business days. Federal electronic reporting requirements for various fisheries, including 24-hour submission, still apply.

Statistical and biological data from landings are continually collected and routinely analyzed by CDFW staff to provide current information on groundfish fisheries and the status of the stocks. California's primary commercial landings database is housed in CDFW's Marine Landings Database System (MLDS). Outside funding also enables California fishery data to be routinely incorporated into regional databases such as Pacific Coast Fisheries Information Network.

Commercial sampling is conducted by PSMFC staff and occurs at local fish markets where samplers determine species composition of the different market categories, measure and weigh fish and take otoliths for future ageing. Market categories listed on the landing receipt may be single species (e.g., Bocaccio), or species groups (e.g., group shelf rockfish). Samplers need to determine the species composition so that landings of market categories can be split into individual species for management purposes. Biological data are collected for use in stock assessments and for data analyses to inform management decisions.

Inseason monitoring of California commercial species landings is conducted by CDFW biologists. This work is done in conjunction with inseason monitoring, management and regulatory tasks conducted by the PFMC's Groundfish Management Team.

In addition to the standardized commercial sampling conducted by PSMFC, CDFW conducted a biological sampling project obtaining commercially landed fish from February through June 2019. CDFW staff, in consultation with NMFS stock assessors, prioritized species based on those identified as potential stock assessment candidates in the near term that would benefit from additional data collection. In addition to age structures, data collected included port of landing, gear type, length, weight, sex, and maturity.

Random sampling protocols were developed to reduce bias in the age data, and samples were stratified geographically across the state. Over 2,000 samples from 14 different species were obtained in port complexes from Crescent City to Santa Barbara, with the majority coming from Morro Bay. Most samples were landed utilizing hook-and-line gear, though some trawl caught samples were also obtained.

Contributed by Andre Klein (Andrew.Klein@wildlife.ca.gov) and Traci Larinto (Traci.Larinto@wildlife.ca.gov

6. Recreational Fishery Monitoring
   CDFW conducts weekly recreational fishery monitoring for several species of concern, including Yelloweye Rockfish, Cowcod, Canary Rockfish, and Black Rockfish (*Sebastes melanops*). To track catches inseason, CDFW generated an Anticipated Catch Value by using sample information directly from CRFS weekly field reports to approximate interim catch during the six-week time lag until monthly CRFS catch estimates are available. Recreational regulations in 2019 differed slightly from those in place in 2018. Relaxed depth restrictions in the Southern Management Area and the Cowcod Conservation area increased fishing depth from 110 to 137 m (60 fm to 75 fm) and from 36 to 73 m (20 fm to 40 fm), respectively. The season for California scorpionfish (*Scorpaena guttata*) also returned to a year-round fishery in the Southern Management Area which opened on March 1 for all other boat-based groundfish species. Inseason increases to the Canary Rockfish sub-bag limit from two to three fish, Black Rockfish sub-bag limit increases from three to four fish, and Lingcod bag limit increases in all management areas south of Cape Mendocino (40° 10' N. lat.) from one to two fish also occurred, and were effective June 1, 2019.

   Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

C. Pacific Halibut & International Pacific Halibut Commission activities

1. Research and Assessment
   Research and assessment activities for Pacific Halibut (*Hippoglossus stenolepis*) off the coast of California are conducted by the International Pacific Halibut Commission (IPHC). During 2019 CDFW staff conducted biological field sampling of commercial fishery catches on behalf of the IPHC.

2. Management
   The CDFW collaboratively manages the Pacific Halibut resource off the coast of California with the IPHC, NMFS, PFMC, other west coast states, and the CFGC. Pacific Halibut management activities occur on an annual timeline, with most changes to management occurring through the PFMC's Catch Sharing Plan and federal regulations published by NMFS. Changes to the Catch Sharing Plan for the following year are approved in November by the PFMC.

In 2018, new regulations allowed for CDFW to conform state regulations to federal regulations for the recreational fishery by notifying constituents within 10 days of publication of the regulations in the Federal Register. Notification is done via press release and the CFGC is notified of the action at their next scheduled meeting. Previously, a full CFGC rulemaking was required to conform state regulations to federal.

3. Commercial Fishery Monitoring
   The directed commercial fishery for Pacific Halibut is managed under a coastwide (WA, OR and CA) quota and operates as a derby fishery. The fishery opened on June 26 and is structured based on 10-hour openers that are spaced two weeks apart. The fishery operates on this schedule until the coastwide quota has been met, which usually allows for two to three fishery openings per year. California effort in this fishery continued in 2019 with nine vessels participating in the fishery; landings totaled 4,620 dressed kilograms (10,186 dressed pounds).

4. Recreational Fishery Monitoring
   The recreational Pacific halibut fishery was scheduled to be open May 1 through October 31, or until the quota was met, whichever was earlier.

   To track Pacific halibut catch, CDFW generated an interim preliminary projected catch value using sample information directly from CRFS weekly field reports to approximate catch during the lag time until monthly CRFS catch estimates are available. This information was made available online so the public could track the progress of the fishery. Final season catch estimates were 17,440 net pounds (7,919 net kilograms), 45 percent of the 39,000 net pound (17,690 net kilogram) quota.

   Contributed by Melanie Parker (Melanie.Parker@wildlife.ca.gov)

V. Publications

Budrick, J, Ryley, L, Prall, M. 2020. Methods for using remotely operated vehicle survey data in assessment of nearshore groundfish stocks along the California coast. 89 p. Available at: ftp://ftp.pcouncil.org/pub/2019%20Nearshore%20ROV%20Surveys%20Methodology%20Review/CA%20Survey/.

April 2020

OREGON'S GROUNDFISH INVESTIGATIONS IN 2019

Marine Resources Program
Oregon Department of Fish and Wildlife

2040 SE Marine Science Drive
Newport, OR 97365
(541) 867-4741

April 2020

OREGON'S GROUNDFISH INVESTIGATIONS IN 2019

OREGON DEPARTMENT OF FISH AND WILDLIFE
2020 AGENCY REPORT

Edited by: Alison Whitman

Contributing Authors:
L. Aylesworth, T. Buell, C. Don, C. Heath, G. Krutzikowsky, S. Malvitch, S. Marion, L. Mattes, P. Mirick, L. Rasmuson, B. Rodomsky, C. Sharpe, M. Sommer, M. Terwilliger, and A. Whitman

Marine Resources Program
Oregon Department of Fish and Wildlife
2040 SE Marine Science Drive
Newport, OR 97365
(541) 867-4741

Agency Overview

MRP Program Manager:	*Dr. Caren Braby*
Resource Management and Assessment:	*Dave Fox*
Fishery Management:	*Maggie Sommer*
Technical and Data Services:	*Justin Ainsworth*

The Oregon Department of Fish and Wildlife's Marine Resources Program (MRP) is responsible for assessing, monitoring, and managing Oregon's marine habitat, biological resources, and fisheries. The MRP's main office is located at the Hatfield Marine Science Center in Newport, OR and includes two additional offices in Newport. There are also field stations in Astoria, Charleston, Brookings, and Corvallis. The MRP has primary jurisdiction over fisheries in state waters (from shore to three miles seaward), and participates in regional and international fishery management bodies including the Pacific Fishery Management Council, the International Pacific Halibut Commission, and the North Pacific Fishery Management Council. Management strategies developed at all levels affect Oregon fish and shellfish stocks, fisheries, resource users, and coastal communities. Staffing consists of approximately 60 permanent and more than 60 seasonal or temporary positions. The current annual program budget is approximately $9 million, with about 76% coming from state funds including sport license fees, commercial fish license and landing fees, and a small amount of state general fund. Grants from federal agencies and non-profit organizations account for approximately 24% of the annual program budget.

ODFW staff place rockfish with barotrauma in a recompression cage during an at-sea survey.

Contents

Surveys

Recreational Fisheries Monitoring and Sampling

Sampling of the ocean boat sport fishery by MRP's Ocean Recreational Boat Survey (ORBS) continued in 2019. Starting in November 2005, major ports were sampled year-round and minor ports for peak summer-fall season. We continue to estimate catch during un-sampled time periods in minor ports based on the relationship of effort and catch relative to major ports observed during summer-fall periods when all ports are sampled. Lingcod (*Ophiodon elongatus*), multiple rockfish species (*Sebastes* spp.), cabezon (*Scorpaenichthys marmoratus*) and kelp greenling (*Hexagrammos decagrammus*) are the most commonly landed species.

The ORBS program continued collecting information on species composition, length and weight of landed groundfish species at Oregon coastal ports during 2019. Since 2003, as part of a related marine fish ageing research project, lingcod fin rays and otoliths from several species of nearshore groundfish, including rockfish species, kelp greenling and cabezon, were gathered. Starting in 2001, a portion of sport charter vessels were sampled using ride-along observers for species composition, discard rates and sizes, location, depth and catch per angler. Beginning in 2003, the recreational harvest of several groundfish species is monitored inseason for catch limit tracking purposes.

Other ODFW management activities in 2019 include participation in the U.S. West Coast Recreational Fish International Network (RecFIN) process, data analysis, public outreach and education, and public input processes to discuss changes to the management of groundfish and Pacific halibut fisheries for 2020.

Contact: Lynn Mattes (lynn.mattes@state.or.us), Christian Heath (Christian.t.heath@state.or.us)

Commercial Fisheries Monitoring and Sampling

Commercial fisheries monitoring data from commercial groundfish landings are collected throughout the year and analyzed by ODFW to provide current information on groundfish fisheries and the status of the stocks off Oregon’s coast. This information contributes to fisheries management decisions, stock assessments, in-season adjustments to nearshore fisheries, and economic analyses.

Commercial fishery data, including logbooks, fish tickets, and biological data, are uploaded to the Pacific Fisheries Information Network (PacFIN) on a regular basis and are used for in-season monitoring and as a primary commercial data source for federal stock assessment. In 2019, preparations continued to add fixed gear fishery logbooks to the PacFIN database. Species composition sampling of rockfish and biological sampling of commercially landed groundfish continued in 2019 for commercial trawl, fixed gear, and hook and line landings. The majority of the landings were monitored at the ports of Astoria, Newport, Charleston, Port Orford and Brookings, with additional sampling occurring routinely at Garibaldi, Pacific City, Depoe Bay, Bandon, and Gold Beach. Biological data including length, weight, age (from collected age structures: otoliths, vertebrae, and fin rays), sex, and maturational status continued to be collected from landings of major commercial groundfish species.

Contact: Cameron Sharpe (Cameron.S.Sharpe@state.or.us), Scott Malvitch (Scott.Malvitch@state.or.us)

Marine Reserves

The ODFW Marine Reserves Program is responsible for overseeing the management and scientific monitoring of Oregon's five marine reserve sites. These sites, from north to south, include: Cape Falcon, Cascade Head, Otter Rock, Cape Perpetua and Redfish Rocks. Reserves are a combination of marine reserves (no fishing) and marine protected areas (some types of fishing activities allowed), as determined by public process. Each reserve has distinct habitat and biological characteristics, and as such, requires site-specific monitoring and research planning. This section presents an update on management and ecological monitoring and research activities from 2019. More information is available on the Oregon Marine Reserves website at http://oregonmarinereserves.com/

Management

Nothing new to report for 2019.

Monitoring

Ecological Monitoring was conducted at five marine reserve sites this past year. Monitoring included sampling with core tools (ODFW-led) and through collaborative activities. Sampling was conducted both in the reserves and in comparison areas outside of the reserves still open to fishing. Sampling with core survey tools conducted this year as part of on-going monitoring included:

- Hook and Line Surveys
- Scuba Surveys
- Video Lander Surveys
- ROV surveys

Sampling through collaborative activities included:

- Oceanographic surveys (PISCO-Oregon State University and ODFW)
- Juvenile fish recruitment surveys (led by Oregon State University)
- Intertidal biodiversity surveys (led by UC Santa Cruz and Multi-Agency-Rocky-Intertidal-Network)
- Sea star wasting disease recovery monitoring in rocky intertidal areas (ODFW, Oregon State University)
- Urchin Surveys (led by ODFW South Coast Shellfish Team)

- Ocean acidification monitoring in rocky intertidal areas (led by PISCO-Oregon State University)
- Microplastic research in black rockfish (led by Oregon State University)

Contact: Cristen Don (cristen.n.don@state.or.us), Lindsay Aylesworth (Lindsay.X.Aylesworth@state.or.us)

Research

A new pilot study began in 2019 to study the diversity of small, cryptic invertebrates with autonomous reef monitoring structures (ARMS). Researchers all around the world – from the Arctic to Antarctica, are setting out ARMS as a standardized way to quantify biodiversity. These invertebrate condos are set out on the ocean floor and consist of 8 PVC plates stacked on top of each other, providing multiple levels for small invertebrates to grow or hide. In Oregon, ARMS were deployed at the Otter Rock Marine Reserve and its comparison area off Cape Foulweather. Invertebrates will settle onto the plates for two years, when researchers will then return and collect the ARMS units for organism identification and processing. When the ARMS are retrieved, species will be documented, identified and then genetic sampling will be conducted. This will be a collaborative effort by the ODFW Marine Reserves Program and researchers at the University of Oregon, Oregon State University, and NOAA Northwest Fisheries Science Center.

REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENT AND MANAGEMENT

Hagfish

Management

The commercial hagfish fishery operates year-round. Two types of trap gear are typically used by the hagfish fleet, a 55-gallon drum and five-gallon bucket. Each of these contains escape holes to increase the size selectivity of the commercial fishery. Commercial hagfish landings in 2019 were 1,587,585 pounds, or 99.2% of state Harvest Guideline (HG) of 1.6 million pounds. No major hagfish management actions were taken by ODFW in 2019.

Contact: Troy Buell (Troy.V.Buell@state.or.us), Brett Rodomsky (brett.t.rodomsky@state.or.us)

Dogfish and Other Sharks

Nothing to report.

Skates

Research
In 2019, the ODFW developed a comprehensive commercial skate catch reconstruction to cover the years 1978 – 2018. This reconstruction covers all observed skate species in Oregon, but primarily longnose and big skates. Unfortunately, skate speciation was inconsistent over time, and therefore, three time periods (1978 – 2008, 2009 – 2014 and 2015 – 2018) were created to apply species compositions to. Species compositions were applied at the time period, gear, PFMC area, and market category level. This methodology was reviewed at a pre-assessment workshop in March 2019.

The majority of landings occurred in the trawl and longline gear categories, and over 99% of all landings were from longnose or big skates. A depth-based approach was necessary in the application of species compositions in the mid-water trawl category, and this remains a source of uncertainty in the reconstruction. Estimated species-specific landings are available upon request from ODFW currently, but will be incorporated into PacFIN eventually.

Contact: Ted Calavan (ted.r.calavan@state.or.us), Cameron Sharpe (Cameron.S.Sharpe@state.or.us)

Assessment
ODFW staff provided data for the longnose and big skate federal stock assessments in 2019. These data include the reconstructed commercial landings (described above) and the enhanced data collection program (EDCP) data at the haul level to aid with estimating discards of skates. Staff also participated in a pre-assessment workshop that reviewed the skate commercial reconstruction in detail but also reviewed the other federal stock assessments for the 2019 cycle.

Contact: Alison Whitman (alison.d.whitman@state.or.us)

Pacific Cod
Nothing to report.

Walleye Pollock
Nothing to report.

Pacific Whiting
Management
The US (and Canadian) whiting TAC and catch continues to be near record high levels. Reducing bycatch of Chinook salmon in whiting and other groundfish fisheries has been a recent focus at the Pacific Fishery Management Council. The Council adopted salmon hard caps and new mitigation tools (e.g., area closures) to prevent the caps from being exceeded. The whiting industry has also made voluntary avoidance a top priority by avoiding hotspots and using salmon excluders. Documentation of avoidance measures by the whiting cooperatives in Salmon Mitigation Plans approved by the National Marine Fisheries.

Service is expected to help minimize Chinook salmon bycatch and support the effective use of these measures in the cooperatives' own real-time operations.

The Council also removed hard caps for rockfish bycatch in the at-sea whiting processing sectors and is now using set-asides, or "soft cap" allocations. This switch reflects the rebuilt status and increasing abundance of these rockfish stocks. For each of several rockfish stocks, the Council has attempted to find a balance of set-asides high enough to allow the fleet to efficiently catch whiting, but low enough to avoid unnecessarily reducing the shore-side trawl sector allocations for these target stocks.

Contact: Patrick Mirick (patrick.p.mirick@state.or.us), Maggie Sommer (maggie.sommer@state.or.us)

Grenadiers

Nothing to report.

Rockfish

Research

Depth-associated variability of Deacon Rockfish (*Sebastes diaconus*) age, growth and maturity parameters in Oregon waters and their effect on stock status. In review.

The goals of this study were to understand how age, growth and maturity parameters vary with sex and depth in the Deacon Rockfish. As efforts were made to sample a variety of size classes, from both the nearshore and offshore, we also assessed how age composition differed between the two areas and determined what the implications of these differences would be on the reproductive output of the population. Finally, we incorporated the results of this study into the most recent Deacon Rockfish stock assessment and evaluated how altering life history parameters influenced the stock status.

Deacon rockfish were collected nearly monthly at offshore and nearshore sites during favorable weather periods out of Newport, Oregon. Samples were collected on 12/13/16, 02/22/17, 3/20/17, 4/21/17, 5/30/17, 5/31/17, 7/5/17, 8/8/17, 8/16/17, 10/04/17, 10/05/17, and 11/06/17. The offshore study area was Stonewall Bank and the surrounding area out to 146 m of water depth. The nearshore study areas included Seal Rock and Siletz reefs. Recreational hook and line gear was used for all collections. Terminal gear included a variety of plastic baits, small to medium sized flies and Sabiki rigs (herring jigs). Prior efforts to collect small Deacon and Blue Rockfish in nearshore waters off Oregon have shown that Sabiki rigs are capable of capturing Deacon Rockfish from adult sizes down to as small as ~8 cm, help-ing to offset gear-related bias in size-selectivity of typical hook and line fishing gear. Ap-proximately 50 Deacon Rockfish were collected per reef area per sampling day. Fish were measured (cm, fork length) and sexed and otoliths collected for age determination. Ovaries and testes were be examined and assigned a maturity stage. For females, a small section of ovary from fish in stages 1, 2, 3, 6 and 7 were collected and placed in cassettes for histological preparation and microscopic evaluation of maturity. Ovary samples were preserved in 10% buffered formalin and later transferred to 70% ethanol for storage. Ages were determined using the break and burn technique applied to sagittal otoliths) or a variation of the technique in which sagittal otoliths are broken and "baked" for several minutes prior to age determination. For all fish 21 cm or shorter, a caudal fin snip was taken and stored in 100% ethanol (molecular grade) for DNA analysis to confirm species identification.

Our primary goal was to better understand how age, growth and maturity parameters differed between Deacon Rockfish that resided in nearshore and offshore waters off central Oregon. Our study suggests that age and growth parameters do differ by both area and sex but, not surprisingly, sex was a more influential factor than area. We were unable to compare nearshore and offshore age and length at 50% maturity due to the small number of immature females collected offshore. We did find that age and length at 50% maturity values were similar between the nearshore and when we combined the nearshore and offshore samples. However, based on larger lengths of offshore females, our work suggests that a significant component of the total reproductive output in Oregon may come from offshore. It is worth noting that this is based on the assumption that the number of females in the nearshore and offshore are equal.

Although our best fit von Bertalanffy model included both sex and area, the effect of area on the parameter estimates was relatively minimal. Primarily, growth rate (k) differed with males in the nearshore growing faster than males in the offshore whereas females in the offshore grew faster than females in the nearshore. Regardless of area, male growth rate was faster than for females. The larger offshore individuals (both male and female) had a more diverse distribution of ages than individuals of the same size class in the nearshore. The offshore individuals we sampled stopped experiencing fishing pressure in 2007 due to the establishment of the Stonewall Yelloweye Rockfish Conservation Area. In the 10 years since its closure, the offshore fish have experienced essentially no fishing pressure allowing larger individuals to obtain older ages than normally occurs for populations experiencing fishing pressure. However, the >10-year age difference suggests that while the complexity of offshore age structure has increased due to the lack of fishing pressure, there were, prior to closure, likely more, older fish offshore. It is worth noting when the offshore re-opens to fishing these larger older individuals are likely to be removed from the population. Although most of the offshore individuals were large mature females, we did capture young-of-the-year individuals. This finding is important because regional knowledge suggests Deacon Rockfish only settle in the nearshore and exhibit an ontogenetic migration from the nearshore to the offshore. Our finding may indicate that there is less movement of individuals between the nearshore and offshore than previously hypothesized.

Re-running the most recent stock assessment and forcing it to use some of the different growth and maturity parameters influences the spawning stock biomass trajectory and estimates of stock status, but all of the estimates were within the range of uncertainty estimated with the base Oregon Blue/Deacon stock assessment model. Although all of these runs were within the range of uncertainty, the stock trends were effectively the same regardless of where the parameter estimates were obtained from, except for the estimates from California, which caused dramatic differences in the stock trend. Incorporating spatiotemporal variability of growth data into stock assessments is increasingly being shown to have profound impacts of stock trajectory and status. As such, for nearshore stocks that are relatively data poor and rely on each individual state to collect their own data, it is important that growth function parameters be estimated (at a minimal) for each state (using locally obtained data) and the relative effect of spatial dynamics are considered. Further, although spatial variation on growth function parameter estimates are often shown to vary with latitude, few studies consider the effects of cross-shelf variability in growth functions. We argue that cross-shelf variability is important to consider as circulation changes dramatically as you move across the shelf and ultimately these differences may affect both growth rates of adults and the dispersal of their larvae.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Sex matters: Otolith shape and genomic variation in deacon rockfish (*Sebastes diaconus*).

Little is known about intraspecific variation within the Deacon Rockfish (*Sebastes diaconus*), a recently described species found off the West Coast of North America. We used an interdisciplinary approach to test for population structure among fish sampled at two nearshore reefs (Siletz Reef and Seal Rock) and one offshore area (Stonewall Bank) off the Oregon coast. We found that fish sampled from the three sample sites are differentiable based on otolith shape and genetic variation whether analyzed independently or classified into nearshore and offshore groups. We also identified 92 outlier loci that distinguish males and females, potentially representing sex-linked, putatively adaptive variation. Although sex-linked genetic variation did not appear to affect geographic comparisons, males and females were readily distinguished. Morphometric results indicated that there was significant secondary sexual dimorphism in otolith shape, but further sampling is required to disentangle potential confounding influence of age-structure. We found small but statistically signif-icant otolith shape and genetic differences among Deacon Rockfish sampled off the Oregon coast, regardless of whether the three sample sites were analyzed independently or organized into nearshore (Siletz Reef, Seal Rock) and offshore groups (Stonewall Bank). Although differentiation was low, the fact that we detected statistically significant otolith shape and genotypic differences over such a small geographic scale (<50 km^2) is remarkable in itself. Furthermore, both morphometric and genetic results were comparable to findings from other marine fishes sampled over larger geographic distances.

Sex mattered in our otolith shape and genetic analyses. We found evidence for secondary sexual dimorphism in otolith shape. This result may reflect differences in the growth and lifespan of males and females, and further research is required to disentangle these poten-tial effects among the sample sites. We identified 92 outlier loci that are likely sex-linked sites in Deacon Rockfish, and males and females exhibited statistically significant neutral and putatively adaptive genetic differences. Our otolith shape and genetic results do not provide strong evidence for two potential fish stocks of Deacon Rockfish in the nearshore and offshore. Although morphological and genetic differences were statistically significant, values were low and there was considerable overlap among specimens, and comparisons analyzing the three sample sites independently demonstrated similar results. Stock assessments using similar methods have relied upon stronger patterns in results in order to delineate a stock boundary.

This study provides a first step towards the investigation of intraspecific variation in the recently described Deacon Rockfish species. This study demonstrates the potential of RAD sequencing studies to provide substantial population genetic information for species that have not been previously investigated. Much work is still required to study how the species differs from Blue Rockfish (and other relatives) in biology and management requirements. If future genetic analyses of *Sebastes* want to include the Deacon Rockfish, the sequence data presented here should be compatible with reads from the previous RADseq studies of other rockfish species that also used the *SbfI* restriction enzyme. The SHAPER otolith digitization method easily allows datasets to be combined as well, and therefore both geometric morphometric and genetic data from this study should permit genus-wide studies of rockfish diversity.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Habitat use and activity patterns of Deacon Rockfish (Sebastes diaconus) at seasonal scales and in response to episodic hypoxia. In review.

Knowledge of fish movements and residency are key to design and interpretation of results from bioacoustic sonar and visual survey methods, which are being developed as tools for use in nearshore rocky reef surveys to estimate biomass and species composition. Fishers in Oregon report that an important component of the nearshore catch, Deacon Rockfish (*Sebastes diaconus*), become unavailable to harvest seasonally, and suggest periodic migration away from nearshore reef areas. Seasonal and spatial variation in landings data potentially support this theory. We used a high-resolution acoustic telemetry array and a combination of presence/absence receiver arrays, to study the daily and seasonal movements and the activity patterns of 11 acoustically tagged Deacon Rockfish on a nearshore rocky reef off Seal Rock, Oregon. Over the 11-month study period, most fish (n=6) exhibited high site fidelity. For the duration of the high-resolution array (5 mo), these fish had small home ranges (mean 95% kernel density estimation=4,907 m^2) and consistent activity patterns, except during seasonal hypoxia (defined as dissolved oxygen concentration [DO] < 2 mg l^{-1}). During the summer months, resident fish were strongly diurnal with high levels of daytime activity above the bottom in relatively rugose habitat, followed by nighttime rest periods in deeper water in habitat of relatively less rugosity. During hypoxia, fish exhibited moderate activity levels with no rest periods and moved well away from their core activity areas on long, erratic forays. Wintertime activity levels were moderate with less defined daily patterns, but fish continued to remain within the array area.
Overall, resident Deacon Rockfish displayed high site fidelity and coherence in both seasonal and daily movement patterns, but those consistent patterns were completely altered

during extended hypoxia. High long-term survival and consistently high detection of resident fish over 11 months indicates that at least some Deacon Rockfish do not exhibit a seasonal migration away from nearshore reefs. Food items ingested by sampled Deacon Rockfish during this study included gelatinous zooplankton and small planktonic crustaceans: the colonial tunicate *Pyrosoma atlanticum*, hydrozoan *Velella vellela*, ctenophore *Pleurobrachia bachei*, brachyuran zoeae/megalopae, and pelagic amphipods. We suggest Deacon Rockfish may be resistant to standard fishing techniques due to these strong prey preferences, hook size, and potentially eye and visual abilities which allow both Blue and Deacon Rockfish to see and feed upon very small and/or transparent prey items such as gelatinous zooplankton.

Although our sample size was necessarily small, detection and position data for tagged fish was excellent, a trade-off due to using a high density of receivers and co-located sync tags. Mid-water schooling behavior of this species benefits detection rates, which can be problematic for more benthic rockfish in high relief habitat. The high-resolution inner VPS array, combined with the perimeter fence, and accelerometer/depth sensors in the tags, provided additional certainty about the fate of fish that remained inside or left the array. A larger study in southern Oregon, using similar methods but tagging both Deacon and Blue Rockfish inhabiting the same area, could shed light on differences in the two species' movements in various habitats including offshore reefs, which may act as refuges for older, more fecund fish in Oregon, in unfished rockfish conservation areas.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Sex identification PCR-RFLP assay tested in eight species of *Sebastes* rockfish. In review.

The phenotypic identification of sex in *Sebastes* rockfish is difficult and often impractical from a management perspective, and the genetic basis of sex determination in the genus is currently uncertain. We tested a previously developed sex identification polymerase chain reaction restriction fragment length polymorphism (PCR-RFLP) assay on 8 species of *Sebastes* rockfish. Results indicated that restriction is species dependent rather than sex dependent in most species.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Operationalizing a survey of Oregon's nearshore semi-pelagic rockfish.

A primary challenge for an acoustic-based rocky reef survey is identifying the species composition and size distribution of schools, as species identification of acoustic targets is currently not possible for mixed schools of morphologically-similar rockfish species. Identifying an efficient strategy for quantifying these variables using a suspended pelagic stereo drop-camera was the goal of this proposed work. Acquiring drop-camera footage from as many different schools as possible, containing a diversity of species compositions and size distributions, informed us about the range of school structures and allowed us to evaluate the level of sampling effort needed for future broad-scale surveys.

In the fall of 2017 we established 50 transects off of Newport at Seal Rock reef. These transects were evenly spaced in areas 2 and 3 of the ODFW black rockfish pit tagging project. These transects were established as a test location for conducting a "mock" hydroacoustic survey for nearshore semi-pelagic rockfish. This location presented an ideal test location due to 1) its nearness to the ODFW offices and 2) the presence of robust population estimates for the reef's black rockfish (*Sebastes melanops*) population. Over the course of four days, using a contracted local charter passenger fishing vessel, we collected hydroacoustic data using a Biosonics 200kHz split beam transducer. For each transect we deployed our suspended stereo camera system 3 times on locations with either large schools of rockfish or rocky reef habitat. For each video drop we collected a minimum of 2 minutes of on bottom time (based on preliminary examination of existing data). A total of 70 miles of acoustics data were collected and 140 video drops were conducted.

We determined that the best way to process our video data was to use a mean MaxN approach rather than the common MaxN approach. We also demonstrated that there was no effect on the size of the fish observed with each method. Finally, regardless of the method used, the distribution of fish size classes from the fishing fleet was similar to that observed with the camera. The only notable difference is the camera saw larger and smaller fish than those observed in the hook and line data. Our system also has downward facing camera that allows us to compare the fish counts in the acoustic deadzone to the counts from the forward camera system. Our work suggests that there was no statistical difference in the number of fish in the down camera for black rockfish and that there were significantly more Blue/Deacon rockfish in the forward camera than the down camera. These data provide an initial suggestion that that the acoustic deadzone will be a manageable concern in relation to our data.

To establish how the deployment and retrieval of the BASS camera affects the behavior of semi-demersal rockfish, we spent multiple days this summer deploying the camera system directly below the transducer that was ensonifying a school of fish. We then remained over the camera system while we ensonified the school and as we retrieved the camera system. Our analyses suggest that the deployment of the camera system on the schools of fish does not result in the attraction or repulsion of fish to the school. Finally, using the data we collected in September of 2017 we were able to generate population estimates for Black and Blue/Deacon rockfish at Seal Rock reef. Our work found similar orders of magnitude population sizes of Blacks as those estimated by the pit tagging project.

A statewide survey was planned for September 2019 however problems with contracting resulted in this work not being operationalized. Therefore we are going to operationalize the survey in fall 2020. The hydroacoustic survey will be conducted using evenly spaced transects conducted over the rocky habitat as identified from available GIS layers of nearshore habitat. For each acoustic transect the suspended stereo camera system will be deployed to provide length and species composition estimates. Once collected these data will be used to generate population estimates for Black, Blue and Deacon Rockfish for the state of Oregon using standard acoustic and video analysis methodologies. This project will provide the first fisheries-independent regional population estimates for Black, Blue and Deacon Rockfish in the state of Oregon.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Assessment

Two rockfish were assessed during the 2019 federal stock assessment cycle, including cowcod and a gopher/black-and-yellow complex. ODFW staff contributed commercial landings to these assessments via PacFIN. However, these species are rarely encountered in Oregon.

Contact: Alison Whitman (alison.d.whitman@state.or.us)

Management

Fixed-Gear Nearshore Commercial Fishery

Nearshore rockfish compose the majority of take in the commercial nearshore fishery. In Oregon, this fishery became a limited-entry permit-based program in 2004, following the rapid development of the open access nearshore fishery in the late 1990's. The commercial nearshore fishery exclusively targets groundfish with separate management groups for Black Rockfish, Blue and Deacon Rockfish, Cabezon, Kelp Greenling, and Oregon's "Other Nearshore Rockfish" complex. The fishery is primarily composed of small vessels (25 ft. average) fishing in waters less than 30 fathoms. Fishing occurs mainly with hook and line jig and bottom longline gear types. The majority of active permit holders are located on the southern Oregon coast, resulting in most of the catch landed in Port Orford, Gold Beach and Brookings. Black Rockfish continue to comprise the majority of landings. The fishery supplies mainly live fish markets, but also provides fresh fish products.

Landings are regulated through bimonthly trip limits, minimum size limits, and annual harvest guidelines (HG). Landings from 2018 commercial nearshore fishing, logbook compliance, economic data, and biological data were published in the 2018 Commercial Nearshore Fishery Data Update (Rodomsky *et al*. 2019). Weekly updates on landings and model projections allow MRP staff to effectively manage the fishery in-season. In 2019, in-season increases of 600 pounds were made to each Black Rockfish bimonthly trip limit for periods 4-6 when catch mid-year was low. This was the only Nearshore Rockfish commercial management action in 2019. End of the year attainment of the Black Rockfish state HG was 95.2%, was 97.4% for Other Nearshore Rockfish, and was 39.6% of the Blue and Deacon Rockfish HG.

Contact: Troy Buell (Troy.V.Buell@state.or.us), Brett Rodomsky (brett.t.rodomsky@state.or.us)

Recreational Fishery

Black rockfish (*Sebastes melanops*) remains the dominant species caught in the recreational ocean boat fishery; however the black rockfish harvest limit continues to decrease by 2-5%

due to the most recent stock assessment and applying the time varying sigma to the output of that assessment. With blue and deacon rockfish taken out of the nearshore rockfish complex, the harvest guideline for that complex was greatly reduced. The retention of yelloweye rockfish (*S. ruberrimus*) was prohibited year-round, as it has been since the early 2000s. In order to remain within the yelloweye rockfish impact cap (via discard mortality), the recreational groundfish fishery was restricted pre-season to inside of 40 fathoms from May 1 to September 30, changed to September 3 inseason. Black rockfish and nearshore rockfish species have become as much of a limiting factor as yelloweye rockfish. The fishery season structure and regulations, such as bag limits (species specific sub-bag limits) and depth restrictions, attempted to balance impacts, as what reduces impacts on one species may increase impacts to the other. Even with those efforts the nearshore rockfish complex harvest guideline was reached in mid-August, at which time ODFW required anglers to release those species. 2019 was another high effort year, with just over 100,000 bottomfish angler trips.

Contact: Lynn Mattes (lynn.mattes@state.or.us), Christian Heath (Christian.t.heath@state.or.us)

Outreach

To reduce bycatch mortality of overfished rockfish species in the sport fisheries, ODFW began an outreach campaign in 2013 with the goal of increasing descending device usage among sport anglers. The effort, branded "No Floaters: Release At-Depth", has distributed over 16,000 descending devices to date, to all charter vessel owners and to the majority of sport boat owners who had previously targeted groundfish or halibut. ODFW staff have also participated in a number of angler education workshops, meetings, and shows to educate anglers and distribute devices. In addition, several thousand stickers and a few hundred hats bearing an emblem of the brand have been distributed with the goal of making rockfish conservation an innate aspect of fishing culture. This outreach and education campaign continue to be successful. Prior to the campaign, fewer than 40 percent of anglers reported using descending devices. Since the campaign began, the percentage of anglers reporting use increased to greater than 80 percent. To further increase usage, anglers requested that ODFW make descending devices mandatory for any vessel fishing the ocean for bottomfish or halibut. This regulation went into place beginning January 1, 2017, and increased the angler reported usage rates to approximately 95 percent in most ports and months. Additional outreach efforts include: videos online that show fish successfully swimming away after release with a device, rockfish barotrauma flyers, and videos on how to use the various descending devices. This outreach campaign has been the result of collaboration between ODFW, two angler groups (Oregon Coalition for Educating Anglers and Oregon Angler Research Society), Utah's Hogle Zoo, ODFW's Restoration and Enhancement (R & E) program, and the National Marine Fisheries Service (NMFS) Saltwater Recreational Policy. ODFW staff are planning to continue the outreach and education efforts.

Additionally, ODFW has been educating anglers on a relatively new opportunity to use what is termed "longleader gear" to target underutilized midwater rockfish species such as yellowtail (*S. flavidus*) and widow (*S. entomales*), while avoiding more benthic species such as yelloweye rockfish. The longleader gear requires a minimum of 30 feet between the weight and the lowest hook, along with a non-compressible bloat above the hooks, to keep the line vertical in the water column. ODFW has produced informational handouts with the gear specifics, species allowed, and other associated regulations.

Contact: Lynn Mattes (lynn.mattes@state.or.us), Christian Heath (Christian.t.heath@state.or.us)

Thornyheads

Nothing to report.

Sablefish

Management

Sablefish is the most economically valuable species in the West Coast bottom trawl and fixed gear fisheries. Sablefish prices were depressed due to market saturation before COVID-19, and market perturbations caused by the pandemic are leading to even more disruption. The Pacific Fishery Management Council has focused on two sablefish management topics recently: revising the method used to allocate sablefish quota between two geographic areas on the West Coast (north and south of 36° N latitude), and the ongoing issue of "gear switching", or using non-trawl gear to harvest sablefish in the trawl IFQ fishery. The revised allocation method relies on a rolling average of fishery-independent trawl survey results from more recent years, rather than a long-term historic average. For the 2021-2022 groundfish management biennium, the result is a shift of some quota from the southern area, where it has consistently been underutilized, to the northern area, potentially resulting in increased economic benefits from the west coast sablefish stock. The gear-switching issue arose during the first 5-year review of the trawl IFQ program, and is centered on concerns by trawl fishermen that fixed gear participation has led to higher sablefish quota lease rates and reduced their ability to catch co-occurring stocks. Gear-switching participants are concerned that limits adopted now could undermine significant investments already made to fish in the IFQ fishery with non-trawl gear, under a legal provision of the program. In June 2020, the Pacific Fishery Management Council will receive a report from an ad hoc committee that has been developing several alternatives that would restrict gear switching for the Council's consideration.

Contact: Patrick Mirick (patrick.p.mirick@state.or.us), Maggie Sommer (maggie.sommer@state.or.us)

Assessment

A full age-based stock assessment for sablefish off the U.S. west coast was completed in 2019. ODFW staff contributed data directly to this assessment, including the historical commercial landings (pre-1986), commercial biological samples that included the grade of the landing, ticket-level landings associated with biological samples, and documentation on sablefish sampling practices. ODFW staff also participated in the pre-assessment workshop in March 2019, where all federal assessments were reviewed.

This assessment was unique in that it used an environmental index (sea level) to estimate recruitment deviations. It was found that the results generally matched the signal from age compositions. The assessment showed that the stock had been subject to overfishing in retrospect, which was mainly attributed to quotas that were based on future projections which assumed an average level of recruitment, whereas actual recruitment was lower. However, the stock is now projected to be above the Pacific Fishery Management Council’s target biomass (40 percent of estimated unfished biomass). The Council just adopted a slightly higher fishery exploitation rate due to these positive assessment results.

Contact: Patrick Mirick (patrick.p.mirick@state.or.us), Maggie Sommer (maggie.sommer@state.or.us)

Lingcod

Management

Recreational Fishery

Lingcod (*Ophiodon elongates*) is a popular target in the Oregon recreational bottomfish fishery. Many anglers especially like to target lingcod during the months when the fishery is open to all-depths, as larger lingcod are thought to occur there. Lingcod have their own daily bag limit (2 per angler per day), separate from the other bottomfish. There is also a minimum size limit of 22 inches. In 2019, anglers landed just over 50,000 lingcod, totaling 152 mt.

Contact: Lynn Mattes (lynn.mattes@state.or.us), Christian Heath (Christian.t.heath@state.or.us)

Atka Mackerel

Nothing to report.

Pacific Halibut

Management

Oregon's recreational fishery for Pacific halibut continues to be a popular, high profile fishery requiring International Pacific Halibut Commission (IPHC), federal, and state technical and management considerations. In 2019, the recommended an annual catch limit for Area 2A (Oregon, Washington, and California) was 1.5 million pounds which the IPHC Commissioners indicated would be in place for four years, until 2022. The recreational fishery for Pacific halibut is managed under three subareas with a combination of all-depth and nearshore quotas. In 2019, the Columbia River subarea quota was 15,127 pounds, the Central coast subarea quota was 271,592 pounds, and the Southern coast subarea quota, was 11,322 pounds. Landings in the sport Pacific halibut fisheries are monitored weekly for tracking landings versus catch limits. The majority of halibut continue to be landed in the central coast subarea, with the greatest landings in Newport followed by Garibaldi or Pacific City. Total 2019 recreational landings in the Central coast subarea was 116,982 pounds, 3 percent of the quota. Landings in the Southern subarea were 7,350 pounds (65% of the quota) and in the Columbia River subarea, landings were 17,258 pounds (114 %). Fishing in the Central Coast Subarea was severely restricted by weather for much of May, June, and August. This is the reason for the low attainment of the allocation. The Columbia River Subarea was allowed to exceed the allocation due to additional quota being available from other Washington subareas.

Contact: Lynn Mattes (lynn.mattes@state.or.us), Christian Heath (Christian.t.heath@state.or.us)

Other Groundfish

Kelp Greenling

Management – Commercial Fishery

The commercial Greenling harvest guideline (HG) for 2019 was 128.5 metric tons. Greenling are targeted by very few commercial fishers regardless of the relatively high HG and price per pound paid for live fish. The bimonthly trip limit in 2019 was 1,000 pounds per period set after considering public input, markets and local depletion concerns. Greenling landings were down with only 7.5% of the HG attained. Barring changes in targeted effort catch rates and markets, Greenling attainment is likely to continue to remain low.

Contact: Troy Buell (Troy.V.Buell@state.or.us), Brett Rodomsky (brett.t.rodomsky@state.or.us)

Cabezon

Research – Age and Growth

Previous aging of cabezon by the ODFW used thin-section method because of the small otolith size and a perceived increase in clarity. However, in 2019, ODFW staff elected to test alternative age methodologies and ultimately chose a break-and-burn methodology to process more recent commercial and recreational samples for the 2019 federal stock assessment of cabezon. The goal of this study was to 1) determine how much bias existed between these two sample methodologies, and 2) assess bias and precision between current and previous ODFW age readers. Additionally, alternative growth models were fit to updated age data, including young fish in some models, and were presented for use in the federal stock assessment.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Management – Commercial Fishery

The commercial harvest guideline (HG) for Cabezon in 2019 was again 30.2 metric tons. Cabezon catch in the fishery ran high, especially late season, continuing the trend seen in 2018. In anticipation of this possibility, ODFW reduced initial 2019 bimonthly trip limits 50 – 60% pre-season to 1,000 pounds for all periods. High Cabezon catch continued all season requiring implementation of a Period 6 daily trip limit. On 12/13/2019, a daily limit of 30 pounds per day went into effect, in addition to the 1,000 pound period 6 trip limit, to slow catch with until year's end to keep the fishery from exceeding the HG. Final commercial fishery attainment was 97.1% with in-season adjustments.

Contact: Troy Buell (Troy.V.Buell@state.or.us), Brett Rodomsky (brett.t.rodomsky@state.or.us)

Management – Recreational Fishery

Cabezon (*Scorpaenichthys marmoratus*) is another popular target for some recreational bottomfish anglers. Cabezon have a one-fish sub-bag limit as part of the general marine bag limit, and a 16 inch minimum size, additionally the season does not open until July 1. The cabezon harvest guideline has remained relatively constant over the last ten years. Even with the average angler catching less than one per day, the quota goes very quickly. In each of the last three years, the quota has been met in six weeks, at which time ODFW prohibits retention. Fishing is prohibited January through June as that is the time that cabezon generally spawn and nest guard. Prohibiting fishing during that time, is intended to protect cabezon during that time.

Contact: Lynn Mattes (lynn.mattes@state.or.us), Christian Heath (Christian.t.heath@state.or.us)

Assessment

ODFW staff were co-authors on the federal 2019 Cabezon stock assessment, in addition to contributing multiple data streams. Data contributions include modelling of multiple indices of abundance from both recreational and commercial data, age compositions, and other fishery dependent data. ODFW staff also participated in a pre-assessment workshop and attended the STAR panel where this assessment was reviewed in detail.

Contact: Alison Whitman (alison.d.whitman@state.or.us)

Ecosystem Studies

Mapping Rogue Reef

The purpose of this study is to provide a map showing the predicted location of hard and soft substrates of Rogue Reef, OR, and the surrounding rocky reef areas. These data will be used to inform survey design for a statewide Black Rockfish assessment, which will target areas where fish are likely to be found (i.e. hard rocky bottom). To create the map, we used acoustic backscattering data and spatial multivariate analysis to predict bottom type over our surveyed region. We employed a stratified line transect design consisting of southern (42.3° N to 42.2° N), central 42.5° N to 42.4° N), and northern (42.6° N to 42.5° N) blocks, with the central block encompassing the Rogue Reef complex. To ground truth acoustic observations, we completed n=20 drops using an underwater stereo video system. Post field collection, backscattering data was imported into Echoview Software Pty Ltd and bottom type was then classified using the Echoview bottom classification algorithm with a ping in-terval of 5. We used seven bottom characteristics from Echoview and multivariate analysis to categorize substrate types into hard and soft bottom types. We used seven bottom char-acteristics from Echoview and multivariate analysis to categorize substrate types into hard and soft bottom types. Specifically, we employed a k-means cluster analysis to group bot-tom pings (n= 84,486) into hard and soft substrate groups. -means clustering identified with 7 clusters of sizes n= 20963, 13979, 17540, 4325, 1760, 10085 and 15834 (Figure 2). The 7-cluster model explains 73.3 % of variation between groups (between SS/ total SS). Depth profile plots suggested that groups 1-4, and 7 represented soft substrates, while groups 4-6 were likely hard substrate types (e.g. bedrock, boulders, rock walls, pinnacles). This observation was verified by drop camera video of the benthos.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us), Alissa Rickborn (alissa.j.rickborn@state.or.us)

Effectiveness of quantitative stereo landers during day and night.

The need to develop fisheries independent estimates of demersal fishes in Oregon remains an important need for ODFW. Remote underwater vehicles (i.e. landers) are being used for this purpose in multiple countries throughout the world as well as providing stock assessment data to at least four of the regional fisheries management councils. A key benefit of their use is their simplicity in deployment and retrieval which ultimately makes them an economically strategic tool for monetarily limited agencies. However, there remain ways for us to increase their efficiency. Chartering vessels is inherently costly and time investment to either 1) have a boat not work at night or 2) make runs back and forth to port is not cost effective. Therefore, being able to operate a vessel both during the day and night allows a vessel to be run more efficiently. However, if the species and number of fish detected differ significantly between day and night the results can have dramatic impacts on the development of an index.

Lander drops are being conducted at three regions: nearshore reef sites (Seal Rock or Siletz Reef), mid-shelf reef site (Stonewall Bank), and near-shelf break (Daisy Bank). At each region three grids of 100 drops were established over areas presumed to have a rocky substrate based on available multibeam data. Sample locations were selected that are >400 m apart. Beginning 5 hours before sunset the odd numbered drop locations were sampled until sunset. Following sunset sampling reversed back on the grid only sampling the even numbers. Two stereo lander systems are hop-scotched throughout the study area to increase efficiency. CTD casts equipped with a light meter are made haphazardly throughout the day to characterize the water column. Landers are left on the bottom for 15 minutes to record video. Videos are then scored for both MaxN and mean MaxN. Field work for this project is ongoing.

Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Untrawlable habitat survey in partnership with NWFSC and AFSC

Survey biologists with NOAA Fisheries in Seattle and Newport are interested in partnering with the commercial and sportfishing industries in the Pacific Northwest to improve stock assessments for lingcod and shelf rockfish. We are planning to charter one commercial and one sportfishing vessel to conduct a study comparing the effectiveness of four different methods for collecting abundance and biological data for groundfish species found in rocky, high-relief habitats. The four methods are:

- Hook and line gear deployed by rod and reel
- Stereo video imagery from a small, stationary lander
- Stereo still camera imagery from a semi-moored housing
- Environmental DNA (eDNA) collected from water samples near the seafloor

The research will be conducted this fall from late October –early November off the Oregon coast between Cascade Head and Heceta Bank in a depth range of 20 –125 fathoms and will target a variety of banks, reefs, and other rocky habitats. Results from this study will help determine the most effective and efficient gear to use in designing a larger, more comprehensive monitoring program for groundfish in the untrawlable habitats of the Pacific Northwest. Sampling was conducted in fall of 2019 and video review is undergoing.

ODFW Contact: Leif Rasmuson (leif.k.rasmuson@state.or.us)

Video Lander Surveys

In December 2019 ODFW published an Informational Report titled "A nearshore video lander study of a nearshore rocky reef". The report examines the practicalities of sampling with the video lander tool, provides quantitative abundance estimates of groundfish species observed, and provides information on certain macro invertebrates with the lander and wildlife observed from the boat during surveys. The document can be found on the Marine Resources Program publications page (HERE).

Contact: Greg Krutzikowsky (greg.krutzikowsky@state.or.us)

Aging Activity

In 2019, a new Age Reading Specialist was hired to replace Lisa Kautzi, who had led the project for several years. Before leaving, Lisa produced break-and-burn age estimates for 218 Cabezon from the recreational fishery (63 tested) and 24 from the commercial fishery (23 tested, with an additional 18 tested that were initially aged in 2018). These ages were used for the 2019 Cabezon federal stock assessment and were included as the primary data for an age and growth study.

A new specialist, hired in late August 2019, prioritized Black Rockfish and aged 954 (191 tested) from the commercial fishery and 508 (102 tested) from the recreational fishery. He also transferred MRP's large, historical aging structure collection to a more suitable storage unit out of the coastal tsunami zone. Historical collections from the late 90's and earlier stored wet (in ethanol or oil/thymol) are in the process of being assessed, cleaned, and dried for proper dry storage.

Contact: Mark Terwilliger (Mark.R.Terwilliger@state.or.us)

Assessing benthic habitat impacts and recovery processes in association with major changes in bottom trawl closed areas off the Oregon coast

The Pacific Fishery Management Council's Groundfish FMP Amendment 28 reopens the current Rockfish Conservation Area to bottom trawling off Oregon and California, and modifies the current configuration of Essential Fish Habitat Conservation Areas along the entire West Coast. In its 2013 Research and Data Needs document the Pacific Council identified evaluating the effects of fishing on habitat and response of habitat to spatial closures as one of its highest priority Ecosystem Based Fisheries Management (EBFM) issues (PFMC 2013). More recently, the Pacific Council's newly updated 5-year research and data needs planning document identifies fishing effects on benthic habitats along with the collection of baseline data as one of its highest priorities. (PFMC 2018) continues to highlight the need for studies on the impacts of fishing to benthic habitats. Referring to the upcoming groundfish EFH amendment (28), the Pacific Council describes areas that will be reopened to trawling after 18 years as "providing unprecedented opportunities to facilitate applied research to address management questions about impacts and recovery of habitats and associated species, and the benefits of long-term closures for fish populations."

In 2019 ODFW initiated a study to focus on the RCA openings, taking advantage of the opportunity that the new openings offer to evaluate the current condition of these areas prior to the onset of bottom trawling. Our research will establish baseline information about condition of habitats and the diversity and abundance of fishes and invertebrates, and subsequently will evaluate of the effects of new trawling on these habitats in the years after reopening.

The preliminary (2019-2020) objectives of the work are: 1) To establish baseline information on representative habitats and associated biota in a segment of the Rockfish Conservation Area (RCA) on the Oregon continental margin after an 18-year bottom trawl exclusion before trawling resumes in areas to be reopened in 2020; and 2) to evaluate the short-term effect of bottom trawling on habitats and associated biota in newly opened trawl areas at depths to 250 m off the Oregon coast. Our approach for achieving these objectives is to conduct before/after non-extractive video transects using a remotely operated vehicle (ROV) to evaluate habitat condition, evidence of substrate disturbance, and associated organisms. By capturing an extensive, high-resolution video record of habitat conditions prior to the RCA opening, we will be providing a baseline dataset that will be valuable in perpetuity for future assessments of changes in habitat structure and utilization.

Observations made during the project's second field year on the same transects surveyed in the first year (approximately nine months after the onset of trawling) will enable evaluation of the short-term effects of trawling on the newly-opened habitats in those specific areas where trawls intersect the established transects. This comparison will be valuable to fishery managers in contributing to an understanding of how 18 years of closure is related to habitat structure and associated biota.

Sampling in 2019 was conducted on 11 days across four separate cruises, beginning August 28 and continuing through Nov. 6. Video surveys were completed covering approximately 19 km of seafloor along 38 individual ROV transects in the Rockfish Conservation Area (RCA), prior to the January 2020 bottom trawl fishery opening. The transects covered a range of substrate types (including trawlable and a few untrawlable sections) between 180 and 300 m depth over a 47 km long survey area between 44° 2′ and 44° 32′ N latitude. Video review has been initiated, and to date complete data have been extracted on fish abundance and fish size distributions in stereo-video footage. Substrate characterization and quantitative assessment of anthropogenic disturbance (e.g., trawl gear marks) is underway. Collaborators at Oregon State University have found opportunities to collect a total of nine sediment cores from locations adjacent to ROV transects on two separate cruises with additional coring operations planned for 2020 and 2021. A revised grant proposal was submitted to the NOAA Fisheries Saltonstall-Kennedy program to support continued ROV sampling and analysis in 2020.

Contact: Scott Marion (Scott.R.Marion@state.or.us)

ROV survey of Redfish Rocks Marine Reserve and associated comparison areas

Remotely operated vehicle (ROV) video surveys were conducted in Redfish Rocks Marine Reserve and associated comparison areas in April 2019, contributing to ongoing monitoring efforts for this reserve established in 2010. Fifty-three dives were conducted, each targeting a 500 m transect. Cape Perpetua Marine Reserve was also surveyed by ROV, adding to a time series of observations originating in 2001. Forward-oblique (30 degrees below horizontal), downward, and stereo-video HD camera systems were utilized.

Contact: Scott Marion (Scott.R.Marion@state.or.us)

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Krutzikowsky, G.K. 2019. A video lander study of a nearshore rocky reef. ODFW Informational Report 2019-10. 63 p.

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Vaux, F., Rasmuson, L., Kautzi, L., Rankin, P., Blume, M., Lawrence, K., Bohn, S., O'Malley, K. 2019. Sex matters: Otolith shape and genomic variation in Deacon Rockfish (*Sebastes diaconus*). Evolutionary Applications 9: 13153-13173

Washington Department of Fish and Wildlife Contribution to the 2020 Meeting of the Technical Sub-Committee (TSC) of the Canada-U.S. Groundfish Committee: Reporting for the period from May 2019-April 2020

April 23rd-24th, 2020
(CANCELLED due to COVID-19 pandemic)

Edited by:
Dayv Lowry

Contributions by:
Jen Blaine, Rob Davis, Larry LeClair, Dayv Lowry, Corey Niles, Robert Pacunski, Todd Sandell, Theresa Tsou, and Lorna Wargo

Washington Department of Fish and Wildlife
1111 Washington St SE
Olympia, WA 98504-3150

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Contents

I. Agency Overview

The Washington Department of Fish and Wildlife is divided into three major resource management Programs (Fish, Habitat, and Wildlife) and three major administrative support programs (Enforcement, Technology & Financial Management, and Capital & Asset Management). Within the Fish Program, research and management of marine fishes is housed within the Fish Management Division, which also oversees research and management of shellfish, warmwater species, and aquatic invasive species. The Marine Fish Science (MFS) Unit, in turn, is broadly separated into two groups that deal with distinct geographic regions (Puget Sound and the Outer Coast), though there is some overlap of senior staff. The Unit is overseen by Dr. Theresa Tsou. Lisa Hillier oversees the Unit budget, participates in various fieldwork projects, oversees the Washington Conservation Corps (WCC) survey group, and models stocks both on the coast and in Puget Sound. Phill Dionne oversees statewide marine forage fish research and management. Together with Phill, this Marine Forage Fish (MFF) Unit is composed of Dr. Todd Sandell, Adam Lindquist, Patrick Biondo, Kate Olson, Eric Bruestle, Aidan Coyle, and Stephanie Lewis. During herring spawning season, the unit receives staff support from members of the Intertidal Shellfish Unit as needed (i.e., the "loan" of four staff at approximately half time for four months).

Staff of the Puget Sound Marine Fish Science (PSMFS) Unit during the reporting period included Dr. Dayv Lowry (lead), Robert Pacunski, Larry LeClair, Jen Blaine, Andrea Hennings, Mark Millard, Ian Craick, and Katie Kennedy. In addition, Courtney Adkins and Peter Sergeeff work as PSMFS employees during the annual spring bottom trawl survey (April through June). Within the Fish Management Division of the Fish Program a second work unit also conducts considerable marine forage fish and groundfish research in Puget Sound, but focuses on the accumulation of toxic contaminants in these species. The Toxics-focused Biological Observation System for the Salish Sea (TBiOS) (formerly Puget Sound Ecosystem Monitoring Program or PSEMP) consists of Dr. Jim West (lead), Dr. Sandy O'Neill, Louisa Harding, Mariko Langness, and Rob Fisk.

PSMFS Unit tasks are primarily supported by supplemental funds from the Washington State Legislature for the recovery of Puget Sound bottomfish populations, and secondarily by a suite of collaborative external grants. The main activities of the unit include the assessment of marine fish populations in Puget Sound, study of marine fish ecology and demography, evaluation of bottomfish in marine reserves and other fishery-restricted areas, and development of conservation plans for particular species (and species groups) of interest. Forage fish in Puget Sound are managed under the auspices of the Puget Sound Forage Fish Management Plan (Bargmann 1998) and managed by members of the statewide MFF Unit described above. Groundfish in Puget Sound are managed under the auspices of the Puget Sound Groundfish Management Plan (Palsson, et al. 1998) and management has become increasingly sensitive to the ESA-listing of Canary Rockfish, Yelloweye Rockfish, and Bocaccio, in Puget Sound since

2010 (National marine Fisheries Service 2010). In 2017 Canary Rockfish were delisted, but Yelloweye Rockfish and Bocaccio still very much drive management of all groundfish species.

Since December of 2016 Dr. Lowry has also served as the Washington State representative on the Scientific and Statistical Committee (SSC) of the North Pacific Fishery Management Council (NPFMC), and members of the PSMFS Unit are occasionally called upon to assist with evaluation of documents pertinent to fisheries in federal waters off Alaska. In 2018 Lisa Hillier was added to the NPFMC Groundfish Plan Teams for both the Bering Sea and Gulf of Alaska. Bill Tweit, who reports straight to the Director of the Department, serves as a member of the NPFMC.

Primary Contacts – Puget Sound:
Groundfish Monitoring, Research, and Assessment – *Contact: Dr. Dayv Lowry 360-902-2558, dayv.lowry@dfw.wa.gov; Dr. Theresa Tsou 360-902-2855, tien-shui.tsou@dfw.wa.gov.*
Forage Fish Stock Assessment and Research – *Contact: Phill Dionne 360-902-2641, phillip.dionne@dfw.wa.gov; Dr. Todd Sandell 425- 379-2310, todd.sandell@dfw.wa.gov.*
Toxics-focused Biological Observation System for the Salish Sea (TBiOS) (formerly Puget Sound Ecosystem Monitoring Program or PSEMP) – *Contact: Dr. Jim West 360-902-2842, james.west@dfw.wa.gov).*
For complete staff contact information see section VIII of this report.

Staff of the Coastal Marine Fish Science (CMFS) Unit during the reporting period included Lorna Wargo (lead), Rob Davis, Donna Downs, Kristen Hinton, Jamie Fuller, Michael Sinclair, and Tim Zepplin. Unit tasks are supported through a combination of state general and federal funds. Long-standing activities of the unit include the assessment of groundfish populations off the Washington coast, the monitoring of groundfish commercial and recreational landings, and the coastal rockfish tagging project. In the last two years unit activity has expanded to include forage fish management and research, though this responsibility is shared and coordinated with the statewide MFF Unit.

The MFS Unit contributes technical support for West Coast groundfish and forage fish management via participation on the Coastal Pelagic Species Management Team (CPSMT, Lorna Wargo), the Scientific and Statistical Committee (SSC, Dr. Theresa Tsou), and the Habitat Steering Group (HSG) of the Pacific Fishery Management Council (PFMC). Landings and fishery management descriptions for PFMC-managed groundfish and coastal pelagic species are summarized annually by the GMT and the CPSMT in the Stock Assessment and Fishery Evaluation (SAFE) document. Additional West Coast fishery management support is provided by the Intergovernmental Ocean Policy Unit, which consists of a currently vacant lead (previously Michele Culver), Corey Niles, Heather Hall, Whitney Roberts, and Victoria Knorr. Heather serves on the PFMC’s Groundfish Management Team (GMT).

Primary Contacts – Coastal Washington:
Groundfish Management, Monitoring, Research, and Assessment – *Contact: Dr. Theresa Tsou 360-902-2855, tien-shui.tsou@dfw.wa.gov; Lorna Wargo 360- 249-1221 lorna.wargo@dfw.wa.gov; Corey Niles, 360-902-2733, corey.niles@dfw.wa.gov (Coastal Marine Policy Lead).*
Forage Fish Management, Monitoring, Research, and Assessment – *Contact: Lorna Wargo 360-249-1221 lorna.wargo@dfw.wa.gov; Phill Dionne 360-902-2641, phillip.dionne@dfw.wa.gov.*
For complete staff contact information see section VIII of this report.

II. Surveys

Puget Sound Bottom Trawl

BRIEF SURVEY HISTORY, DESIGN, METHODOLOGY – Since 1987, the Washington Department of Fish and Wildlife (WDFW) has conducted bottom trawl surveys in Puget Sound – defined as all marine waters of the State of Washington east of the mouth of the Sekiu River in the Strait of Juan de Fuca – that have provided invaluable long-term, fisheries-independent indicators of population abundance for benthic organisms living on low-relief, unconsolidated habitats. These surveys have been conducted at irregular intervals and at different geographic scales since their initiation (Quinnell et al. 1991; Quinnell et al. 1993; Palsson et al. 1998; Palsson et al. 2002; Palsson et al. 2003; Blaine et al. 2020). Surveys in 1987, 1989, and 1991 were semi-stratified random surveys of the majority of Puget Sound. From 1994-97 and 2000-07, surveys were annual, stratified-random surveys focusing on individual sub-basins (WDFW unpublished data; Palsson et al. 1998; Blaine et al. 2020). Starting in 2008, surveys became synoptic again, sampling annually at fixed index sites throughout Puget Sound (Blaine et al., in prep).

The specific objectives of the annual index trawl survey are to estimate the relative abundance, species composition, and biological characteristics of bottomfish species at pre-selected, permanent index stations. Key species of interest include Pacific Cod, Walleye Pollock, Pacific Hake, English Sole, North Pacific Spiny Dogfish, and all species of skates; however, all species of fishes and invertebrates are identified to the lowest taxonomic level practicable, weighed, and recorded. For key species, size distribution data and various biological samples are collected from a subset of individuals from each sampling location. For the index survey, the study area is subdivided into eight regions (eastern Strait of Juan de Fuca, western Strait of Juan de Fuca, San Juan Islands, Georgia Basin, Whidbey Island sub-basin, Central Puget Sound, Hood Canal, and South Puget Sound) and four depth strata ("S"= 5-20 fa, "T"= 21-40 fa, "U"= 41-60 fa, "V"= >60 fa). A total of 51 fixed index stations throughout the study area are sampled each spring (late April-early June) (Figure 1).

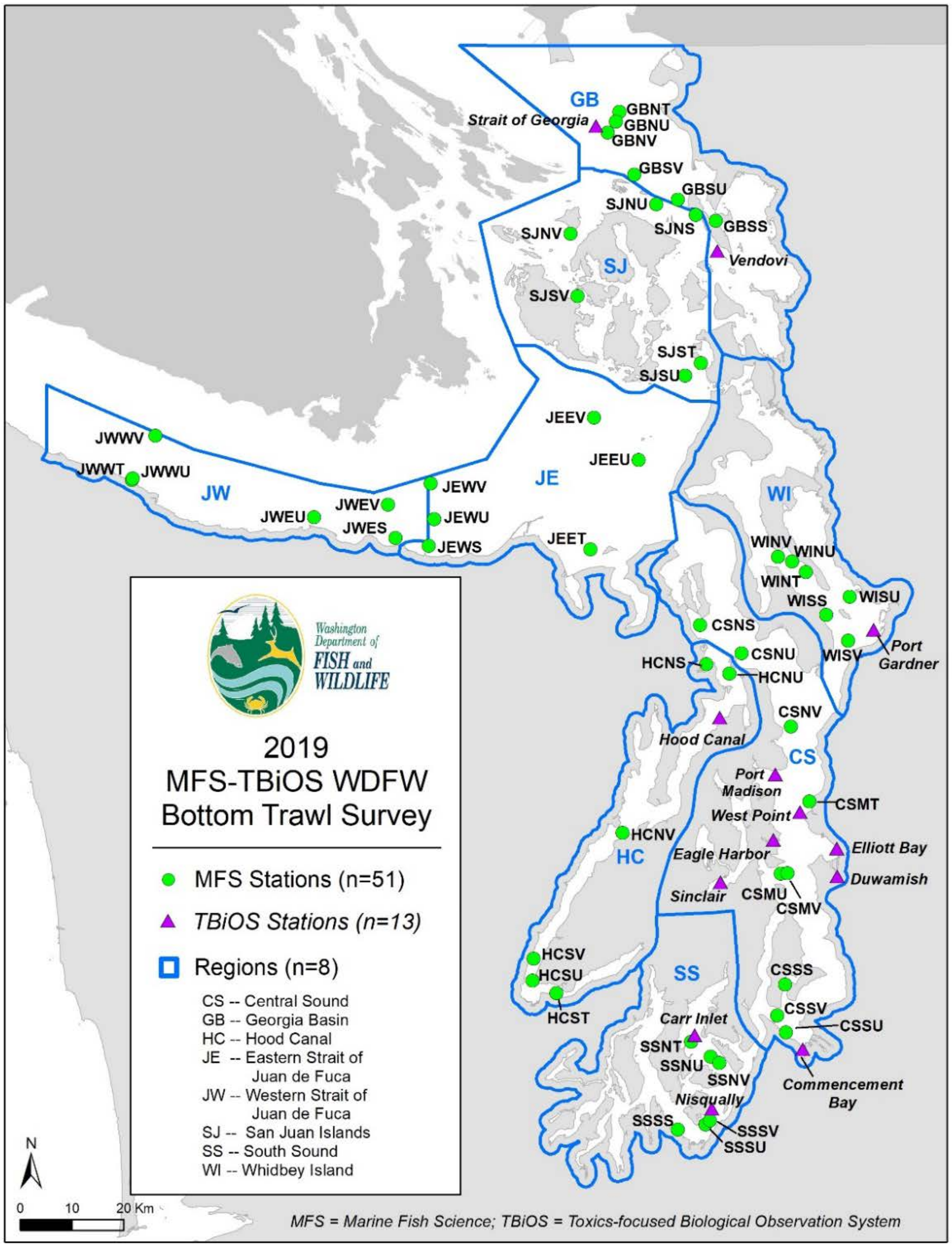


Figure 1. Trawl site locations for the index survey, sampled 2008-19. Stations CSNV and JEWU were moved several hundred yards in 2014/15 to reduce the potential for interactions of trawl gear with previously unknown submarine cables. Vessel time in 2019 was split between the Marine Fish Science (MFS) Unit and the Toxics-focused Biological Observation System (TBiOS) team, which conducts their bottom trawl survey biennially and samples 13 independent stations.

Index stations were originally selected from trawl stations sampled during previous survey efforts at randomized locations throughout Puget Sound. Station selection was based on known trawlability and other logistical concerns, and was informed by previously obtained biological data. Stations are named using a four-letter system with the first two letters designating the region, the third letter indicating the sub-region or position within the region (north, south, middle, east, west), and the final letter designating the depth stratum. The index stations have remained relatively consistent since 2008, with a few exceptions: starting in 2009, 5 stations were added to make the current 51-station design; in 2012 and 2013, stations in the shallowest stratum (S) were not surveyed because of concerns from NOAA about impacts to juvenile salmonids; and in 2014 and 2015, stations JEWU and CSNV were moved slightly to accommodate concerns raised by fiber-optic cable companies.

The trawling procedure of the survey has remained largely consistent throughout the historical survey period and complete details can be found in Blaine et al. (2016). The 57-foot F/V CHASINA is the chartered sampling vessel, and it is equipped with an agency-owned 400-mesh Eastern bottom trawl fitted with a 1.25-inch codend liner. The net is towed at each station for a distance of ~0.40 nautical miles at a speed of 1-3 knots, and the tows last approximately 11 minutes. The resulting catch is identified to the lowest taxonomic level possible, weighed, counted, and most of the catch is returned to the sea. The density of fish at each station is determined by dividing the catch numbers or weight by the area sampled with the net, which is based on a mensuration study conducted in 1994 (WDFW unpublished data). A small portion of the catch is retained for biological sampling, either when fresh on deck or after being preserved (freezing, ethyl alcohol, or formalin) for processing in the laboratory. Samples collected may include: fin clips (genetics); scales, spines, and otoliths (ageing); stomachs and intestines (gut contents); and muscle tissue (stable isotopes). When necessary, whole specimens may also be retained for positive identification or special projects being conducted by the WDFW or its collaborators.

From 2008 to 2013, two trawl samples were collected at each station and were spaced several hundred meters apart to be close to each other but not directly overlapping. However, based on the similarity of catches in these paired tows at most stations, and in the interest of minimizing bottomfish mortality associated with the trawl survey, the protocol was altered in 2014. After the first tow is completed, the processed catch is compared to the average catch at that station since 2008. If the species comprising the majority (>75% by weight) of the catch fall within the previous years' average (+/- standard deviation), no second tow is conducted at that station. If it is determined that the species composition was substantially different than expected, a second tow is conducted. This greatly improves the efficiency of the survey, as an average of only 4 stations have required a second tow each year. This newly gained efficiency has allowed institution of a new sampling program, conducting vertical plankton tows, to assess primary prey availability. In 2014 bottom-contact sensors were also added to the footrope to improve understanding of net performance and increase the accuracy of density estimates from the trawl, and a mini-CTD was deployed on the headrope to collect water quality data at each station and provide more accurate depth readings. In 2017, a Marport unit was also attached to the headrope to provide a live data feed regarding the net's depth, proximity to the bottom, and opening height.

2019 SURVEY RESULTS – The WDFW conducted the 12th annual index trawl survey from April 22 through June 3, 2019. Vessel time was split between the PSMFS Unit and the TBiOS group, which conducts their bottom trawl survey biennially and samples separate stations. During the 15 survey days allocated to the PSMFS Unit, all 51 index stations were occupied, and a total of 53 index bottom trawls were conducted, as 2 stations required a second tow.

All Fish

An estimated 49,918 individual fish belonging to 84 species or taxa and weighing 10.2 mt were caught during the survey. Overall, the total estimated bottomfish biomass and abundance for Puget Sound was 125,670 mt and 550.6 million individuals, respectively. Compared to the estimates from the 2018 survey (96,967 mt; 582.2 million individuals), the biomass increased but the abundance decreased slightly (Figure 2). Among the regions, Central Sound (CS) again supported the highest densities of bottomfish at 571 kg/ha and 1,984 fish/ha, substantially greater than those from any other region (Figure 3). The Eastern Strait of Juan de Fuca (JE) had the second highest biomass and population densities, which were both higher than the 2018 estimates by 131% and 40%, respectively. The largest increases from 2018, though, occurred in the Western Strait of Juan de Fuca (JW), in which biomass estimates jumped 216% and abundance estimates increased 81%, primarily due to higher catches of Spotted Ratfish, but also in part due to higher numbers of several flatfish species. Other than JE and JW, the San Juan Islands (SJ) was the only other region whose biomass and abundance estimates both increased (27% and 11%, respectively), while both estimates in the Georgia Basin (GB), Hood Canal (HC), and Whidbey Island (WI) decreased.

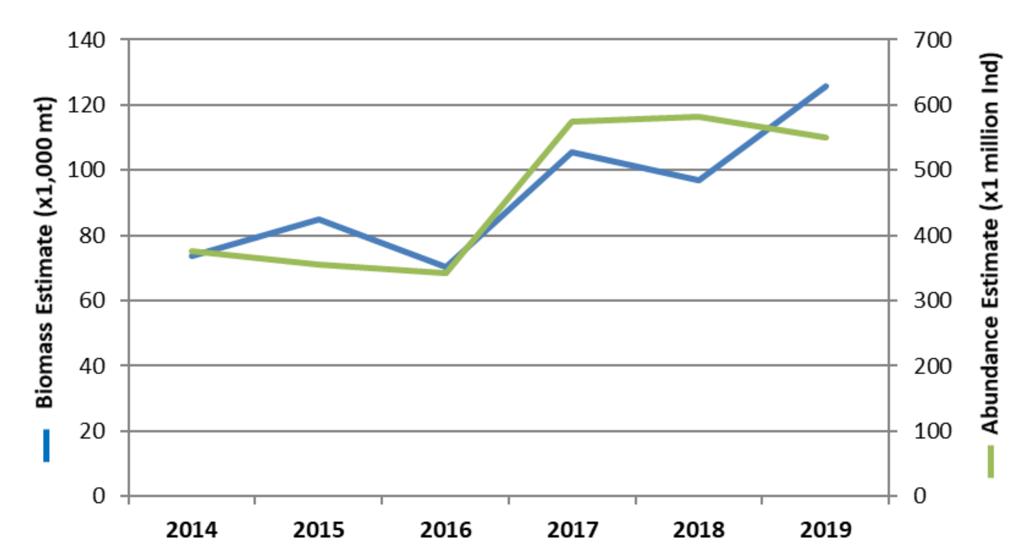


Figure 2. Estimates of bottomfish biomass (x 1,000 mt) and abundance (x 1 million individuals) throughout Puget Sound from the annual bottom trawl surveys since 2014.

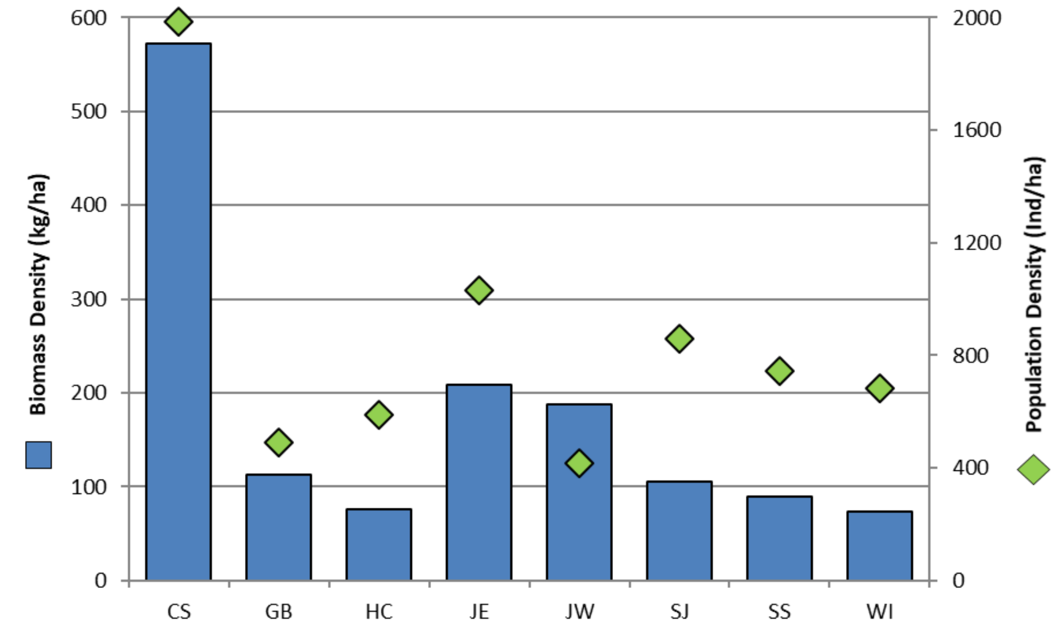


Figure 3. Estimates of bottomfish biomass density (kg/ha) and population density (ind/ha) in each of the eight regions of Puget Sound.

Similar to previous years, Spotted Ratfish dominated the catch, constituting 64% of the total fish catch by weight and 36% of the total number of individual fish, followed by English Sole at 10% and 16%, respectively. These catch rates equate to a biomass estimate of 80,798 mt for Spotted Ratfish and 11,520 mt for English Sole, and abundance estimates of 213 million and 92.8 million individuals, respectively (Figure 4). The remaining fish species contributed 4% or less to the total fish catch weight and 5% or less to the total number of individual fish (other than Walleye Pollock at 12%), and were categorized into the following species groups for comparisons: Other Flatfishes, Sharks & Skates (Elasmobranchs), Sculpins (Cottoidea), Codfishes (Gadiformes), and Other Fishes (e.g., forage fish, eelpouts). Other Flatfishes and Sharks & Skates actually had very similar biomass estimates (12,027 mt and 11,600 mt, respectively) to that of English Sole. After Ratfish and English Sole, Other Flatfishes and Codfishes had the highest abundance estimates (86.3 million and 83.7 million individuals, respectively) among the species groups. The 'Other Fish' category includes most species that the bottom trawl was not designed to target due to their size and/or behavior (including habitat preference), the most abundant of which were Blackbelly Eelpouts and Shiner Perch.

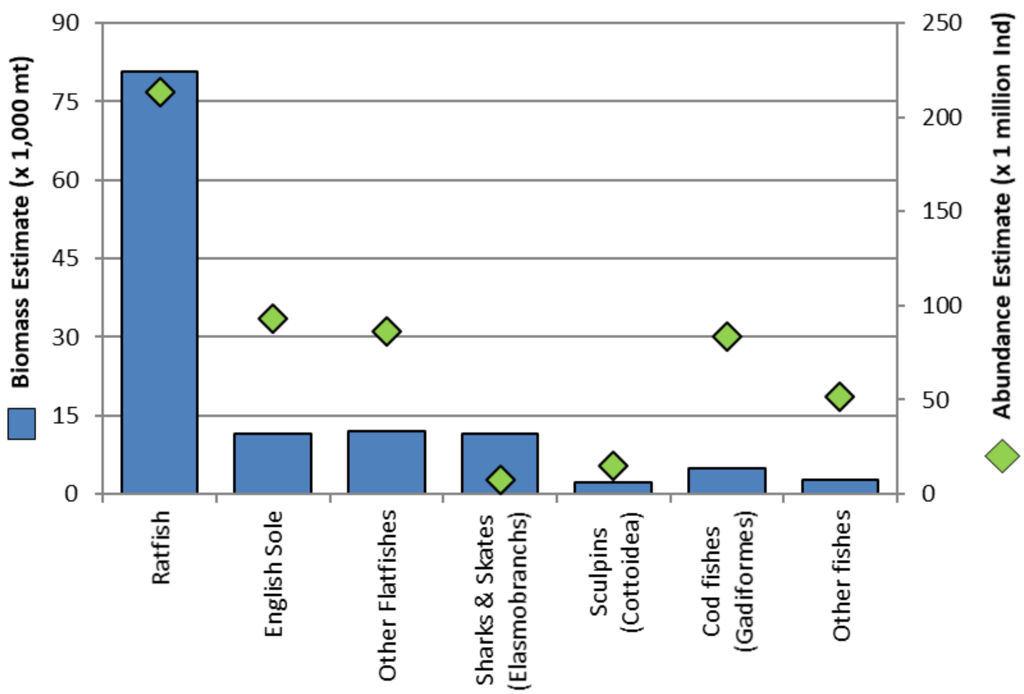


Figure 4. Estimates of bottomfish biomass (x 1,000 metric tons) and abundance (x 1 million individuals). Species were combined into groups by taxa, other than Spotted Ratfish and English Sole, the two most prominent species.

Flatfish

English Sole, as previously mentioned, were the most prevalent species of flatfish, with estimates of 11,520 mt and 92.8 million individuals (Figure 4); these estimates are over 25% lower than those in 2018. Among regions, CS supported the highest densities of English Sole at 40 kg/ha and 276 fish/ha; the smallest population was found in JW at 2.8 kg/ha and 19 fish/ha. In terms of other flatfish species, Rock Sole (3,785 mt & 24.2 million individuals), Starry Flounder (3,106 mt & 8 million individuals), and Pacific Sanddab (1,742 mt & 31.7 million individuals) were the most dominant by both weight and abundance after English Sole.

While these estimates are for all of Puget Sound, each region supported its own composition of flatfish species, although English Sole dominated the flatfish biomass in 5 of the 8 regions. Rock Sole, albeit closely followed by English Sole, comprised the largest proportion (47%) of flatfish biomass in GB; Dover Sole comprised the largest proportion (34%) in JW, and Starry Flounder (51%) did so in SS. Rock Sole also contributed 24% and 37% to SS and WI flatfish biomass, respectively, while Arrowtooth Flounder made up 25% in JW and Starry Flounder 27% in HC. Otherwise, all other flatfish species comprised 16% or less of a region’s flatfish biomass. Among the regions, South Sound supported the highest biomass density of non-English Sole flatfish species at 50 kg/ha, while WI supported the highest population density at 199 individuals/ha.

Sharks and Skates (Elasmobranchs)

Compared to 2018, the 2019 North Pacific Spiny Dogfish catch was higher both in terms of individuals, with 170 dogfish caught versus 87 in 2018, and in terms of weight, with 181 kg caught versus 142 kg. Dogfish populations can be migratory, however, and individuals are frequently in the water column rather than on the bottom, so their catchability in the bottom trawl is variable. Nevertheless, dogfish were found in all eight regions, with 33% of the weight being caught in GB and 31% of the individuals caught in JE.

Brown catsharks were again caught in the survey after being caught last year for the first time since 2014. Four females ranging from 45-48 cm total length were caught; one was found in GB, one in HC, and two in WI. Genetic samples (tissue plugs) were taken, and all were kept for researchers at the WDFW and Moss Landing Marine Labs for further analysis.

Bluntnose Sixgill Sharks were caught for the first time since 2013 and were found at station SSSU, where the species had been previously caught in 2010, 2011, and 2013. Not just one Sixgill, but three, were brought up in the net. The largest shark was a female, 2.46 m long (total length); another female was 1.42 m long. The third shark was a male and 1.89 m. Decaying bits of a seal carcass also came up in the catch, so it was predicted that the three Sixgills were feeding on the carcass at depth. Fork and total lengths were taken on the sharks, as well as tissue plugs for genetics, but the sharks were too big to be weighed safely. Instead, weights were estimated based on measured total lengths using the growth rates from Williams et al. (2010).

Big Skate biomass and abundance estimates increased from the 2018 survey 168% and 73%, respectively, to 6,008 mt and 2.5 million individuals. Encounter rates of Big Skates were highest in SJ, which accounted for over 40% of the abundance, but those caught in JE comprised over 50% of the Big Skate biomass. Longnose Skate biomass estimates also increased 77% to 2,222 mt, while abundance estimates increased 58% to 2 million individuals; estimates were highest in CS and WI. Lastly, 18 Sandpaper Skates were caught in 2019, which is on par with last year's catch rate of 19. Sandpaper Skates were primarily caught in JE, but were also found in GB and SJ.

Codfishes (Gadiformes)

Pacific Cod catch increased again from last year's catch of 17 fish; 21 were caught in this year's survey, weighing a total of 20 kg. This catch rate resulted in an estimated population density of 1.7 ind/ha in JW, 1.9 ind/ha in GB, 0.18 ind/ha in CS, and 0.08 ind/ha in SJ (Figure 5). While the density in JW was similar to that from the 2018 estimates, the density in GB doubled, and it was also the first year that Pacific Cod were caught in CS since 2015. Pacific Cod caught this year ranged in size from 30 cm to 63 cm, with an average length of 43 cm and a median of 38 cm.

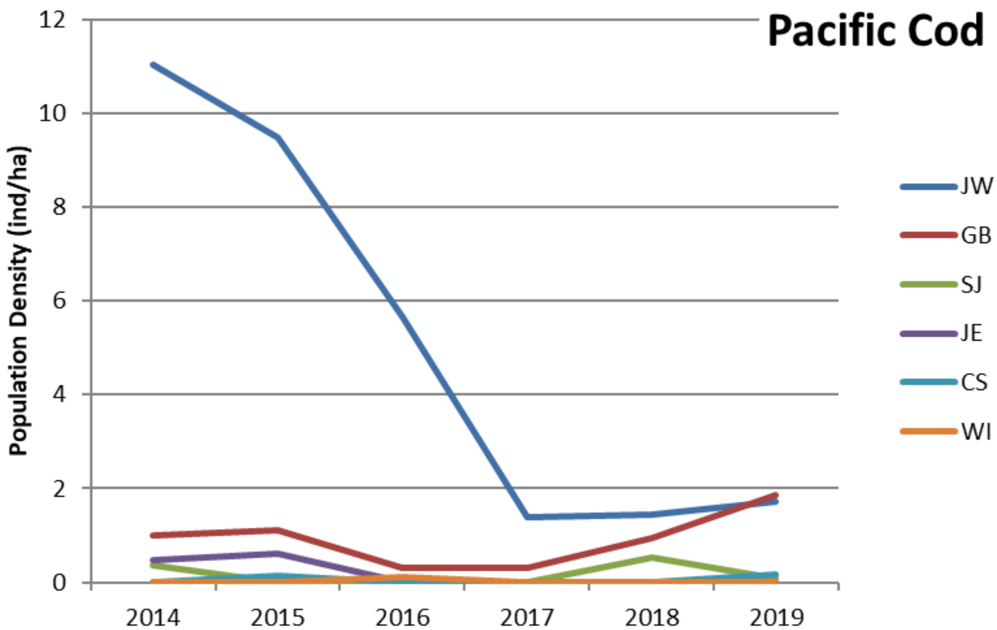


Figure 5. Population density (individuals/hectare) of Pacific Cod caught in the 2014-2019 bottom trawl surveys, by region.

Pacific Hake biomass and abundance estimates both decreased 64% from the 2018 survey to 1,152 mt and 14.6 million individuals, making this year's estimates more similar to those from 2016-2017; hake were found in all eight of the regions. Walleye Pollock also were found in all regions but saw growth in both estimates; biomass and abundance estimates increased 18% and 17%, respectively, from 2018 to 3,206 mt and 65.4 million individuals.

ESA-Listed Species

Pacific Eulachon was the only ESA-listed species encountered during the 2019 survey; 62 individuals were caught (19 in 2018, 29 in 2017) in regions GB, JE, JW, and SJ. While this was a smaller regional distribution compared to previous years, this was the most Eulachon caught in the bottom trawl survey, despite sampling design and effort reductions, since 2004. All Eulachon were kept and sent to the WDFW Forage Fish lab for further analysis.

No other ESA-listed species were caught, including Bocaccio, which had been caught in each of the past three years in northern portions of the survey area (JW, JE, SJ, and GB).

Other Fishes/Notable Finds

Because rockfish tend to exhibit preferences for rocky, untrawlable habitats, the bottom trawl survey serves as a poor indicator of rockfish populations. With this in mind, however, there was a noticeably higher catch of rockfish in the 2018 survey compared to the previous years, but the catch in the 2019 survey was closer to that of the 2017 survey, and less than half of what was caught in 2018 (Table 1). Nine different species were caught, including Shortspine Thornyhead, which were seen in 2018 for the first time since 2010. Quillback Rockfish were, as usual, the most abundant species, followed by Brown Rockfish, and very few Copper and Yellowtail Rockfishes were caught this year compared to last.

Table 1. Rockfish species counts caught in the bottom trawl survey from 2014-19.

Species	2014	2015	2016	2017	2018	2019
Black Rockfish	1	-	-	-	-	-
Bocaccio	-	-	11	7	3	-
Brown Rockfish	2	13	15	16	42	14
Canary Rockfish	-	1	-	2	3	3
Copper Rockfish	27	7	4	4	123	9
Greenstriped Rockfish	2	5	2	8	5	1
Puget Sound Rockfish	9	2	-	-	1	-
Quillback Rockfish	41	34	117	235	344	207
Redbanded Rockfish	-	-	1	-	-	-
Redstripe Rockfish	5	4	6	8	4	9
Shortspine Thornyhead	-	-	-	-	1	1
Splitnose Rockfish	-	-	2	-	3	1
Yellowtail Rockfish	-	7	-	13	59	5
Total	**87**	**73**	**158**	**293**	**588**	**250**

Like rockfish, Lingcod exhibit a preference for untrawlable habitats, and therefore the bottom trawl is a poor survey method for assessing their populations; however, in the 2019 survey, 14 Lingcod were caught, which is the highest catch rate since 2013. Individuals ranged in size from 28 cm to 87 cm, with a median length of 48 cm; before this survey, only 3 Lingcod less than 35 cm had been caught since 2013. The majority of individuals were caught in JW, but one each was caught in CS, GB, and SJ. All but two small Lingcod, which were retained for WDFW and NOAA biologists, were released alive.

Sablefish (aka “Black Cod”), which have been caught in the survey the previous two years, were again found in the survey this year. Eight Sablefish were caught, all in JW; this is 6 more than were caught in 2018, and the same number as 2017. Lengths ranged from 39 cm to 52 cm, with an average of 48 cm. Fin clips were taken for genetic analysis, and all individuals were released alive. A few other less-frequently caught species found in the 2019 survey include a Wolf-eel, a Red Brotula, and two Pacific Spiny Lumpsuckers.

SUMMARY – The WDFW bottom trawl survey is the largest, and longest-running, fishery-independent survey of benthic organisms in Puget Sound. As such, this dataset provides an invaluable monitoring opportunity for populations of bottomfish and select benthic invertebrates, particularly given the inter-annual variation of many fish species. Continued collection of these data is important, as they can serve as a baseline for evaluating future population shifts due to fishery management actions, disease outbreaks, catastrophic events, and/or environmental shifts.

Additionally, the data, samples, and estimates from the trawl survey are not only important for the WDFW's marine fish monitoring efforts but are also used by other entities both within and outside the agency. The WDFW's Shellfish Team uses the estimates of Dungeness Crab and Spot Prawns to better inform fishery management decisions; a researcher and her students at Mount Holyoke College are researching the reproductive development of Spotted Ratfish; NOAA is building a collection of fish genetics; and three University of Washington researchers are furthering their studies on Longnose Skates, Spotted Ratfish, and poachers, all of which are possible thanks to data and samples from the trawl survey. These are just a few examples of how the bottom trawl survey includes such far-reaching applications that influence the knowledge and management of other species and supports other research efforts.

If you are interested in reading the full cruise report from the 2019 bottom trawl survey, please contact Jen Blaine (Jennifer.blaine@dfw.wa.gov). Unless cancelled due to COVID-related restrictions, the 2020 Index bottom trawl survey will occur from May 4 – June 5 and may include exploratory stations in South Sound to continue the effort that began in 2018 to test the representativeness of the Index stations.

Annual Pacific Herring Assessment in Puget Sound – Annual herring spawning biomass was estimated in Washington in 2019 using spawn deposition surveys. The WDFW recognizes twenty-one different herring stocks in Puget Sound and two coastal stocks, based primarily on timing and location of spawning activity. There are currently three distinct genetically distinguishable groupings within Puget Sound (Cherry Point, Squaxin Pass, and the "other stocks" complex). PSMFS Unit and MFF staff based in the Olympia, Mill Creek, and Port Townsend offices attempt to conduct spawn deposition surveys of all herring populations in Washington annually (acoustic-trawl surveys were discontinued in 2009 due to budget cuts; as a result, we are no longer able to estimate the age structure of the herring stocks). Locations sampled in 2019 are shown in Figure 6. Stock biomass assessment activities for the 2020 spawning season were underway when statewide response to the COVID-19 pandemic forced the suspension of field surveys. Unfortunately, anecdotal observations from citizen scientists and house-bound MFF staff indicate that spawning in 2020 is occurring at extraordinary, possibly record setting, levels in some locales.

The herring spawning biomass estimate for all Puget Sound stocks combined in 2019 was 7,891 metric tons, a 23% decrease from 2018 (10,280 tonnes) (Table 2). The 2019 total is a 19% increase from the recent 2013 low point of 6,651 tonnes and is 84% of the ten-year average (9,366 tonnes).

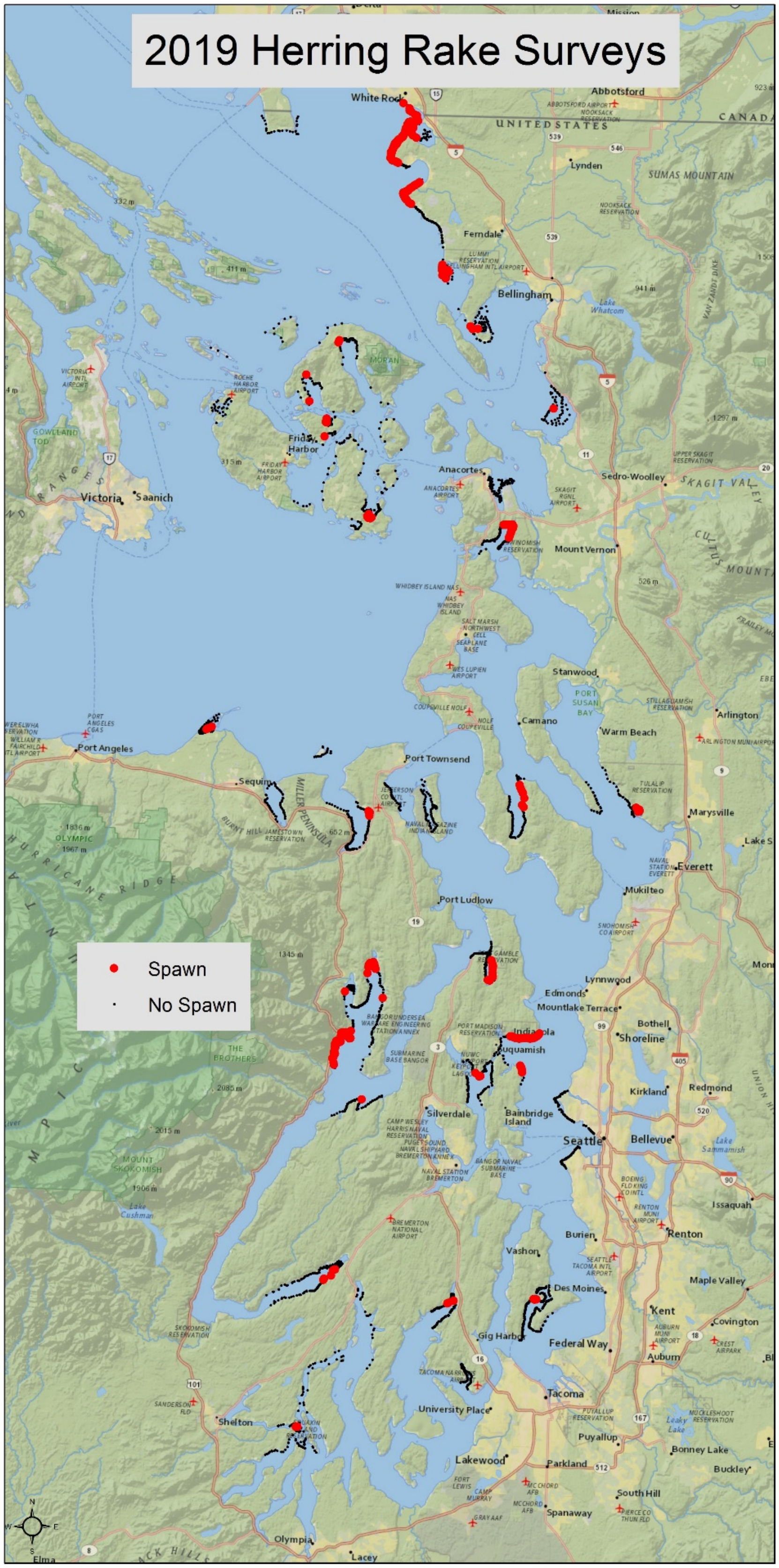


Figure 6: Locations of all rake surveys conducted in 2019, with red dots indicating detection of eggs.

Table 2. Pacific Herring spawning biomass estimates (metric tonnes) in Puget Sound by stock and year

Stock and Region (Unique genetic groups *italic*)	**PUGET SOUND HERRING SPAWNING BIOMASS ESTIMATES (Metric Tons), 2010-2019**									
South Puget Sound	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Squaxin Pass	463	513	534	503	357	294	236	271	381	14
Purdy	454	645	122	236	75	29	0	20	15	110
Wollochet Bay	10	19	28	9	35	0	0	5	0	0
South Puget Sound Total	926	1,177	685	748	468	323	236	297	396	124
Central Puget Sound										
Quartermaster Harbor	130	87	98	142	40	50	0	0	11	22
Elliott Bay			263	194	26	122	99	68	199	0
Port Orchard-Port Madison	318	112	197	167	82	83	0	0	13	1,867
Central Puget Sound Total	447	199	558	503	148	256	99	68	222	1,889
Hood Canal										
South Hood Canal	194	142	239	181	102	256	226	90	58	38
Quilcene Bay	1,825	4,031	2,382	1,880	2,810	3,717	6,496	4,482	5,816	2,960
Port Gamble	393	1,328	367	248	154	313	163	164	451	207
Hood Canal Total	2,412	5,500	2,988	2,308	3,065	4,286	6,884	4,736	6,325	3,205
Whidbey Basin										
Port Susan	138	125	55	26	62	64	55	103	67	64
Holmes Harbor	611	2,724	615	531	416	414	448	70	341	385
Skagit Bay	365	425	402	412	267	259	44	176	310	208
Whidbey Basin Total	1,113	3,275	1,072	969	745	736	547	349	718	657
North Puget Sound										
Fidalgo Bay	93	108	81	91	200	73	5	5	0	0
Samish/Portage Bay	589	351	390	629	706	507	929	451	379	204
Semiahmoo Bay	825	1,456	797	516	2,566	5,309	1,631	2,097	1,603	1,175
Cherry Point	702	1,180	1,016	824	910	475	468	337	249	290
Interior San Juan Islands	22	0	5	0	5	34	0	0	61	167
NW San Juan Islands	0	0	0	0	0	0	0	0	0	0
North Puget Sound Total	2,231	3,095	2,289	2,059	4,386	6,398	3,033	2,890	2,292	1,836
Strait of Juan de Fuca										
Discovery Bay	24	0	95	0	5	11	221	93	232	102
Dungeness/Sequim Bay	68	94	39	64	65	7	40	153	93	78
Kilisut Harbor	0	0	0	0	5	0	0	0	0	0
Strait of Juan de Fuca Total	92	94	134	64	74	18	261	247	326	180
Other Stocks total *(excludes Cherry Pt. and Squaxin)*	6,056	11,647	6,176	5,325	7,620	11,247	10,356	7,979	9,649	7,587
Puget Sound Total	**7,221**	**13,340**	**7,726**	**6,651**	**8,887**	**12,017**	**11,060**	**8,587**	**10,280**	**7,891**

Decreased spawning biomass was observed in every region of Puget Sound from 2018 to 2019 except for Central Puget Sound; and the Central Puget Sound and Strait of Juan de Fuca regions are the only regions that remained above the 10-year average. The Squaxin Pass stock in South Puget Sound decreased to only 14 tonnes in 2019, about 340 tonnes below its 10-year average. This decrease was partially mitigated in South Puget Sound by a 95 metric ton increase of the Purdy stock, but Purdy too is below its 10-year average of 171 tonnes. The Central Puget Sound increased 750%; driven mostly by the increase of the Port Orchard/Port Madison stock from 13 tonnes to 1,867 tonnes. Quartermaster Harbor doubled from 2018 to 22 tonnes but remained below half of its 10-year average of 58 tonnes.

Hood Canal, which accounted for over 60% of the spawning biomass in 2018, decreased by nearly 50% in 2019, and was below the 4,171 metric ton 10-year average. This decrease was driven by the 2,856 decrease of the Quilcene Bay stock, but both the South Hood Canal and Port Gamble stocks decreased as well. Despite continuing to decline and remain below the 10-year average of 1,018 tonnes, the Whidbey Basin stocks remained relatively stable from 2018 to 2019, with less than a 10% difference between the annual estimates.

In North Puget Sound, a minor increase (16%) was observed at Cherry Point, and the Interior San Juan Islands also increased and surpassed its 29-metric ton 10-year average. However, this increase may be attributed to improved survey coverage of the Interior San Juan stock in 2019 thanks to collaboration with the UW Friday Harbor Marine Lab and San Juan Co. Resource Conservation Organization. The Dungeness/Sequim Bay, and Discovery Bay stocks in the Strait of Juan de Fuca both decreased from 2018 but remained above their respective 10-year averages of 70 and 78 tonnes.

A number of stocks in the region that were previously abundant continue to hold at low levels (Figure 7), and several stocks again had no spawn detected in 2019. The NW San Juan Islands stock is considered a disappearance with no spawn documented in the past decade, and the Kilisut Harbor stock is also now considered a disappearance, with only one year of spawn detected in the past decade. The Wollochet Bay stock in South Puget Sound has only had spawn documented once in the past 4 years, and for the second year in a row, no spawn was documented at Fidalgo Bay. Also, for the first time since it was documented in 2012, no spawning was documented at Elliott Bay.

In the coastal estuaries, Willapa Bay and Grays Harbor, while spawning activity was observed in Willapa Bay at one site in 2018, no spawn was detected in Willapa Bay or Grays Harbor in 2019. The number of surveys in these estuaries were again restricted due to weather and logistical challenges in 2019.

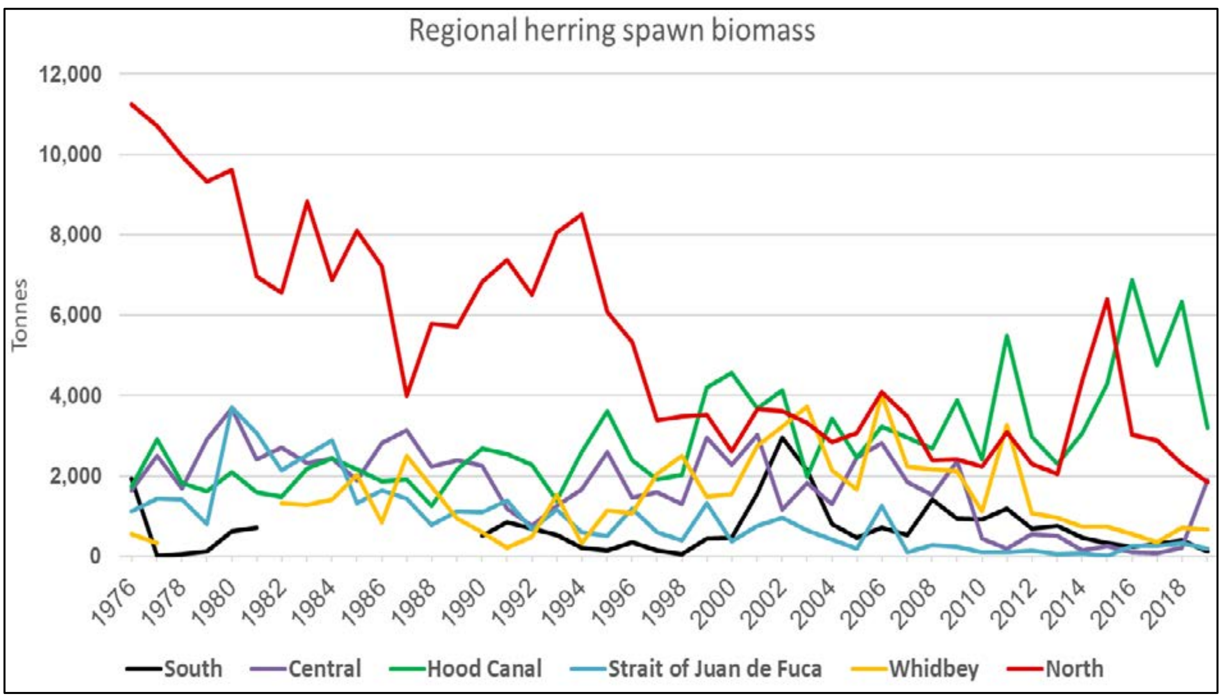


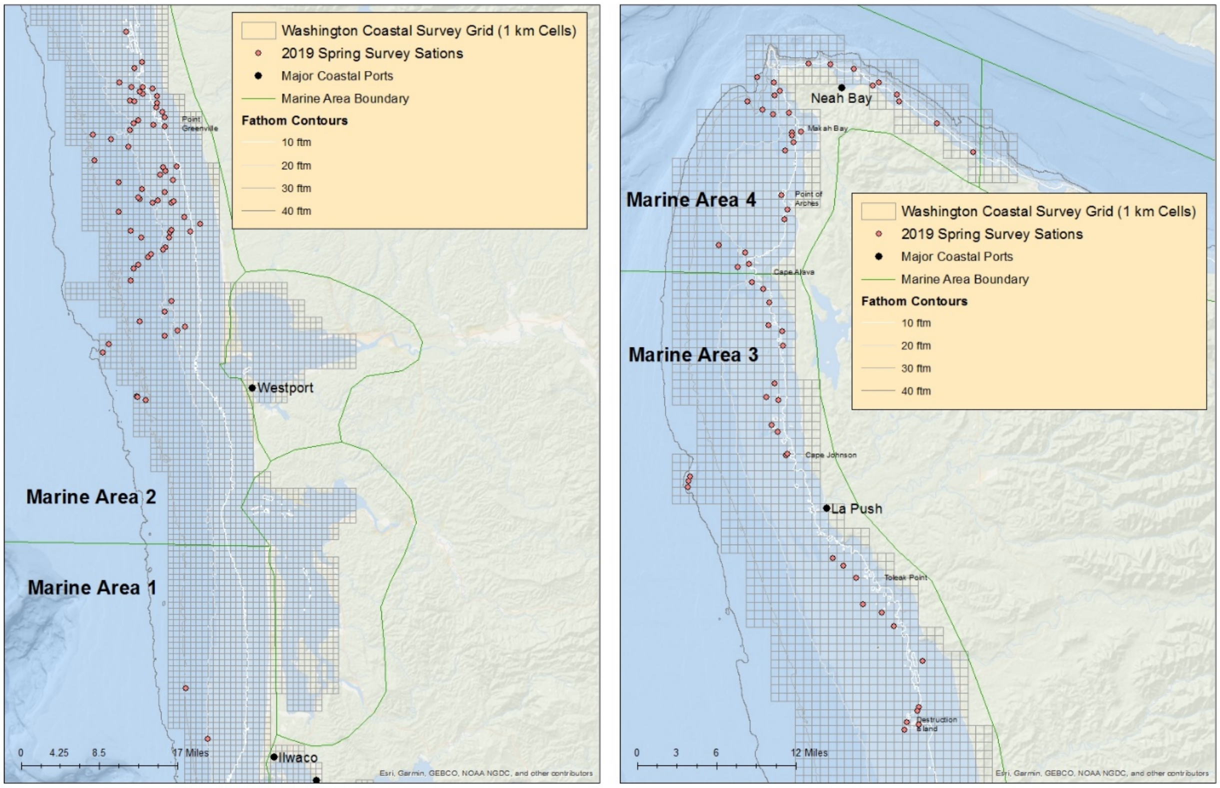
Figure 7. A comparison of Pacific Herring spawning biomass estimates for notable stocks in Puget Sound (note that only Squaxin Pass and Cherry Point are genetically distinct from the "Other stocks" complex)

Coastal Black Rockfish Rod and Reel Survey – The WDFW has conducted fishery independent rockfish surveys on the Washington coast since the 1980s. Historically, these surveys have primarily focused on Black Rockfish due to the predominance of this species in recreational fishery landings. Concerns over population sizes of other less dominant, but highly sought after, nearshore groundfish species has recently motivated survey design changes to address this data need. From 2014 through 2017, the WDFW conducted a series of experimental rod and reel surveys devoted to the development of a multispecies nearshore rockfish survey by evaluating nearshore rockfish distribution, life history, and fishing gear selectivity. This effort indicated that due to variable behaviors and terminal tackle selectivity among species, Washington's nearshore groundfish species would be best described with two separate coastal surveys: one targeting rockfish that typically school above rock piles and another targeting demersal groundfish species.

A standardized rod and reel survey designed to describe relative changes in population abundances of nearshore rockfish species and other associated groundfish species along the entire Washington Coast over time was implemented in 2018. Specifically, a "Black Rockfish Survey" was conducted in the spring to describe nearshore schooling species and a "Demersal Groundfish Survey" focusing on nearshore demersal rockfish and other associated groundfish species including Kelp Greenling and Cabezon was implemented in the fall. This effort was continued in 2019 with adjustments to survey methods addressing some standardization concerns.

The 2019 Black Rockfish rod and reel survey was conducted in the spring due to unsuitable ocean weather conditions in the winter, low charter vessel availability in the summer, and higher Black Rockfish catch rates in the spring when compared to fall WDFW rod and reel surveys. The survey began the day after the Washington coastal recreational groundfish season opened on March 9 to avoid any possible differences in catch rates due to varying recreational fishing pressure before and after the season opener.

Spring survey locations spanned the entire Washington Coast from the mouth of the Columbia River to the confluence of the Sekiu River with the Strait of Juan de Fuca and included all coastal marine areas (Figure 8). Location depths were limited to under 40 fathoms, which includes the typical depth range of Black Rockfish, and all locations where WDFW rod and reel surveys have encountered Black Rockfish in the past. Survey fishing effort was spatially distributed within the confines of the Washington coast survey grid scheme developed by the WDFW for the 2015 spring rod and reel survey. This grid is composed of one-kilometer squared cells superimposed over the entire Washington coast. Within this schema, one-kilometer squared grid cells were chosen for survey operations (Figure 8).



A) South Coast B) North Coast

Figure 8. The Washington coast survey grid scheme (1 km grid cells) and survey station (single GPS locations) selected for the 2019 spring Black Rockfish Survey in Marine Area 1 and 2 (A) and Marine Area 3 and 4 (B).

Targeted cells were chosen based on known rockfish habitat and observed catch rates of Black Rockfish from previous WDFW surveys. The presence of rockfish habitat within each grid cell was confirmed with rod and reel survey data spanning from 1998 to 2017. A grid cell was determined to have known rockfish habitat when at least one rockfish, Lingcod, Cabezon, or Kelp Greenling had been captured in it in a previous survey. One hundred and fourteen cells were then random-systematically chosen from cells with known habitat. Of these selected locations, seven were removed prior to the start of the survey due to known hazards, location issues or uncertainties in historic location data accuracy. Eighteen additional cells were chosen purposefully to more effectively distribute survey locations relative to the amount of known rockfish habitat by Marine Area and depth, and to include both marginal and superior habitat locations based on catch rates from previous WDFW rod and reel surveys.

Each Station was defined as a single GPS position located within each selected grid cell (Figure 8). Fishing effort consisted of four drifts that began within 50 yards of the single GPS position and 32 minutes of total fishing time. This was the most significant adjustment to methodology from the 2018 studies where 60 minutes of total fishing time was devoted to each selected grid cell and effort could be deployed anywhere within the one-kilometer squared cell. This further standardized our survey efforts, reducing the effect of inconsistent skipper fishing techniques.

Additionally, the decrease in station size reduced time spent searching for schools of fish and allowed for more stations to be surveyed in a single charter day.

Three recreational charter vessels were used to complete the 2019 spring survey. Each cruise was staffed with five hired anglers and three to four WDFW scientific staff. All contracted skippers had at least seven years of professional captain experience fishing for rockfish on the Washington Coast and each angler deployed had over 10 years of experience fishing for rockfish on the Washington Coast.

Fishing rods, reels, and terminal tackle were kept consistent across all stations surveyed. Terminal tackle consisted of two shrimp flies tied on a leader above a dropper weight and leaders were pre-tied at specified lengths before the charter day to ensure consistency. The weight of sinkers used for each drift was chosen by the vessel's captain after taking into consideration depth and weather conditions, but were kept consistent among anglers for each drift.

All fishing effort was conducted during daylight hours and charter days ranged from 8-11 hours. All stations in Marine Area 1 and 2 were fished before moving survey operations to the northern coast. Cells to be visited on any given charter day were chosen before leaving port by the lead biologist after consultation with the vessel's captain and considering ocean conditions.

At each chosen one-kilometer squared grid cell, captains took time to scout for fish aggregations and hard bottom/high relief areas, and to consider previous survey and personally known catch locations within each cell. Survey "stations" were then chosen as a single GPS position within each grid cell at the center of rocky substrate that would most likely provide high rockfish catch. Fishing effort at each station consisted of four eight-minute fishing drifts that began within 50 yards of the central GPS position. A fishing "drift" is defined as any consecutive time span that is spent fishing, beginning when the first angler's hook enters the water and ending when the last angler's hook leaves the water for any reason. Depending on weather conditions, the vessel either drifted or anchored over the target area, but vessel disposition remained constant for each individual station. For recordkeeping purposes, each anchored fishing event was recorded as a drift.

Five anglers fished for the total fishing time at each station surveyed. Each charter day the same five anglers fished all stations. Individual anglers were assigned a position on the vessel to fish for all drifts at a single station. These standard angler fishing positions were established on either the port or starboard side of the vessel, depending on the captain's preference. Angler positions were evenly spread out on the chosen side of the vessel from bow to stern. Before fishing began for each survey station, anglers were randomly assigned to one of the standard fishing positions. Due to space limitations on the F/V TOPNOTCH, the captain was used as an angler for all drifts.

Because he needed access to a specific fishing position in order to set up drifts and fish effectively, we were not able to randomize his fishing position.

For each drift, anglers started and ended fishing at the same time but were allowed to retrieve their gear as many times as necessary during the drift to land catch or maintain gear. Individual angler times per drift were recorded as total time hooks were in the water, which excludes any time that fishing gear was out of the water either to land a fish or work on the gear. Anglers were allowed to fish anywhere in the water column that they expected to catch the most fish and captains were encouraged to describe the depths of fish aggregations to them.

Catch and effort information collection included station number, GPS location of the start and end of each drift, depth, disposition of vessel (anchored or drifting), drift speed and direction, number of anglers, total fishing time per station, and terminal tackle gear type. Individual angler's fishing time, catch by species, gear loss, and fishing depth (benthic or pelagic) were recorded for each angler. The intensity and direction of weather conditions including tide, wind, and swell were also recorded, and benthic habitat observations inferred from the vessel's sonar and captain's descriptions were noted for each station visited.

Catch was identified to species, measured (fork length), and scanned for previously implanted tags. Fish that were not chosen for age structure sampling were released at capture location with a descending device when necessary. Released Yelloweye Rockfish were tagged with both an internal PIT tag and an external Floy tag. Released Cabezon, Kelp Greenling, China, Copper, Deacon, Quillback, Tiger, and Vermilion rockfish were tagged with a Floy tag and released.

Over 22 charter days, 125 stations were successfully surveyed along the Washington coast (Table 3). Four to eight stations were surveyed each charter day dependent on the distance of target locations from port. Drift speeds ranged from 0.2 to 1.7 knots and six stations were fished while at anchor. Total angler rod hours at successfully surveyed stations ranged from 2.4 to 2.9.

Table 3. Number of stations successfully surveyed in the 2019 spring survey by Marine Area and 10 fathom depth bins.

	0-10 fathom	11-20 fathom	21-30 fathom	31-40 fathom	All Depths
Marine Area 1			2		2
Marine Area 2	10	33	20	3	66
Marine Area 3	11	14	1	2	28
Marine Area 4	9	15	5		29
Coastwide	30	62	28	5	125

Black Rockfish was by far the most predominant specie captured across all Marine Areas in waters less than 30 fathoms (Table 4). Other high catch species included Yellowtail Rockfish, Deacon Rockfish, and to a lesser extent Lingcod and Canary Rockfish. Less than 16 individuals of all other species encountered were captured, but species diversity did increase by Marine Area up the coast.

Table 4. Catch by number of all species per Marine Area and depth bin in the 2019 spring survey.

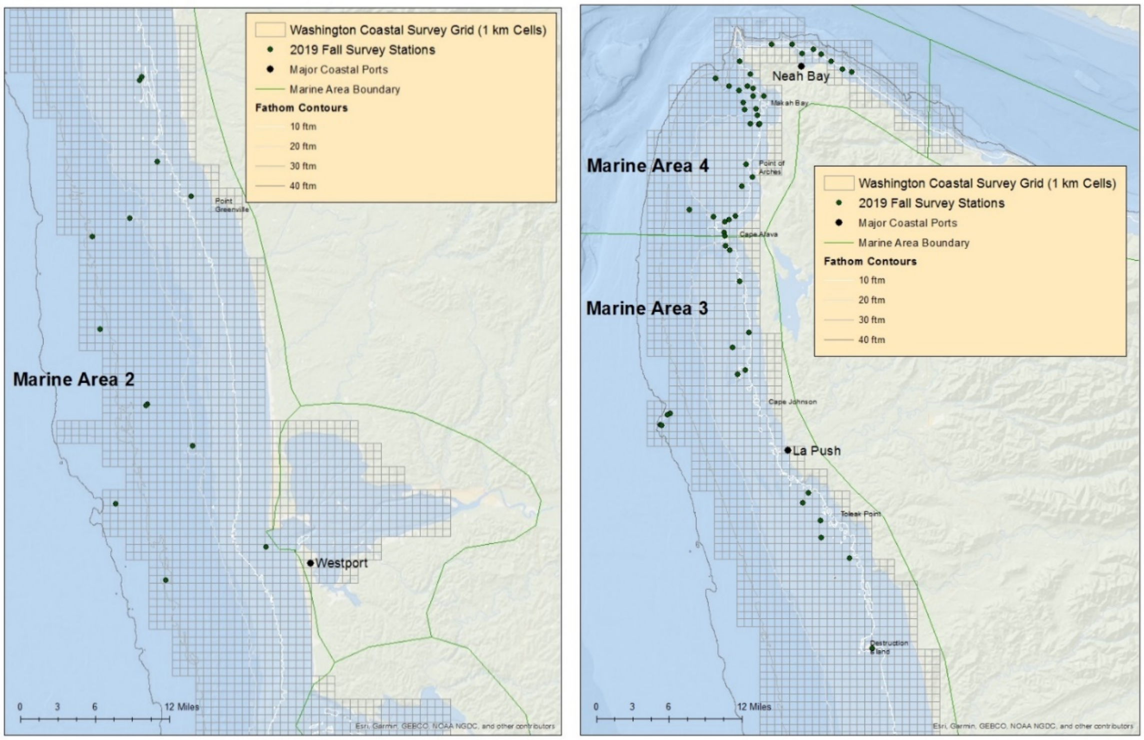
Species	Marine Area 1	Marine Area 2					Marine Area 3					Marine Area 4				Grand Total
	21-30 fathom	0-10 fathom	11-20 fathom	21-30 fathom	31-40 fathom	Total	0-10 fathom	11-20 fathom	21-30 fathom	31-40 fathom	Total	0-10 fathom	11-20 fathom	21-30 fathom	Total	
Black Rockfish	15	252	464	208	12	936	279	206	5		490	45	135	120	300	1741
Blue Rockfish							6				6	2	7		9	15
Buffalo Sculpin			2			2										2
Cabezon							1	1			2	4			4	6
Canary Rockfish			1	13	6	20		9		4	13	1	32	23	56	89
China Rockfish								4			4		4		4	8
Coho Salmon												1	1		2	2
Copper Rockfish													8	6	14	14
Deacon Rockfish			1	1	5	7	108	58	23	15	204	8	64	20	92	303
Kelp Greenling							1	1			2	1	5	1	7	9
Lingcod		6	5	6		17	3	4	3	2	12	3	17	5	25	54
Pacific Herring			1			1										1
Pacific Sanddab	1												1		1	2
Quillback Rockfish				2	1	3		1		1	2		3	6	9	14
Vermilion Rockfish													1		1	1
Widow Rockfish									6	4	10			2	2	12
Yelloweye Rockfish				1		1			2	1	3			2	2	6
Yellowtail Rockfish			1	11	65	77	13	73	10	51	147	2	42	30	74	298
Grand Total	16	258	475	243	89	1064	411	357	49	78	895	67	320	215	602	2577

The 2020 Black Rockfish Survey began March 9th with no significant changes to survey methods or station locations but is currently suspended due to the COVID-19 pandemic.

Coastal Nearshore Demersal Groundfish Rod and Reel Survey – As part of the WDFW multispecies coastal nearshore rockfish rod and reel survey efforts, the Demersal Groundfish Survey was continued in the fall of 2019. The primary objective of fall survey efforts was to describe relative changes in population abundances of a variety of nearshore demersal groundfish species along the entire Washington Coast over time. These demersal focus species include China, Copper, Quillback, Tiger, Vermilion, and Yelloweye rockfish, as well as Kelp Greenling and Cabezon. Survey methods in the fall of 2019 were identical to the methods described in the spring Black Rockfish Survey, with a few key changes to target demersal species.

The demersal survey was conducted in the fall due to unsuitable ocean weather conditions in the winter, low charter vessel availability in the summer, and limited staff and vessel time in the spring due to other survey priorities. Study locations spanned the Washington Coast Marine Areas 2, 3 and 4, in depths from subtidal to 40 fathoms. Marine Area 1 has little known habitat containing demersal species and was not included in the survey.

As with the spring survey, fishing effort was spatially distributed within the confines of the Washington Coast survey grid scheme developed by WDFW for the 2015 spring rod and reel survey. Within this schema, one-kilometer squared grid cells were chosen for survey operations (Figure 9). Targeted grid cells in the fall survey were chosen based on known habitat of demersal rockfish species.



A) South Coast B) North Coast

Figure 9. The Washington coast survey grid scheme (1 km grid cells) and survey station (single GPS locations) selected for the 2019 fall Demersal Groundfish Survey in Marine Area 2 (A) and Marine Area 3 and 4 (B).

Rod and reel survey data spanning from 1998 to the spring of 2018 was used to confirm the presence of demersal rockfish habitat within a grid cell. For each target species, a grid cell was determined to have known habitat when at least one target species individual had been captured in the cell in a previous survey. Sixty-four cells were then chosen for survey operations roughly relative to the amount of known habitat for each target species by Marine Area and depth. Cells were selected to include both marginal and superior habitat locations for each target species, based on catch rates from previous WDFW rod and reel surveys. Similar to the 2019 spring Black Rockfish Survey, survey “stations” were chosen as a single GPS position within each grid cell (Figure 9) at the center of rocky substrate that would most likely provide high demersal groundfish catch.

Other method changes from the 2019 Black Rockfish Survey included a terminal tackle change to a salmon mooching rig baited with a white worm and a restriction of all angler fishing effort to on or near the bottom; schools of fish in the water column were not targeted. All other data collection and fishing effort methods were kept consistent with the spring survey described above.

Over 11 charter days, 64 stations were successfully surveyed along the coast (Table 5). Three to seven stations were surveyed each charter day dependent on weather conditions and the distance of target locations from port. Drift speeds ranged from 0.1 to 1.3 knots and no stations were fished at anchor. Total angler rod hours at successfully surveyed stations ranged from 2.5 to 2.9.

Table 5. Number of stations successfully surveyed in the 2019 spring survey by Marine Area and 10-fa depth bins.

	0-10 fathom	11-20 fathom	21-30 fathom	31-40 fathom	All Depths
Marine Area 2	4	1	6	2	13
Marine Area 3	5	8	2	2	17
Marine Area 4	12	17	5		34
Coastwide	21	26	13	4	64

While Black Rockfish was the most predominant specie captured across all Marine Areas, China Rockfish was encountered second most coastwide (Table 6). Other high catch demersal species included Cabezon, Kelp Greenling, and Copper Rockfish. Catch was diverse in Marine Areas 3 and 4 with 11 different rockfish species, Cabezon, Kelp Greenling, and Lingcod encountered.

Table 6. Catch (number) of all species per Marine Area and depth bin in the 2019 fall survey.

Species	Marine Area 2					Marine Area 3					Marine Area 4				Grand Total
	0-10 Fathoms	11-20 Fathoms	21-30 Fathoms	31-40 Fathoms	Total	0-10 Fathoms	11-20 Fathoms	21-30 Fathoms	31-40 Fathoms	Total	0-10 Fathoms	11-20 Fathoms	21-30 Fathoms	Total	
Black Rockfish	67	28	19	5	119	28	73			101	39	44	6	89	309
Buffalo Sculpin							2			2					2
Cabezon		1			1	2	14			16	14	16	1	31	48
Canary Rockfish			5	3	8	2		9	5	16	1	10	22	33	57
China Rockfish						27	26			53	31	33	4	68	121
Coho Salmon													1	1	1
Copper Rockfish						6				6	5	26	4	35	41
Deacon Rockfish	5		1		6	8	5		2	15	10	42		52	73
Flathead Sole			1		1										1
Jack Mackerel							1			1					1
Kelp Greenling						11	19			30	12	25	1	38	68
Lingcod	5		2	1	8	3	9	2	1	15	9	12	1	22	45
Pacific Sanddab			5		5										5
Pile Surf Purch			1		1										1
Quillback Rockfish				3	3			2	4	6	1	12	2	15	24
Red Irish Lord												2		2	2
Redstripe Rockfish								2		2					2
Tiger Rockfish						2	3		1	6					6
UNSP. Blue/Deacon Rockfish						1				1					1
Vermilion Rockfish						1				1			2	2	3
Yelloweye Rockfish			1		1		1	7	8	16					17
Yellowtail Rockfish			2	1	3	5	7	10	16	38		16	9	25	66
Grand Total	77	29	37	13	156	96	160	32	37	325	122	238	53	413	894

The 2020 Demersal Groundfish Survey is scheduled to occur in September and October with no significant changes to survey methods or station locations.

Summary of the 2019 Nearshore Coastal Pelagic Species Acoustic Trawl Methodology Survey of the California Current off Washington and Oregon – In 2019, the WDFW Marine Fish Science unit placed biologists onboard the F/V LISA MARIE in collaborative survey conducted by the NOAA/Southwest Fishery Science Center (SWFSC), the West Coast Pelagic Conservation Group (WCPCG) – a commercial fishery industry coalition, and the WDFW. The work accomplished in 2019 was a continuation of a “proof of concept” study initiated by industry in 2017 to extend acoustic surveying and sampling of the coastal pelagic species (CPS) assemblage to the nearshore, complementing the offshore NOAA/SWFSC California Current Ecosystem survey (CCES).

The CCES acoustic trawl methodology survey conducted annually by the NOAA Southwest Fisheries Science Center (SWFSC) is a critical tool for understanding the abundance and distribution of Coastal Pelagic Species (CPS) such as Pacific Sardine, Northern Anchovy, Pacific Herring, Pacific Mackerel, Jack Mackerel, and mesopelagic fishes. Although the survey employs the latest in technology, it has certain limitations. The NOAA R/V REUBEN LASKER does not survey nearshore, in waters shallower than 35-50 meters (m). As CPS distribution is known to extend into much shallower depths, a major point of concern – the potential bias of survey estimates of CPS biomass – has been identified in peer reviews of the survey and in Pacific sardine stock assessments, by the Pacific Fishery Management Council Scientific and Statistical Committee, and fishermen (PFMC 2018, 2018a). The second limitation relates to gear and sample timing. Species and size composition sampling are conducted with trawl gear at night after the daytime acoustic portion of the survey. Fishermen's experience suggests that species presence and composition in the upper water column can vary significantly from day to night. Additionally, very few fish samples are taken with trawl gear and this is also a concern noted in stock assessment reviews (PFMC 2017). In contrast to the NOAA research vessel, industry-operated seine vessels can fish in waters as shallow as six meters which, in some cases where the continental shelf is broad, may be over 10 miles closer to shore than the 35-50 m depth curve. Industry seiners can collect large numbers of samples, day or night, and release un-sampled catch with low mortality. They can also be equipped to collect acoustic data in nearshore waters.

Recognizing these limitations and opportunities, NOAA/SWFSC collaborated with the WCPCG in 2017 and 2019 to capitalize on the abilities of fishermen, the capacity of their vessels, and their specialized harvest equipment to achieve a survey methodology that could ultimately become the foundation for a more robust stock assessment. The approach – using an industry vessel to sample (acoustic and biologic) the nearshore – has been cited among preferred methods for addressing the potential bias of the CCES survey because it supports direct synoptic observation of the nearshore CPS assemblage and is most comparable (PFMC 2019). The costs of the first year were covered by industry (through the WCPCG) and by SWFSC Cooperative Research funds supplemented by the Washington Department of Fish and Wildlife in 2019. The WCPCG has applied for a federal Saltonstall-Kennedy grant to continue and expand the effort in 2020.

In 2019, The F/V LISA MARIE completed acoustic surveys of the nearshore distribution of CPS biomass off Washington and Oregon between June 17 and July 3. During this period, a total of 78 transects (27 transects off Washington and 51 off Oregon) as well as 30 purse seine sets were completed (Figure 10). Captained by a fisherman, the F/V LISA MARIE was outfitted with a Simrad EK 60 GPT echosounder, provided, installed and calibrated by NOAA scientists. The echosounder was connected to the vessel's hull-mounted 38-kHz split-beam transducer (Simrad ES38-B). WDFW biologists were onboard for the duration of the project to collect species composition and biological data, as well as monitor the acoustic equipment and maintain a log of seining operations. All project data were submitted to NOAA/SWFSC. Ageing was accomplished by the WDFW Ageing Unit.

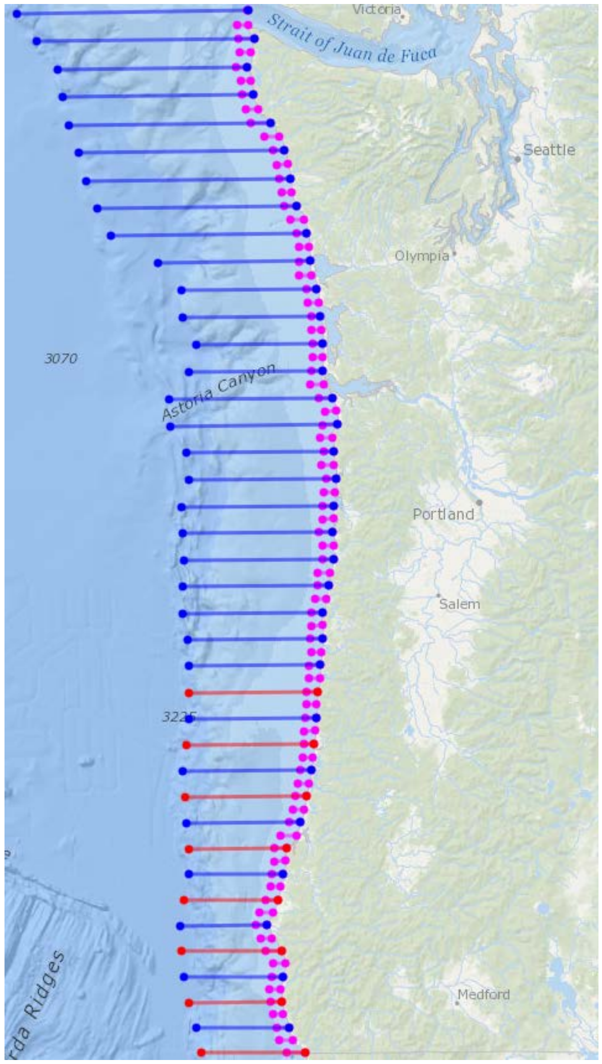


Figure 10. The R/V REUBEN LASKER's compulsory (red) and adaptive transect lines (blue) overlaid on the F/V LISA MARIE's nearshore lines (pink). Both vessels will run the transects to the east as close to shore as safely navigable.

The vessel completed transect lines moving from east to west, beginning as near to shore as safely navigable following the planned transect lines starting at the Canada-Washington border and ending at the Oregon-California border. Acoustic surveying began most mornings around 0630 PST (sunrise) and ended around 1900 PST (sunset). Sets were made after the completion of the transect and in proximity to the transect line if fish had been observed. Schools of fish observed while transiting to the next transect line were also set on. For all sets, the date, time, latitude, longitude, and general species composition were recorded. Size of schools wrapped and estimate of tonnage released were not documented. Released fish were presumed alive. Of the 30 completed sets, one was aborted due to the net getting stuck in the skiff, and four were dumped due to appearing to be all jellyfish. No sets were made on June 30 due to foul weather.

Biological data and species composition of each set was accomplished by collecting three dip net samples of approximately 4.5 kg (10 pounds) from the seine. The total weight of all species retained for sampling was 0.09 metric tons (Table 7). For each species per set, a total weight in grams and total number were reported. For Pacific Sardine, Northern Anchovy, Pacific Mackerel, Jack Mackerel, and Pacific Herring, a 50 fish sample was randomly collected from the total combined dip netted sample and weighed. Then each of the 50 fish were sampled for length and weight, with 25 of the fish also being sampled for sex, macroscopic maturity, and age structures (Table 8).

Table 7. Total weight and number of species retained for sampling.

Species	Count	Weight (g)
American Shad	1	225
Black Rockfish	2	4340
Cabezon	1	
Chinook Salmon	9	190
Chum Salmon	1	42
Greenling	4	4
Jack Mackerel	44	52559
Lamprey	1	386
Market Squid	364	4116
Northern Anchovy	57	2017
Pacific Cod	24	249
Pacific Herring	588	22254
Pacific Sardine	148	5790
Pacific Tomcod	14	29
Pacific Whiting	2	
Pomfret	5	650
Rockfish Unid	6	2
Rockfish Unid 2	2	8
Sandlance	25	288
Starry Flounder	9	1802
Surf Smelt	29	1028
Whitebait Smelt	189	951
Grand Total	**1525**	**96930**

Complete results from the study are reported in: Stierhoff, Kevin L., Juan P. Zwolinski, and David A. Demer. 2020. Distribution, biomass, and demography of coastal pelagic fishes in the California Current Ecosystem during summer 2019 based on acoustic-trawl sampling. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-626. https://doi.org/10.25923/nghv-7c40

Table 8. Length data from select species sampled from purse seine sets.

	Count	Length_mean	Length_max	Length_min
Fork length	581	176	536	20
Black Rockfish	1	50	50	50
Jack Mackerel	44	473	536	435
Pacific Cod	24	82	185	53
Pacific Herring	496	157	196	135
Pacific Tomcod	7	59	85	48
Starry Flounder	9	106	236	20
Standard length	296	141	243	91
Northern Anchovy	57	143	165	91
Pacific Herring	91	140	160	120
Pacific Sardine	148	141	243	122
Grand Total	**877**	**164**	**536**	**20**

References cited

PFMC 2017. Pacific Sardine STAR Pane Meeting Report. April 2017 Agenda item G.5.a STAR Panel Report. Pacific Fishery Management Council, Portland, Oregon.

PFMC 2018. Methodology Review Panel Report: Acoustic Trawl Methodology Review for Use in Coastal Pelagic Species Stock Assessments. April 2018 Agenda item C.3.a Attachment 2. Pacific Fishery Management Council, Portland, Oregon.

PFMC 2018a. Scientific and Statistical Committee Report on Acoustic Trawl Methodology Review – Final Approval. April 2018 Agenda item C.3.a Supplemental SSC Report 1. Pacific Fishery Management Council, Portland, Oregon.

Toward a Synoptic Reconstruction of West Coast Groundfish Historical Removals – Understanding and quantifying the historic fishery removals from a stock is essential to generating a time series of these data, which is, in turn, a crucial input to a variety of stock assessment methods and catch-based management approaches. Estimating population-specific removals is exceptionally hard, though, especially for periods with limited record keeping, aggregation of species into market categories, and aggregation of catch by outdated or poorly described geographic area. Sampling protocols, fishery diversity, catch versus landing location, dead discards, and species identification are significant additional complications that vary across time and space, and for which the level of reporting detail can vary widely.

Given that many groundfish stocks are distributed coast-wide and a complete time series of removals is needed, there is a need to coordinate approaches across the states of Washington, Oregon, and California to confront removal reconstruction challenges and establish common practices. Both California and Oregon have attempted historical removal reconstructions and continue making necessary revisions. Washington's first attempt in reconstructing commercial landings for Lingcod and rockfish market categories was completed to support 2017 PFMC groundfish stock assessments. Efforts are continuing to reconstruct flatfish catch histories. At least one report detailing data sources and analytical assumptions, and one report providing details on the history of fishery technology and prosecution, are expected to be completed in the next year. Additionally, significant progress has been made on a report documenting the history of the fishery, fishing technology, and harvest patterns for groundfish in Puget Sound. A definitive compendium on the topic is anticipated to be complete by the end of 2020.

Port Sampling/Creel Surveys of Recreational Fisheries – Estimates are made for recreational harvest of bottomfish, Pacific Halibut, salmonids, and other fishes caught in marine waters on an annual basis in Washington waters. Catch composition is estimated in two-month "waves" throughout the year via angler intercept surveys (i.e., creel sampling). Effort is estimated via a phone survey, which also samples two-month waves. Staffing for angler intercept surveys, contracting of the phone surveys, and all estimation procedures are the responsibility of the Fish Management Division's Coastal and Puget Sound Sampling Units, respectively. Details on the methods and results can be obtained by contacting Wendy Beeghley (coastal; Wendy.beeghley@dfw.wa.gov), Anne Stephenson (Puget Sound; Ann.stephenson@dfw.wa.gov), or Eric Kraig (estimation; Eric.kraig@dfw.wa.gov).

III. Reserves

Marine Reserve Monitoring and Evaluation – Due to changes in program priorities and staffing limitations brought on by intensive ROV survey work since 2011, very little directed monitoring of marine protected areas and reserves has occurred in Puget Sound in recent years and no monitoring activities were conducted in 2019.

A systematic evaluation of data from SCUBA-based surveys collected between 1995 and 2010 at six sites for which sufficient data are available has been performed to evaluate reserve efficacy (LeClair et al. 2018). When only results from short-term monitoring programs are available it can be difficult for resource managers to gauge the effects of regulatory actions aimed at long-term resource conservation. This is particularly true for species that are long-lived, slow-growing, and late to mature. For these species, demographic changes in response to management actions may be slow to manifest and difficult, or impossible, to detect over time spans of fewer than two generations. Data obtained from long-term monitoring is more likely to capture changes over time in fish communities composed of a wide variety of life spans and other life history attributes.

The PSMFS Unit examined a sixteen-year series of dive data for long-term changes or trends in abundance, size, and distribution of several key bottomfish species. Comparisons were made among and between those sites surveyed that fall within marine protected areas (MPAs) and those that do not. In order to gain added perspective, data were compared to those acquired from four different scuba-based studies conducted prior to the commencement of surveys at four of the sites (Figure 11).

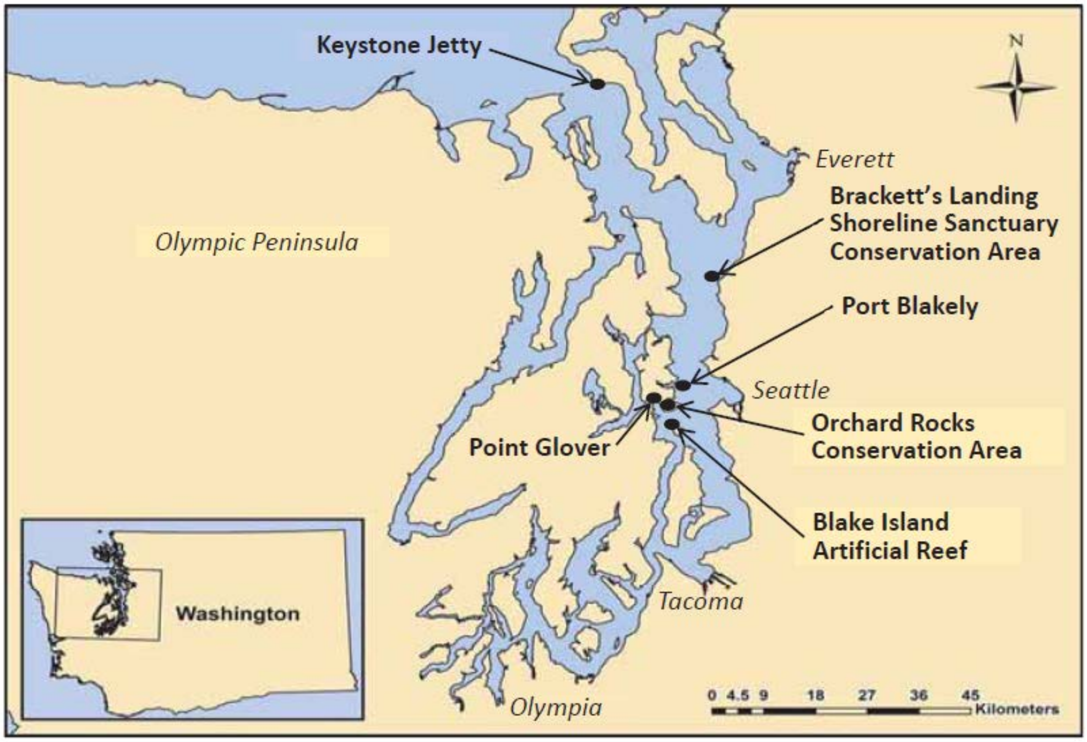


Figure 11. Locations systematically surveyed via scuba from 1995 through 2010.

At all six sites, species composition was dominated by just three taxonomic groups: rockfishes, surf perches, and greenlings, though the relative proportions of those groups varied among sites. Species richness also varied within and among groups, and within and among sties. Curiously, the greatest number of species observed was at the most heavily fished site, while the fewest number observed was at the most protected MPA. In pairwise comparisons of species composition by season (spring and fall), nearly all were significantly different both within and between sites. Though not confirmed, the data suggest that differences in species composition may occur along a latitudinal gradient. The species that contributed most to the differences between sites were Striped Seaperch, Puget Sound Rockfish, and Brown Rockfish.

At most sites, there was evidence of strong juvenile rockfish recruitment in 2006/07 for one or more of the following species: Black Rockfish, Quillback Rockfish, and Copper Rockfish. This event was made apparent by relatively high density "pulses" in length classes over time, whereby, unusually high numbers of juvenile fish enter a population and, with growth, sequentially moved from smaller to larger length-classes over time (i.e., a detectable "pulse" in length-class frequency was detected over time.)

Findings were compared to studies that were conducted at four of the surveyed sites during years prior to 1995. One of the most striking contrasts was the complete absence of Lingcod noted at Bracket's Landing during surveys conducted in 1975/76. From 1995-2010, Lingcod frequency of occurrence at Bracket's Landing was 100%. Furthermore, the annual mean lengths for Lingcod were greater at Bracket's Landing than at any other site surveyed. All four of the comparable studies indicate changes over time in rockfish species composition.

The informative perspective on the recent status of several key bottomfish species at six nearshore sites in central Puget Sound in this report will serve as an important benchmark for future surveys. However, the ability to identify and interpret trends over time, particularly for rockfishes, was confounded by factors such as high interannual variability in juvenile recruitment, poorly understood post recruitment inter- and intraspecific interactions, and, at some sites, discontinuous sampling and changes in protection statuses. In comparing MPA sites to non-MPA sites, we were not able to discern any trends that could be unequivocally linked to harvest management actions, though at least two observations suggest evidence of a protection response. First, at the Orchard Rocks Conservation Area, subsequent to the year (1998) that it was afforded MPA status, a persistent increase in rockfish density and biomass occurred. Second, the mean length, density, and biomass of Lingcod at the Keystone Conservation Area increased after the year (2002) that it was afforded MPA protection. Unlike rockfishes, which typically grow at substantially slower rates in Puget Sound, Lingcod grow rapidly, particularly during the first several years of their life. The rapid growth, and accompanying rapid increase in fecundity, of Lingcod makes it a potentially valuable first-response species for detecting positive effects of conservation efforts.

Based on the findings of this evaluation, the PSMFS Unit is currently collaborating with the Seattle Aquarium and Point Defiance Zoo and Aquarium to resume surveys in 2020, coinciding with approximately two elapsed generations for key species.

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LeClair, L, Pacunski, R, Hillier, L, Blaine, J, and D Lowry. (2018). Summary of findings from periodic scuba surveys of bottomfish conducted over a sixteen-year period at six nearshore sites in central Puget Sound. Washington Department of Fish and Wildlife Technical Report. Olympia, WA. FPT 18-04. 189 pp.

IV. Review of Agency Groundfish Research, Assessment, and Management

A. Hagfish

The Washington Hagfish Commercial Fishery – Opened in 2005 under developmental regulations, the Washington hagfish fishery is small in scale, exporting hagfish for both frozen and live-fish food markets in Korea. Management of the Washington hagfish fishery is challenged by a lack of life history information, partial fishery controls, and high participant turnover. Active fishery monitoring and sampling began in 2009. Due to limited agency resources, only fishery dependent data programs have been developed to inform management, including logbooks, fish receiving tickets, and biological sampling of catch. Efforts have been undertaken to refine and improve these programs, including improving systematic sampling, developing species composition protocols, and shifting to use the maturity scale developed by Martini (2013). The time series using this scale now supports evaluation. Interest remains in conducting a study similar to research conducted in California to evaluate escapement relative to barrel dewatering-hole size but funding sources have not been identified.

The Washington hagfish fishery operates by rule only in offshore waters deeper than 50 fathoms and is open access. Figure 12 presents annual landings since 2005. Landings do not necessarily represent where fishing occurred. Washington licensed fishers can fish federal waters off Oregon and land catch into Washington. Live hagfish vessels typically fish grounds closer to their homeports, while at-sea freezing allows some vessels to fish further afield. The fishery catches predominantly Pacific Hagfish. Occasionally, Black Hagfish are landed incidentally. A few trips attempting to target Black Hagfish were successful but the market was not receptive. Fish ticket landing data cannot distinguish between species as only one code exists. Hagfish are caught in long-lined barrels constructed from olive oil or pickle barrels modified with an entrance tunnel and dewatering holes (Figure 13).

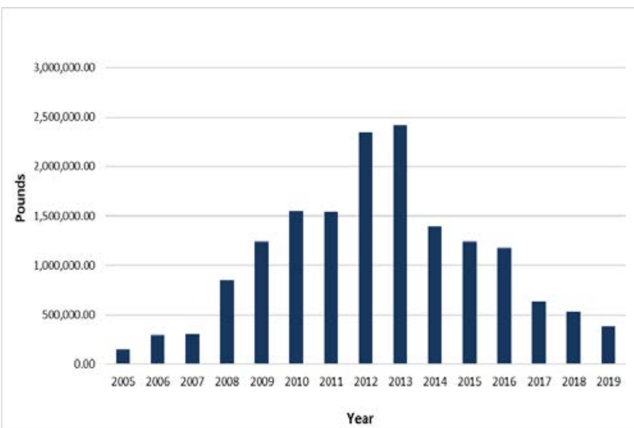

Figure 12. Hagfish Landings in pounds by Washington 2005-2019.

Figure 13. Barrels used in the WA commercial hagfish fishery.

Fishing occurs on soft, muddy habitat along the entire outer coast of Washington and northern Oregon (Figure 14). Pacific Hagfish predominate from 50-80 fa. Deeper sets, up to 300 fa, have been made to target Black Hagfish. Pacific and Black Hagfish ranges appear to overlap between 80 and 100 fathoms. Median CPUE is about 4.5 pounds. Instances of high CPUE are evident, as evidenced by reports of “plugged” barrels.

Biological sampling data is collected from Pacific and Black Hagfish and consist of length, weight, maturity, and egg counts for female maturity stage 4 through 7; however, only Pacific Hagfish data are reported here. Male and female hagfish present similar size distributions (Figure 15). The in-sample largest specimen was a 67 cm female, the smallest a 26-cm female. An evaluation of maturity suggests year-round spawning. Fecundity is low, with the number of mature eggs --stages 6 & 7 (Table 9) averaging 24 eggs per female. Few females with developed eggs have been sampled; the 2017-2019 sample contained 13% mature females.

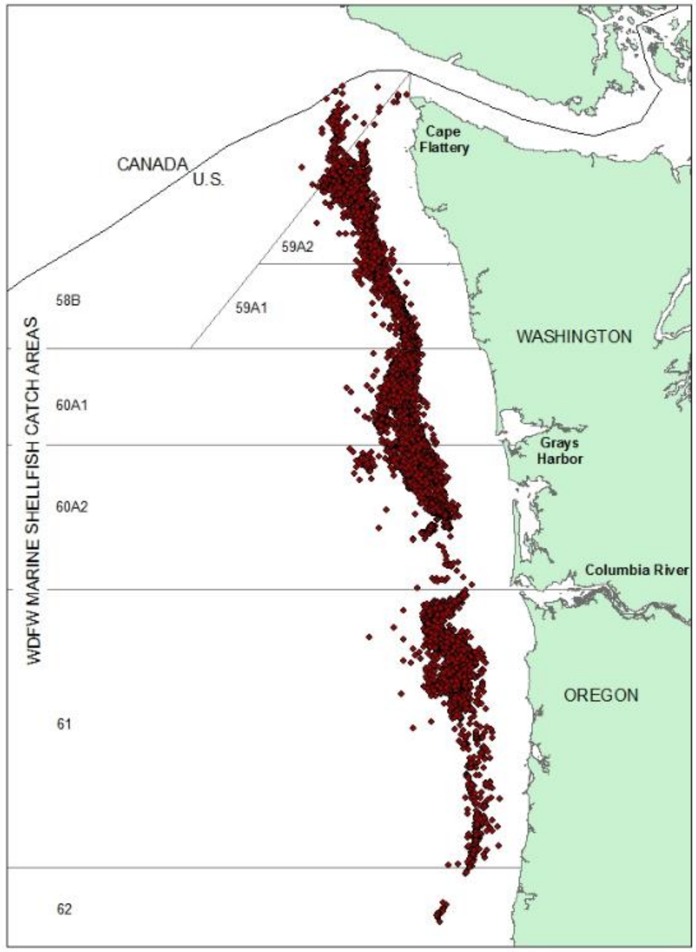

Figure 14. Distribution of Hagfish fishing trips off WA and OR, from Washington logbooks, 2005-18.

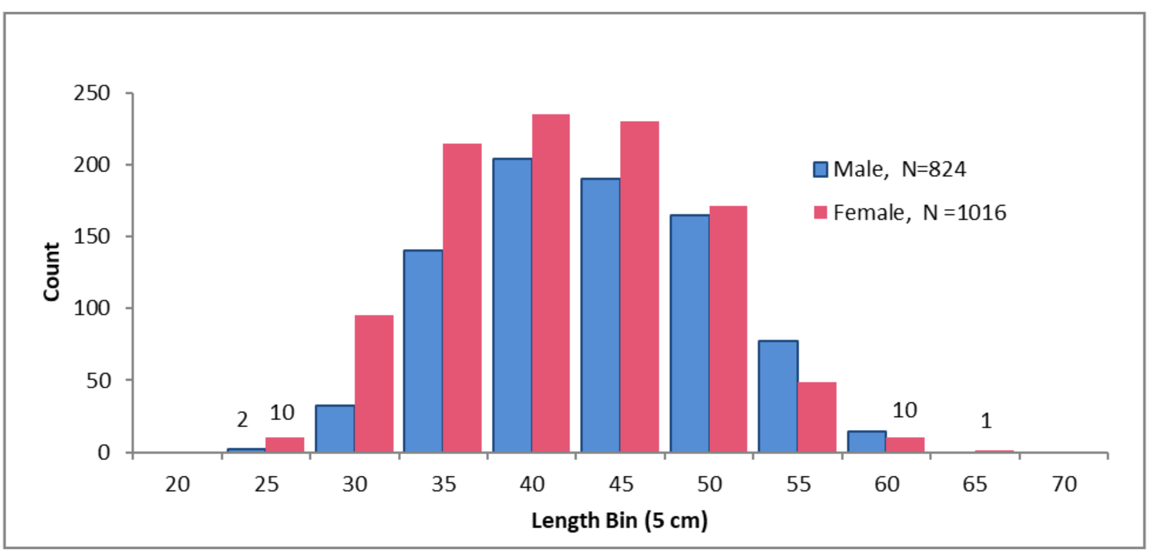

Figure 15. Length (cm), male and female Pacific Hagfish only, 2017-19.

Table 9. Average egg count per female for mature Pacific hagfish collected from Washington landings during 2017-19.

Pacific Hagfish	Count_samples	Egg Count_ min	Egg Count_max	Egg Count_average
Maturity stage 6	117	9	49	25
Maturity stage 7	16	5	39	19
Total	133			24

B. North Pacific Spiny Dogfish and other sharks

Books Series on Sharks of the Northeast Pacific Ocean – Together with Dr. Shawn Larson of The Seattle Aquarium, in 2018 Dayv Lowry co-edited a pair of books entitled Northeast Pacific Shark Biology, Research, and Conservation, Part A and Part B (Figure 16). In addition to co-editing the books Dayv also co-authored the introduction to each volume and was the sole author of the conclusions chapter in Volume 78. The concept for the books grew out of a biennial meeting on cowshark research and management that began in 2004 and eventually morphed into the Northeast Pacific Shark Symposium (NEPSS). This conference, the fourth of which was held in La Paz, MX in March of 2020, is now the second largest international gathering of elasmophiles in North America, behind only the American Elasmobranch Society's annual meeting.

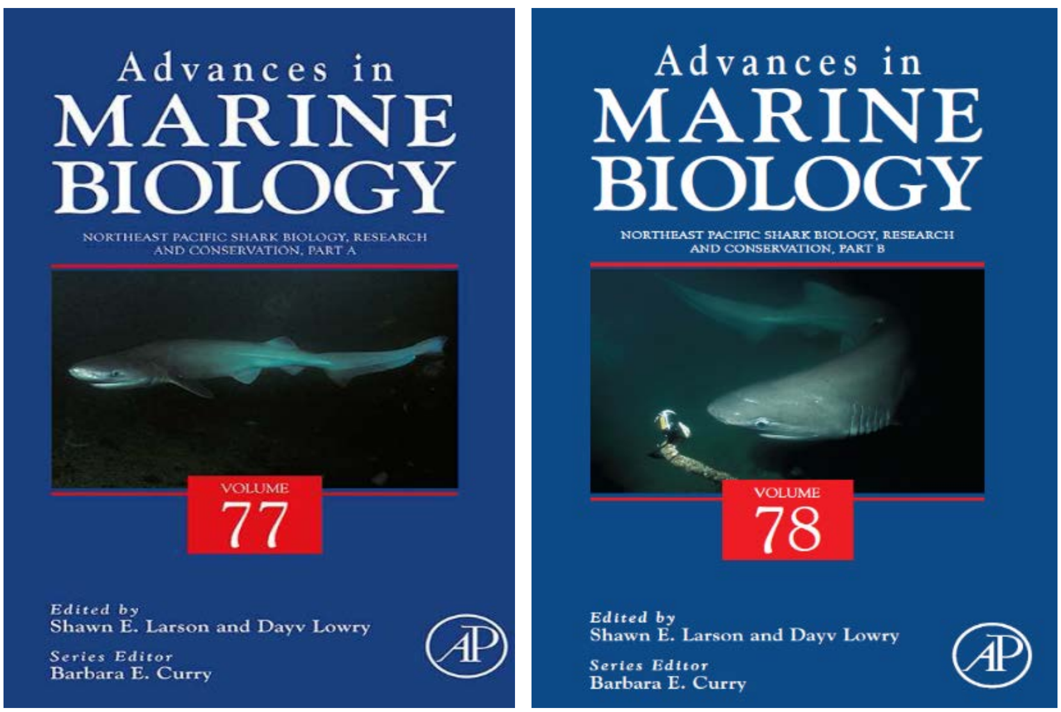

Figure 16. Covers of the two volumes on shark research and management published in 2018.

Following on the heels of the 2018 volumes, which largely dealt with research and management from Alaska to California, Mexican colleagues who had attended the 2018 NEPSS inquired about a companion volume focusing on research and management in Mexican waters. Shawn and Dayv agreed to co-edit this volume, which was subsequently broken into two volumes by the publisher, and lead authors were selected for chapters paralleling those in the 2018 volumes. In late 2019 Volume 83 was published, and in early 2020 Volume 85 followed it (Figure 17).

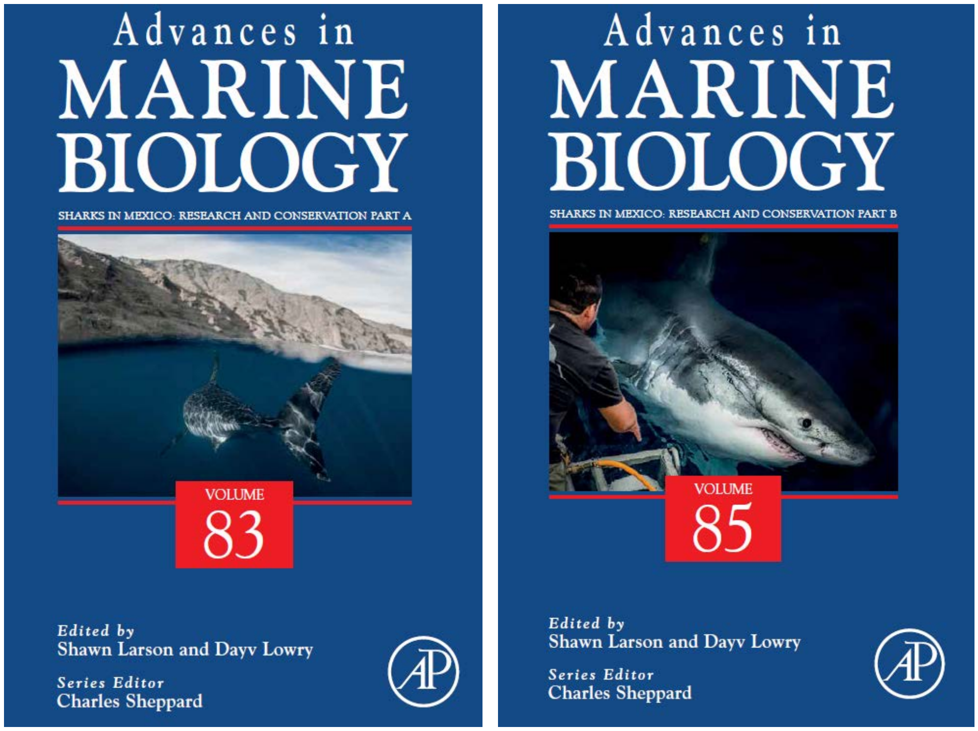

Figure 17. Covers of the two volumes on shark research and management in Mexico.

As of March 2020, chapters in the three published volumes had been cited 59 times and purchased for direct download through the publisher over 1,300 times (Table 10). This citation rate is slightly low, but the download rate is well above normal and chapters have also been featured in blog postings and other social media almost 600 times.

Table 10. Details for chapters in both volumes of Northeast Pacific Shark Biology, Research, and Conservation.

Volume	Authors	Title (abbreviated)	Cites	Downloads	Social
77	Lowry+Larson	Introduction to Vol 77	3	49	10
77	Ebert et al.	Biodiversity, life history, and conservation	7	101	24
77	Larson et al.	Review of current conservation genetics	7	161	76
77	Bizzaro et al.	Diet composition and trophic ecology	11	109	60
77	Reum et al.	Stable isotope applications	3	144	37
77	Matta et al.	Age and growth of elasmobranchs	4	89	47
78	Larson+Lowry	Introduction to Vol 78	3	50	13
78	King et al.	Interactions with directed and incidental fisheries	5	93	10
78	Kacev et al.	Modeling abundance and life history parameters	2	44	22
78	Grassman et al.	Sharks in captivity: husbandry, breeding, education	3	151	46
78	Mieras et al.	Economy of tourism and citizen science	5	177	189
78	Lowry	Conclusion: future of management and conservation	5	91	16
83	Lowry+Larson	Introduction to Vol 83	1	9	3
83	Sladaña-Ruiz et al.	Shark biodiversity and conservation in Pac MX	0	21	18
83	Galván-Magaña et al.	Ecology, role of apex predator, and conservation	0	26	16
83	Sandoval-Castillo	Conservation genetics of elasmobranchs in Pac MX	0	11	3

Collaboration on DFO Dogfish Longline Survey – In October of 2019 Dayv Lowry joined DFO staff aboard a 6-day leg of their annual dogfish longline survey. This afforded the opportunity to observe DFO's at-sea, integrated electronic monitoring system and get hands-on experience with IT infrastructure necessary to support such a system. This will be invaluable as the WDFW moves forward with building out the data collection system on the newly acquired 56' R/V SALISH ROVER.

Several North Pacific Spiny Dogfish and Spotted Ratfish were brought back to Olympia for use in educational presentations. The first of these was at Washington State University in Pullman, where Dayv lectured on shark research, management, and conservation to the WSU Shark Conservation Club, followed by a detailed dissection of two dogfish and one ratfish. The second was to over 300 sixth grade students at Rainier Middle School in Puyallup, where Dayv dissected a shark, showcased a collection of preserved jaws and other specimens, and answered questions about general shark biology and ecology. Both presentation were well received and return engagements have been booked for 2020.

C. Skates

No specific, directed research or management to report.

D. Pacific Cod

No specific, directed research or management to report.

E. Walleye Pollock

No specific, directed research or management to report.

F. Pacific Whiting (Hake)

No specific, directed research or management to report.

G. Grenadiers

No specific, directed research or management to report.

H. Rockfishes

i. Research

Developing an Index of Abundance for Yelloweye Rockfish Off the Washington Coast – Yelloweye Rockfish was declared overfished by the PFMC in 2002 and since has been a "choke species" limiting groundfish fishing opportunities along the U.S. west coast. One of the many challenges in monitoring and managing this stock is the lack of adequate fisheries-independent surveys. The conventional bottom trawl survey does not consistently sample Yelloweye Rockfish habitat; and the only survey used in the past assessments was the International Pacific Halibut Commission's fixed-station setline survey. For Yelloweye Rockfish caught by the IPHC survey off the Washington coast, more than 90% were from one single station off Cape Alava and the minimum size was 40 cm (older than 10 years old). The abundance trend derived from the IPHC survey is uninformative for the population in Washington waters, thus the need for another survey.

Since 2006, the Washington Department of Fish and Wildlife has been conducting pilot projects to identify the best location, season, and hook-size for constructing a representative Yelloweye Rockfish abundance index trend. Working together with Jason Cope from NOAA's FRAM Division, the CMFS Unit has conducted pilot projects, compared abundance trends, and is working toward future research recommendations. Surveys continued in 2019 as noted above in the Surveys section (due to captures of more than just Yelloweye Rockfish).

ROV Studies of Yelloweye Rockfish in the greater Puget Sound/Georgia Basin DPS – The PSMFS Unit completed a two-year survey of the U.S. portion of the Yelloweye Rockfish and Bocaccio DPSs in January 2017 (see previous TSC reports for preliminary results). Survey stations where Yelloweye Rockfish were observed were prioritized to enable a population estimate for the species to be made as soon as possible. No Bocaccio were encountered at any survey station, though four fish were noted during "exploratory" deployments. Video review of these transects is on-going, with the majority of the remaining videos containing few or no fish of interest.

In March and April of 2018, the WDFW conducted a three-week survey in a portion of the Yelloweye Rockfish and Bocaccio DPSs lying in Canadian waters of the Gulf Islands within the southern Strait of Georgia. The goals of this survey were to: 1) estimate the population size of Yelloweye Rockfish (and Bocaccio as possible) within the survey area; and 2) utilize a stereo-camera system to collect accurate length information of Yelloweye Rockfish, which is needed for the length-based spawner-per-recruit (SPR) model that will be used as a basis for tracking recovery of the species per the conditions of the federal Recovery Plan. The survey was designed using the same Maximum Entropy (MaxEnt) modelling approach as the 2015-16 Puget Sound survey. The model was developed by Bob Pacunski with data provided by Dana Haggarty (DFO Canada). Funding for the survey was provided by NOAA (Dan Tonnes). A total of 64 transects were completed over 13 sampling days. Yelloweye rockfish were scarce in the southern portion of the survey area, but encounters increased as sampling moved northward. Preliminary review of the video has identified at least 57 Yelloweye rockfish, but additional fish may be detected during the full video review process. No Bocaccio were observed during the survey. Initial review of the video transects is now complete and secondary reviews are ~90% complete.

In August 2018, the WDFW conducted a three-week survey of the San Juan Islands, which lies within the US portion of the DPSs for Bocaccio and Yelloweye Rockfish, with a total of 60 transects completed over 13 sampling days. This survey had the same goals and sampling design as the survey of the Canadian Gulf Islands and was meant to facilitate cross-border comparison of rockfish prevalence and size distribution. Consistent with previous ROV surveys of the San Juan Islands in 2008 and 2010, Yelloweye Rockfish were seldom encountered, with only 11 fish observed on eight transects. Canary rockfish were rarely encountered in the 2008 and 2010 surveys, but 33 fish were seen on eight transects in the most recent survey. No Bocaccio were seen in this survey. Initial review of the video transects is now complete and secondary reviews are ~75% complete.

In October 2018, the WDFW partnered with DFO Canada to conduct a 14-day survey of the southern and central Strait of Georgia. This survey utilized the WDFW-owned ROV deployed from the 40-m long Canadian Coast Guard Ship VECTOR. The primary goals of this survey were to 1) evaluate densities of “inshore rockfish,” as defined by DFO, inside and outside established Rockfish Conservation Areas; and 2) use a stereo camera system to obtain length measurements of Yelloweye Rockfish that will be used in population recovery models. This survey was also designed based on the results of a MaxEnt habitat suitability model. The majority of stations were randomly assigned to High probability polygons inside and outside of selected RCAs, but is some cases it was necessary to hand-place stations due to a lack of matching habitat outside of an RCA. A total of 85 transects were completed in 14 survey days. The habitat in this survey was characterized by high densities of sponges, which provided a highly-complex and crevice-rich environment utilized by several rockfish species. In contrast to the previous two surveys, Yelloweye Rockfish were commonly encountered, with over 200 fish of all sizes observed during the survey. No Bocaccio were observed. Reviews of the transect videos have just started and are being conducted jointly by the WDFW and DFO, with the bulk of the effort provided by DFO.

In August 2019 the WDFW MFS unit initiated an ROV survey focused on benthic rockfishes, Lingcod, and Kelp Greenling within the interior marine waters of Washington using a two-stage survey design. Within the Yelloweye Rockfish and Bocaccio DPSs, the survey design was based on the results of a MaxEnt habitat suitability model. Due to a lack of reliable bathymetry coverage for the waters of the Strait of Juan de Fuca west of the western DPS boundary, the MaxEnt approach could not be implemented, and the survey design was based on an evaluation of known and suspected habitats identified during previous drop-camera and ROV surveys. After 450 stations were randomly selected (Figure 18), the survey began on August 6 but was suspended on September 26th due to an equipment failure on the support vessel R/V MOLLUSCAN. Because the WDFW was already in the process of purchasing a replacement vessel for the MOLLUSCAN, we opted not to replace the failed equipment in order to apply those funds to the purchase price of the new vessel. The new vessel, the R/V SALIH ROVER, was acquired in December 2019 and is currently undergoing final retrofitting and testing prior to resuming the survey in June 2020.

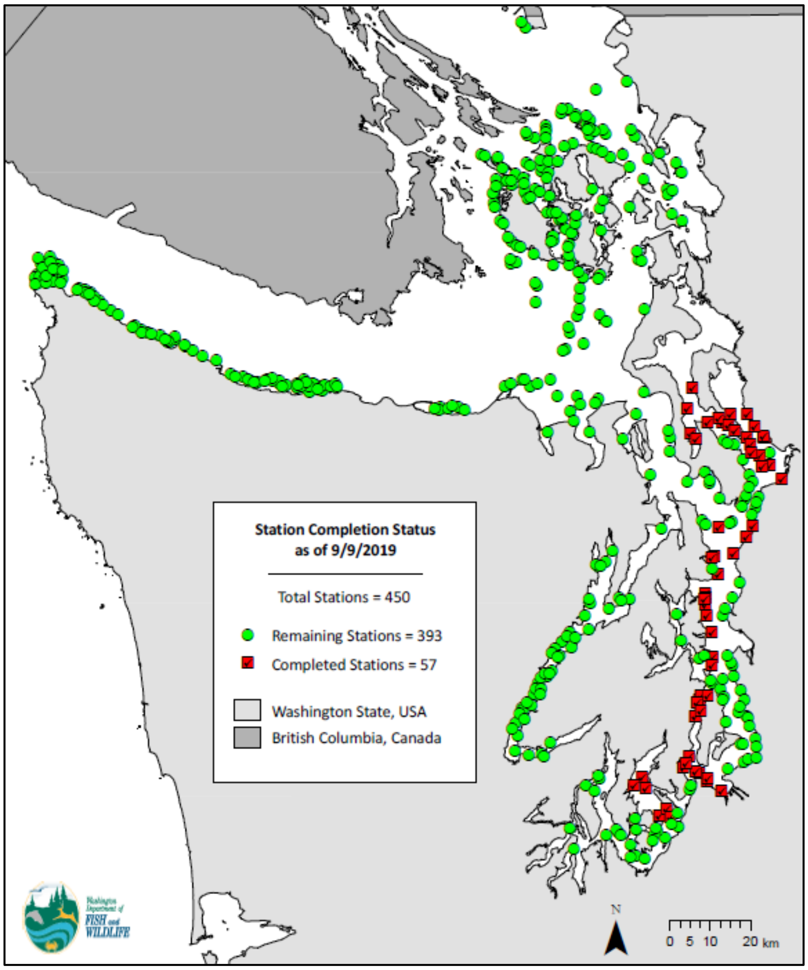

Figure 18. Randomly selected stations for the 2019-21 ROV survey. Stations all far within the highly suitable stratum predicted by the MaxEnt model based on prior ROV survey data.

ii. Management

No specific, directed management to report.

I. Thornyheads

No specific, directed research or management to report.

J. Sablefish

No specific, directed research or management to report.

K. Lingcod

Formal Stock Assessment in Puget Sound – Over the past several years concerns have been raised by the public about Lingcod populations within Puget Sound, especially in the San Juan Archipelago and Central Puget Sound off Edmonds. Specifically, some constituents are concerned that the current management regime is not protective enough, as legal-sized fish (26-36”) are hard to find after only a few weeks into the six-week season (May 1 – June 15). Though declining trends in CPUE are apparent in some regions, the issue seems largely to be a result of increased fishing pressure/effort, especially near urban centers, since 2010. In addition to the slot limit and short season noted above, the daily bag limit is one fish per angler and fishing is not allowed deeper than 120' to reduce barotrauma impacts on rockfish. The WDFW considers this a highly conservative management regime.

The WDFW has nearly completed an evaluation of Lingcod populations using a Stock Synthesis model, which is a size- and age-structured population assessment tool. This type of model is commonly used for coastal fisheries and is data intensive. The model structure for Puget Sound Lingcod utilizes commercial and recreational landings, length frequency data, age data, and catch-per-unit-effort data to evaluate historic and current trends in the population. When complete, managers will be able to use the output from the Stock Synthesis model to inform management decisions for Lingcod in Puget Sound. Finalization of the report is expected in late 2020.

Pre-season Lingcod Rod and Reel Test Fishing Survey to Evaluate Claim of "No More Fish" – The PSMFS Unit conducted a four-day test fishing survey targeting Lingcod in Marine Catch Area 7 (San Juan Islands) during April 2019 prior to the opening of the recreational Lingcod fishing season (Figure 19). This was a pilot study with a primary goal of obtaining basic catch per unit effort (CPUE) and length frequency data for Lingcod under simulated recreational fishery conditions for potential use in a Puget Sound Lingcod stock assessment, and to evaluate the claim made by several recreational anglers that "no more legal sized fish are around." Secondary goals included documenting bycatch and obtaining genetic samples from select fish species to inform demographic models of Puget Sound bottomfish.

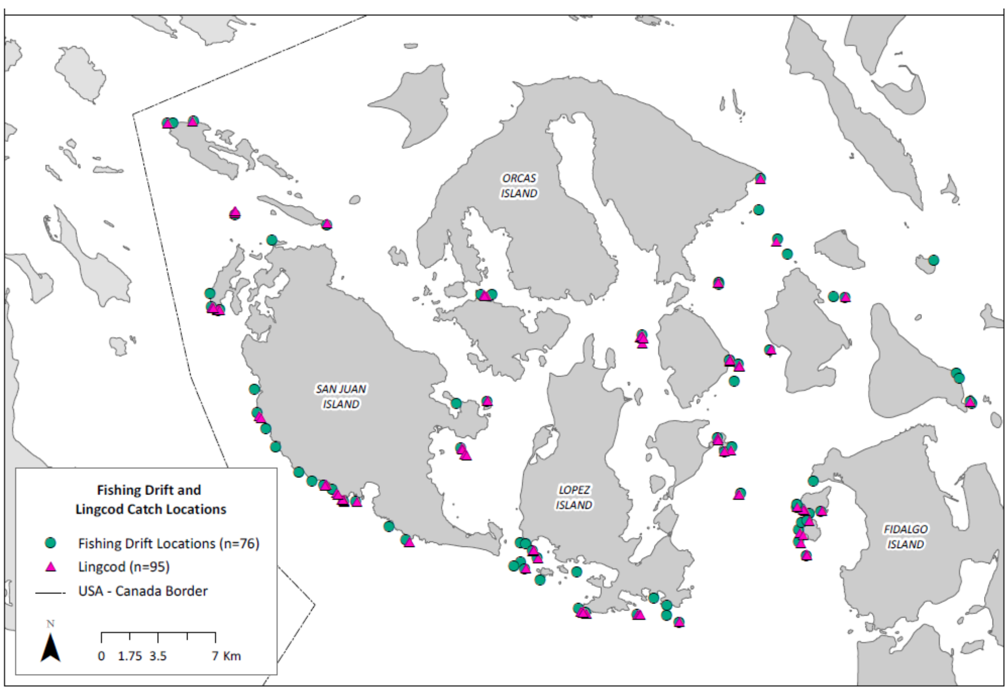

Figure 19. Fishing sites and locations of Lingcod caught during the 2019 pre-season survey.

Fishing was conducted from two WDFW Enforcement Program vessels during daylight hours on April 25-26 and 29-30, 2019. Six Unit staff, seven WDFW Police officers, and two Washington Conservation Corps (WCC) members fished during the survey.

A map of potential fishing locations was developed from prior remotely operated vehicle (ROV) surveys, SCUBA observations, and known recreational fishing locations. Fishing sites were chosen on the water as weather and currents allowed and were coordinated among vessels in an attempt to distribute effort across the broadest geographic extent possible (Figure 1). Tidal exchanges during the hours fished were less than 5 feet and were assumed to have a negligible effect on catches. One or more drifts were performed at each site and all fishing was conducted in accordance with WDFW recreational bottomfish regulations. The starting and ending times and locations of each drift were recorded when the first line went into the water and when the last line was retrieved, respectively. The number of anglers actively fishing varied and was also recorded for each drift. Terminal tackle was chosen by the individual angler and included curly tail jigs, flies, Point Wilson darts, whole squid, whole herring, and live bait.

The total fishing time over 76 drifts was 40 hours and 55 minutes resulting in a total of 174 rod-hours (Table 11). In total, 139 fish were caught with Lingcod being the most numerous (n = 95). Lingcod were caught throughout the study area, with the majority of fish ranging from 400mm to 550mm (total length) and legal-sized fish (650mm and 900 m) accounting for 14% of the lingcod catch (Figure 20). Bycatch included Cabezon (n = 8), Kelp Greenling (n = 5), Quillback Rockfish (n = 4), Red Irish Lord (n = 4), Brown Irish Lord (n = 1), and Brown Rockfish (n = 1). Genetics samples were taken from select Cabezon, Copper Rockfish, and Lingcod. All fish were released alive, except for two Kelp Greenling that were retained as live bait. Two Quillback Rockfish were released using a SeaQualizer descending device after showing signs of barotrauma post-capture. The conclusion of the survey was that Lingcod are abundant in the area and that competition due to high angler interest is the most likely reason that some anglers are unable to land a legal fish. Management options are being considered to reduce competition in this derby style fishery.

Table 11. List of fishing locations, number of rods, and fishing times during the 2019 pre-season Lingcod survey.

General Fishing Location	Number of Rods	Total Fishing Time	Fishing Start Latitude	Fishing Start Longitude	Fishing End Latitude	Fishing End Longitude
Bell Island Marker	4	00:40:00	48.594653	-122.977087	48.593793	-122.973013
Bellevue point	4	00:36:00	48.529208	-123.163414	48.525044	-123.159724
Bird Rocks	3	00:55:00	48.484478	-122.761285	48.483075	-122.762981
Black Rock	4	00:53:00	48.558348	-122.770048	48.559028	-122.769979
Black Rock	4	00:01:00	48.546774	-122.766345	48.546620	-122.766851
Blakely Island Shoal	4	01:12:00	48.572093	-122.842897	48.570897	-122.841083
Boat Harbor	4	00:29:00	48.547613	-122.578653	48.547882	-122.579612
Broken Point	5	00:09:00	48.594902	-122.968057	48.592857	-122.952450
Buckeye Shoal	3	00:24:00	48.625075	-122.729912	48.623054	-122.731761
Burrows Lighthouse	5	00:12:00	48.476818	-122.714636	48.476563	-122.714289
Burrows Lighthouse North	5	00:07:00	48.478369	-122.714358	48.479255	-122.713612
Castle Island	5	00:28:00	48.422311	-122.822879	48.422305	-122.822877
Cattle Pass	10	00:22:00	48.444364	-122.950023	48.444937	-122.948719
Cone Islands	4	00:45:00	48.593011	-122.683262	48.609457	-122.722026
Cypress Reef	4	00:13:00	48.616796	-122.721639	48.614240	-122.723502

Danger shoal	6	00:58:00	48.638724	-123.182234	48.638971	-123.183524
Davidson Rock	5	00:56:00	48.413419	-122.812572	48.422369	-122.820222
Davis Point	3	00:38:00	48.452964	-122.934680	48.452371	-122.933455
Deadman Bay	4	00:16:00	48.510106	-123.148105	48.507616	-123.143870
Deadman Island	5	00:16:00	48.457595	-122.944560	48.456940	-122.942661
Deadman Island 2	2	00:04:00	48.457024	-122.940215	48.456622	-122.939870
Dennis Shoal	4	00:32:00	48.457748	-122.713328	48.439272	-122.692606
Eagle Point	4	00:39:00	48.458894	-123.039603	48.458153	-123.038909
East Blakely, Black Rock	4	00:27:00	48.558037	-122.769991	48.552744	-122.769496
East James Island	4	01:20:00	48.510559	-122.768492	48.550349	-122.771679
East Vendovi Island	3	00:06:00	48.612852	-122.599731	48.611421	-122.598564
Fidalgo Head	3	00:21:00	48.491122	-122.700765	48.491068	-122.698376
Green Can North of Black Rock	4	00:55:00	48.555979	-122.762967	48.546822	-122.765356
Green Point, Speiden Island	4	00:43:00	48.633059	-123.105967	48.634462	-123.106311
Griffon Bay	5	01:33:00	48.509762	-122.994171	48.501778	-122.999540
Hughes Bay	5	00:23:00	48.426757	-122.833448	48.422916	-122.832773
Iceberg Point	7	00:30:00	48.418466	-122.891672	48.417421	-122.887789
Iceberg Point	7	00:32:00	48.420916	-122.896306	48.418123	-122.892464
Kanaka Bay	5	00:29:00	48.480180	-123.081182	48.479867	-123.085526
Kellett Bluff	5	00:52:00	48.585913	-123.196223	48.585885	-123.196674
Kellett south	2	00:10:00	48.586221	-123.195031	48.585891	-123.195388
Kellett Bluff	4	00:45:00	48.587793	-123.201949	48.586604	-123.200561
Long Island	5	00:10:00	48.436927	-122.927889	48.435388	-122.926003
Lydia Shoal	4	00:46:00	48.601275	-122.778796	48.602100	-122.780615
Lydia Shoal	4	01:18:00	48.600190	-122.778756	48.601931	-122.781804
McKay Harbor	5	00:20:00	48.441268	-122.897590	48.441807	-122.897876
Mummy Rocks	4	00:19:00	48.448946	-122.930481	48.448290	-122.928492
N Lime Kiln	4	00:12:00	48.520565	-123.156192	48.519994	-123.155065
N Stuart Island	4	00:21:00	48.690334	-123.217095	48.689816	-123.218828
North Allan Island	7	00:18:00	48.469021	-122.706190	48.468372	-122.711029
North Allan Island	7	00:29:00	48.468298	-122.710812	48.470047	-122.700749
North Boat Harbor	4	00:18:00	48.550343	-122.581123	48.551106	-122.582586
North of north of pile	5	00:23:00	48.491545	-123.117900	48.491069	-123.117034
North of pile	4	00:30:00	48.489407	-123.108202	48.488796	-123.106701
North Pile Point	4	00:33:00	48.486844	-123.101000	48.483750	-123.096211
North Turn Island	4	00:18:00	48.535765	-122.972161	48.535954	-122.971671
Northeast turn	5	00:09:00	48.689394	-123.234315	48.689376	-123.234340
NWR North of Eagle Point	4	00:29:00	48.466356	-123.053652	48.464754	-123.049839
Outside Roche ROV transect	4	00:15:00	48.624639	-123.151447	48.624330	-123.146068
Pea Pod Rocks	4	00:07:00	48.641081	-122.745241	48.641012	-122.744518
Pile Point	4	00:47:00	48.480127	-123.091382	48.481028	-123.092532
Point Colville	5	00:31:00	48.417195	-122.823115	48.414904	-122.818897
Smallpox Bay	3	00:14:00	48.542308	-123.165795	48.542200	-123.164363
South Brown Island	5	00:27:00	48.534473	-122.997776	48.532254	-122.997850
South Burrows Island	4	00:49:00	48.473018	-122.704210	48.475145	-122.710127
South Huckleberry	4	00:22:00	48.533955	-122.568465	48.532601	-122.567457
South Huckleberry Island	4	01:21:00	48.534792	-122.569914	48.535267	-122.566763
South James Island	3	00:29:00	48.507401	-122.774707	48.507782	-122.772073
South Point Lawrence	4	00:22:00	48.658838	-122.743757	48.658670	-122.744853
Southeast Burrows Island	5	00:26:00	48.474237	-122.694504	48.474328	-122.694352
Southwest Burrows	5	00:10:00	48.475804	-122.711478	48.475908	-122.711814
Swirl Island	4	00:33:00	48.417585	-122.847488	48.416597	-122.845533
The Cones	5	00:22:00	48.592841	-122.673922	48.592468	-122.672948
Turn point	5	00:10:00	48.689243	-123.239098	48.689599	-123.238354
West Allan Island	5	00:42:00	48.464220	-122.713151	48.456669	-122.704580
West Henry Island	1	00:07:00	48.595265	-123.202960	48.593514	-123.203389
West James Island	4	01:31:00	48.515487	-122.780168	48.511911	-122.764342
West SJI south of Deadman Bay	4	00:11:00	48.496163	-123.128662	48.495754	-123.126755
West Strawberry Island	4	00:50:00	48.563835	-122.736760	48.563807	-122.736992
Whale Rocks	5	00:12:00	48.446732	-122.944352	48.447824	-122.944199
Williamson Rock	4	00:52:00	48.450032	-122.706980	48.451208	-122.703493

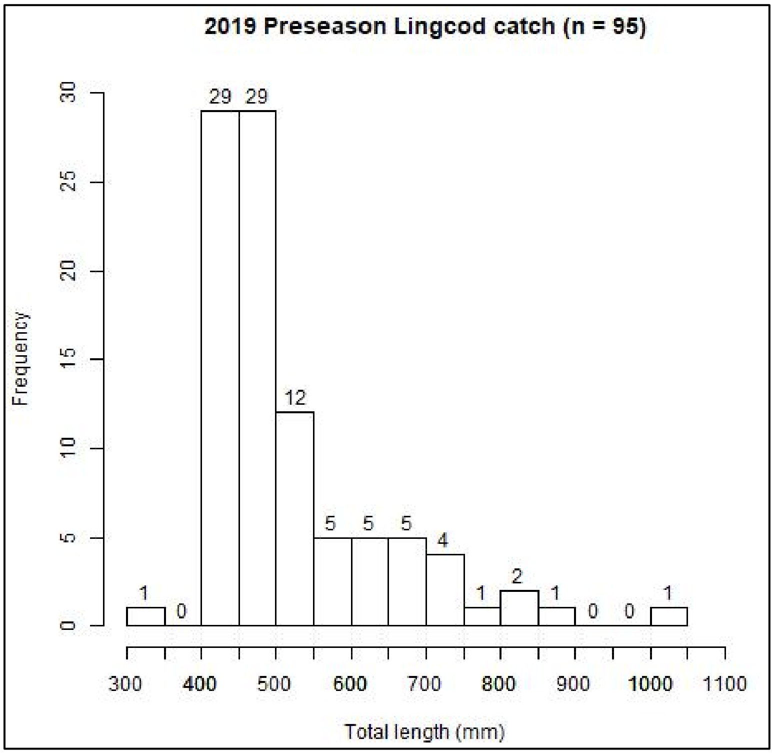

Figure 20. Length distribution of Lingcod in the 2019 pre-season survey.

L. Atka mackerel

No specific, directed research or management to report.

M. Flatfishes

No specific, directed research or management to report.

N. Pacific halibut & IPHC activities

Disagreement Regarding Permitted Activities has been Resolved – In 2010 the Puget Sound/Georgia Basin distinct population segments of three species of rockfish were listed under the federal Endangered Species Act. As a result, action immediately began to: 1) close several commercial fisheries with the potential to bycatch these species; and 2) ensure all remaining State-level fishery activities in the region were appropriately permitted. In 2012 a five-year Section 10(a)1(A) permit was issued to cover recreational bottomfish hook-and-line and shrimp beam trawl fisheries in Washington waters affected by the listing. In 2017 this permit was up for reassessment and renewal. After consultation with NOAA Fisheries, MFS Unit staff revised the Incidental Take Permit Application and Fishery Conservation Plan associated with this permit to include recreational and commercial shrimp pot fisheries, for which recent research had demonstrated a very small risk of bycatch for listed rockfish species. All documentation for permit renewal was submitted to NOAA well in advance of the October 2017 renewal deadline.

Unfortunately, during the term of the initial permit, a regulation change had been made regarding the prosecution of recreational Pacific Halibut fisheries in Puget Sound. Specifically, on halibut fishing days in Marine Catch Area 6 (the eastern Strait of Juan de Fuca, from Low Point to Port Townsend) it was made permissible to retain Lingcod and Pacific Cod from waters deeper than 120'. The 120' depth restriction was put in place for all bottomfish fisheries in 2010 (Pacific Halibut are not bottomfish as defined by Washington Administrative Code), and was a conservation measure considered when evaluating bycatch levels associated with recreational fishing for the original Section 10 permit. NOAA Fisheries viewed any and all harvest of Lingcod and Pacific Cod during this fishery as a potential violation of the Section 10 permit, while the WDFW's Intergovernmental Ocean Policy Unit contended that such harvest was being duly reported on the permit covering Pacific Halibut fisheries, thus all potential risks to ESA-listed rockfish were being adequately accounted for.

In March of 2019 the WDFW agreed to eliminate Lingcod retention in the Pacific Halibut fishery in Marine Catch Area 6, removing the threat of targeted fishing over rocky habitat. This decision was arrived at after considering the increased Pacific Halibut quota for 2019, and thus the potential for increased exposure duration of deep-water rockfish to fishing pressure during the targeted halibut fishery. The new Section 10 permit covering recreational bottomfish fishing, commercial shrimp trawling, and now including both recreational and commercial shrimp pot fishing, was submitted in March of 2020.

O. Other groundfish (and forage fish) species

Pacific Sand Lance Genetic Research – Together with partners at the NWFSC, Shoreline Community College, Sea Doc Society, Washington State DNR, North Pacific Research Board, and UW's Friday Harbor Labs members of the PSMFS Unit and MFF unit are working to investigate regional variation in population structure of Pacific Sand Lance. Samples have been collected from the San Juan Archipelago, Eagle Harbor (Bainbridge Island), and Nisqually River delta thus far, and additional collections are planned. Fish have been obtained via beach seining and digging on mud flats during low tide. Thus far, amplification of the DNA has gone well, and is being overseen by the Shoreline Community College molecular genetics lab. Results thus far show no population differentiation at any observable geographic scope. Additional funding is being sought to process samples recently acquired from three sites in British Columbia and five sites in Alaska.

Other species – No addition directed research or management to report. Various species of groundfish are counted, and density and abundance estimates are derived for them, during ROV, scuba, and trawl surveys described above and below.

V. Ecosystem Studies

Puget Sound Ecosystem Monitoring Program (PSEMP) update – The Toxics-focused Biological Observation System (TBiOS) team at WDFW has been conducting regular status and trends (S&T) monitoring of toxic contaminants in a wide range of indicator species in Puget Sound, including assessments of health effects on biota, since 1989. TBiOS' most recent regular S&T monitoring includes assessments of English sole (a benthic indicator) in 2015, 2017, and 2019, and Pacific herring (a pelagic indicator) in 2014, 2016, and 2018. In addition, TBiOS recently conducted a large-scale assessment of contaminants in winter adult Chinook salmon (i.e. Blackmouth) from sport fisheries in seven marine areas of Puget Sound (winter 2016/17). Data from the Blackmouth study was used by the Washington Department of Health to set fish consumption advisories for this species in Puget Sound. Data from the English sole, Pacific herring, and Blackmouth studies are summarized online at the Puget Sound Partnership's Toxics in Fish Vital Sign website. The Toxics in Fish Vital Sign is a communication tool that helps distill TBiOS' complex contaminant monitoring information into usable metrics for ecosystem recovery managers.

In addition to benthic and pelagic indicator species, TBiOS has recently adopted two new indicators for assessment of contamination in the *nearshore* environments of Puget Sound. To ascertain the effects of contaminants on early the life-stages of salmon, TBiOS conducted two assessments (2016 and 2018) of juvenile Chinook salmon from 12 major rivers and deltas of Puget Sound. In addition, TBiOS recently adopted mussels as a nearshore indicator and has conducted three, Puget Sound-wide, assessments of contaminants using transplanted (i.e. caged) mussels over the winters of 2012/13, 2015/16, and 2017/18. TBiOS has secured long-term funding to conduct regular nearshore contaminant surveys with these species into the future.

TBiOS has also conducted a number of special studies in recent years. For instance, in 2012 they conducted a large-scale assessment of contaminants in Dungeness crab and spot prawn from nine marine areas and three urbanized bays of Puget Sound. This data was used by the Department of Health to set shellfish consumption advisories for these species. In addition, TBiOS has conducted several recent studies to track the effectiveness of large-scale removals of creosote-treated wooden pilings (Port Gamble Bay 2014 and 2015, and Quilcene Bay 2012-2015). In these studies, TBiOS used Pacific herring embryos, a particularly sensitive life-stage, to test for ecological impacts of chemicals leaching out of the pilings. Publications and reports for a number of these studies are available at the TBiOS list of publications website, as well as at the aforementioned Toxics in Fish Vital Sign website. For additional details on TBiOS research regarding toxic contaminants in Puget Sound biota contact Jim West at james.west@dfw.wa.gov or 360-902-2842.

VI. Publications

In 2019-20 staff of the MFS Unit published the documents indicated below.

Blaine, J, Lowry, D, and R Pacunski. (2020). 2002-2007 WDFW scientific bottom trawl surveys in the southern Salish Sea: species distribution, abundance, and population trends. Fish Program Technical Report No. 20-01. Washington Department of Fish and Wildlife, Olympia, WA. 237 pp.

Burger, M, Sandell, T, Fanshier, C, Lindquist, A, Biondo, P, and D Lowry. (2020). Findings of the 2016-17 southern Salish Sea acoustic mid-water trawl survey. Fish Program Technical Report No. 20-03. Washington Department of Fish and Wildlife, Olympia, WA. 48 pp.

Hersherberger, P, MacKenzie, AH, Gregg, JL, Lindquist, A, Sandell, T, Groner, ML, and D Lowry. (2019). A geographic hot spot of *Ichthyophonus* infection in the Southern Salish Sea, USA. Diseases of Aquatic Organisms. Accepted, online.

Larson, SE, and D Lowry (eds.) (2019). *Sharks in Mexico: Research and Conservation Part A.* Advances in Marine Biology. Academic Press. Volume 83. 157 pp. ISBN: 9780081029169.

- Lowry, D and S Larson. (2019). Introduction: The sharks of Pacific Mexico and their conservation: why should we care? In: Larson, SE, and D Lowry (eds). *Sharks in Mexico: Research and Conservation Part A.* Advances in Marine Biology. Academic Press. Volume 83: 1-9.

Lowry, D, Pacunski, R, Kraig, E, Tribble, V, and T Tsou. (2020). Conservation Plan for reducing the impact of selected fisheries on ESA-listed species in Puget Sound, with an emphasis on bocaccio and yelloweye rockfish. Washington Department of Fish and Wildlife, Olympia, WA. 100 pp.

Petrou, EL, Fuentes-Pardo, AP, Rogers, LA, Orobko, M, Tarpey, C, Moss, ML, Yang, D, Pitcher, TJ, Sandell, T, Lowry, D, Russante, DE, and L Hauser. (submitted) Functional genetic diversity in an exploited marine species and its relevance to management. Nature Ecology and Evolution. Submitted Nov 2019.

Sandell, T, Lindquist, A, Dionne, P, and D Lowry. (2019). 2016 Washington State herring stock status report. Fish Program Technical Report No. 19-07. Washington Department of Fish and Wildlife. 87 pp.

VII. Conferences and Workshops

In 2018-19 staff of the MFS Unit presented at, participated in research presented at, and/or arranged symposia at, several regional scientific meetings, and education/outreach events, as indicated below.

WKUSER Workshop on Unavoidable Survey Reduction. Seattle, WA, January 2019. Theresa Tsou, Bob Pacunski, and Jen Blaine attended.

PFMC ROV Survey and Statistical Methods Review Panel. Santa Cruz, CA, February, 2019. Theresa Tsou, Bob Pacunski, and Dayv Lowry attended.

Northeast Pacific Shark Symposium. La Paz, MX, March 2019. Dayv Lowry attended, co-organized, and presented two talks.

Three additional conferences were planned but were cancelled due to COVID-19 concerns.

VIII. Complete Staff Contact Information

WDFW permanent marine fish management and research staff include (updated 4/2020):

Headquarters and State-wide Staff

Statewide Marine Fish Lead Theresa Tsou 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 tien-shui.tsou@dfw.wa.gov 360-902-2855	Statewide Marine Forage Fish Lead Phill Dionne 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 phillip.dionne@dfw.wa.gov 360-902-2641	Senior Forage Fish Biologist Todd Sandell 16018 Mill Creek Blvd. Mill Creek, WA 98012 todd.sandell@dfw.wa.gov 425-379-2310
Forage Fish Biologist Adam Lindquist 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 adam.lindquist@dfw.wa.gov 360-902-2704	Forage Fish Biologist Patrick Biondo 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 patrick.biondo@dfw.wa.gov 360-902-2672	Forage Fish Technician Kate Olson 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 katie.olson@dfw.wa.gov 253-569-9442
Forage Fish Biologist Eric Bruestle 16018 Mill Creek Blvd. Mill Creek, WA 98012 eric.bruestle@dfw.wa.gov 425-775-1311	Forage Fish Technician Aidan Coyle 16018 Mill Creek Blvd. Mill Creek, WA 98012 aidan.coyle@dfw.wa.gov 425-775-1311	Forage Fish Technician Stephanie Lewis 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 stephanie.lewis@dfw.wa.gov 360-545-2365
Marine Fish Biologist Lisa Hillier 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 lisa.hillier@dfw.wa.gov 253-250-9753	NPFMC Member Bill Tweit 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 william.tweit@dfw.wa.gov 360-902-2723	

Puget Sound Staff

Puget Sound Marine Fish Lead Dayv Lowry 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 dayv.lowry@dfw.wa.gov 360-902-2558	Marine Fish Research Scientist Bob Pacunski 16018 Mill Creek Blvd. Mill Creek, WA 98012 robert.pacunski@dfw.wa.gov 425-775-1311 Ext 314	Senior Marine Fish Biologist Larry LeClair 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 larry.leclair@dfw.wa.gov 360-902-2767
Marine Fish Biologist Jen Blaine 16018 Mill Creek Blvd. Mill Creek, WA 98012 jennifer.blaine@dfw.wa.gov 425-379-2313	Marine Fish Biologist Andrea Hennings 16018 Mill Creek Blvd. Mill Creek, WA 98012 andrea.hennings@dfw.wa.gov 245-379-2321	Senior Technician, Captain Mark Millard 16018 Mill Creek Blvd. Mill Creek, WA 98012 mark.millard@dfw.wa.gov 360-301-4256
Scientific Technician Katie Kennedy 16018 Mill Creek Blvd. Mill Creek, WA 98012 katherine.kennedy@dfw.wa.gov 425-379-2315	Scientific Technician Ian Craick 16018 Mill Creek Blvd. Mill Creek, WA 98012 ian.craick@dfw.wa.gov 425-379-2315	
TBiOS Lead Jim West 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 james.west@dfw.wa.gov 360-902-2842	Toxics Research Scientist Sandy O'Neill 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 sandra.oneill@dfw.wa.gov 360-902-2666	Toxics Research Scientist Louisa Harding 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 louisa.harding@dfw.wa.gov 360-480-2882

Toxics Biologist Rob Fisk 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 robert.fisk@dfw.wa.gov 360-902-2816	Toxics Biologist Mariko Langness 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 mariko.langness@dfw.wa.gov 360-902-8308	

Coastal Staff

Coastal Marine Fish Lead Lorna Wargo 48 Devonshire Rd Montesano, WA 98563 lorna.wargo@dfw.wa.gov 360-249-4628	Marine Fish Biologist Rob Davis 48 Devonshire Rd Montesano, WA 98563 robert.davis@dfw.wa.gov 206-605-5785	Marine Fish Biologist Donna Downs 48 Devonshire Rd Montesano, WA 98563 donna.downs@dfw.wa.gov 360-249-4628
Senior Scientific Technician Jamie Fuller 48 Devonshire Rd Montesano, WA 98563 jamie.fuller@dfw.wa.gov 360-249-1297	Senior Scientific Technician Tim Zepplin 48 Devonshire Rd Montesano, WA 98563 timothy.zepplin@dfw.wa.gov 360-580-6286	Marine Fish Biologist Kristen Hinton 48 Devonshire Rd Montesano, WA 98563 kristen.hinton@dfw.wa.gov 360-249-4628
Scientific Technician Michael Sinclair 48 Devonshire Rd Montesano, WA 98563 michael.sinclair@dfw.wa.gov 360-249-4628		
Intergovernmental Coastal Policy Manager **VACANT** 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 360-902-2182	Coastal Marine Policy Lead Corey Niles 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 corey.niles@dfw.wa.gov 360-902-2733	Coastal Shellfish and Halibut Lead Heather Hall 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 heather.hall@dfw.wa.gov 360-902-2487
Coastal Marine Policy Analyst Whitney Roberts 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 whitney.roberts@dfw.wa.gov 360-902-2675	Coastal Biologist Victoria Knorr 1111 Washington St SE, 6th Floor Olympia, WA 98504-3150 victoria.knorr@dfw.wa.gov 360-480-9130	

Committee of Age Reading Experts

2020 Committee Report

Prepared for the Sixty-first Annual Meeting of the

Technical Subcommittee of the Canada-USA Groundfish Committee

April 23 – 24, 2020

Prepared by
Delsa Anderl
2019-2021 CARE Chair

National Oceanic Atmospheric Administration
National Marine Fisheries Service
Resource Ecology and Fisheries Management
Alaska Fisheries Science Center
Age and Growth Program
7600 Sand Point Way NE
Seattle, Washington
98115

A. CARE Overview

1. History

The Committee of Age-Reading Experts (CARE) is a subcommittee of the Canada-USA Groundfish Committee's Technical Subcommittee (TSC) charged with the task to develop and apply standardized age determination criteria and techniques and operate within the Terms of Reference, approved by the TSC in 1986, and the CARE Charter, developed in 2000 and approved by the CARE in 2004.

2. Report Period

This report covers the work period of January 1 – December 31, 2019. This reporting period includes information from the 2019 Committee Report and Executive Summary prepared by outgoing CARE Chair Kevin McNeel. Current officers through June 30, 2019 (elected at April CARE 2017 Meeting) are:

- Chair – Kevin McNeel (ADF&G-Juneau)
- Vice-Chair – Barbara Campbell (CDFO)
- Secretary – Nikki Atkins (NWFSC)

The 2019 CARE Conference Minutes* have been approved by the CARE members and will be added to the CARE websites 'Previous Meetings' section. The Secretary prepared the first draft minutes for the 2019 CARE Conference and was reviewed by the exiting officers (Chair, Vice-Chair and Secretary) prior to distributing the final draft to members for review and approval.

*All tables and appendices refer to the 2019 CARE Conference Minutes (pp. 9 – 34).

3. CARE Conference

CARE meets biennially for a conference that usually lasts three days. Conferences typically consist of one and a half "business" days and one and a half days for a hands-on calibration workshop at microscopes to review and standardize age reading criteria with any extra time scheduled for a specific focus group or workshop.

a. Overview:

The most recent biennial CARE Conference was held in Seattle, WA, April 9-11, 2019 at the NOAA Western Regional Center at the Alaska Fisheries Science Center (AFSC), Sand Point facility, and hosted by the Age and Growth AFSC staff. The conference was attended by 34 CARE members (Table 1) from seven participating agencies: ADF&G (3), AFSC (15), CDFO (3), IPHC (3), NEFSC (1), NWFSC/PSMFC (4), ODFW (2), and WDFW (3). Following the CARE conferenced, AFSC hosted a two-day FT-NIRS workshop (Appendix II). The next CARE Conference in 2021 will be held prior to the TSC meeting in April in Newport, Oregon. The following officers were elected at the April 2019 meeting and will take office July 1, 2019:

- Chair – Delsa Anderl (AFSC)
- Vice-Chair – Andrew Claiborne (WDFW)
- Secretary – Nikki Atkins (NWFSC-PSMFC)

b. Business Session Highlights:

i. Scientific presentations:

An unofficial Call for Presentations and Posters for the 2019 CARE Conference was sent to members on November 2, 2018 (Appendix II). Submissions were requested to address current research and the 2018 TSC recommendations: yelloweye rockfish, differentiating cryptic species, and evaluating machine reading of otoliths.

Abstracts were due to the CARE Chair by March 8, 2019. There were two oral presentations submitted for the scientific presentation session. (Appendix III).

Two oral presentations in PowerPoint format were given during the CARE meeting:

1. Andrew Claiborne, Results of the yelloweye rockfish exchanges: comparison of age determinations from Alaska, British Columbia, and the coasts of Washington and Oregon

2. Chris Hinds, Importance of juvenile sablefish growth and methods of estimation

ii. Agency Reports:

AFSC (Thomas Helser), CDFO (Steve Wischniowski), IPHC (Joan Forsberg), ADF&G (Kevin McNeel), NWFSC-PSMFC (Patrick McDonald), WDFW (Andrew Claiborne), and ODFW (Lisa Kautzi) provided reports summarizing and updating agency activities, staffing, organization, new species and projects. There was no representative at CARE from SWFSC, CDFG, or ADF&G- Homer and Kodiak, but a written report was sent from Kodiak and presented at the meeting. Details from agency reports are available in the meeting minutes.

iii. Discussion of long-term storage of otoliths in glycerin-thymol:

This discussion was continued from the 2013, 2015, and 2017 CARE meetings and in response to ongoing TSC recommendations and the development of an ad-hoc working group. Stephen Wischniowski (DFO), Joan Forsberg (IPHC), and Delsa Anderl (AFSC) gave updates on their agency's progress on otolith storage. DFO is continuing to remove glycerin solutions from their historical otoliths and moving them to dry storage, but IPHC and AFSC is continuing to store otoliths in glycerin-thymol. Inconsistencies in climate-controlled storage and/or incorrect preparation of the glycerin solution likely caused degradation in the otoliths. IPHC is combating otolith degradation by controlling the mixing of glycerin solutions and AFSC sent samples of both degraded and intact otoliths to Seattle University to analyze and find potential reasons for degradation.

iv. Workshop on the Rapid Estimation of Fish Age Using Fourier Transform Near-Infrared Spectroscopy (FT-NIRS)

An international workshop was held at the Alaska Fisheries Science Center in Seattle, WA, April 11th - 12th, 2019, after the CARE meeting. The 2-day workshop was given to kick-off a NOAA strategic initiative by distributing information on near-infrared spectroscopy, multivariate predictive modeling, stock assessments, and fish age estimation. The workshop focused on the underlying technology, recent developments and case studies in estimation of age and animal physiology, and issues and research need to operationalizing FT-NIRS for age estimation. During the workshop, 63 individuals from the United States, Canada, Australia, and Korea participated in seminars, hands-on operation, and discussion panels. This workshop was the first part of a two-year initiative to evaluate FT-NIRS for age estimation and work is ongoing.

v. Hands-on Session Highlights and Demonstrations:

A total of 21 readers reviewed 7 species during the hands-on workshops and, mainly for the purpose of calibration between age readers and agencies. Members aged yelloweye rockfish, Pacific cod, sablefish, longnose skate, and shortspine thornyhead. A demonstration for measuring rockfish otolith with image analysis was demonstrated by Charles Hutchinson (AFSC) and Kevin McNeel (ADF&G). See species aged, participating members, and agencies in Table 2.

B. CARE Subcommittee (Working Group) Reports:

1. **CARE Website Subcommittee:** Jon Short (AFSC) lead and webmaster, Nikki Atkins (NWFSC).

Subcommittee members addressed topics and recommendations drafted in 2017. Topics included summarizing the outdated state of the current website, the utility of old website, and the development of the new website as well as the updated forum. The new site is active at caredev.psmfc.org, but the subcommittee members needs help to develop the new site and maintaining the database supplying the table information. The CARE Forum is currently active and old topics have been moved to the new site.

2. **CARE Manual/Charter Subcommittees:** Elisa Russ (ADF&G-Homer), Betty Goetz (AFSC), Barb Campbell (DFO).

   Most subcommittee members were not able to attend the 2019 CARE meeting, but the lead was able to provide input post-workshop. Final drafts of chapters will be finalized for review by the CARE membership and update prior to the 2021 meeting. Charter subcommittee members will review charter update recommendations and edit the charter for review at the 2021 CARE meeting. The subcommittees are seeking further membership to help with finalizing documents.

3. **Yelloweye rockfish ad hoc working group:**

   Age readers from CDFO, WDFW, ADF&G-ADU, and PSMFC aged specimens from the radiocarbon sample using images. Specific features discussed were identification of the 1st, preferred aging axis, edge interpretation, splitting vs. banding of fine annuli in older specimens, and the importance of tracing annuli from the surface onto the reading surface to help interpret noise.

4. **Rougheye/Blackspotted/Shortraker Rockfish ad hoc working group:**

   AFSC, DFO, and ADF&G worked together to provide updates, collect morphometric and shape data, and compare model results at CARE. Steve Wischniowski provided a sample of rougheye and blackspotted otolith images and Charles Hutchinson created otolith measurements using ImagePro Plus and compared measurements with otolith weight and age to the current AFSC model output. Kevin McNeel created shape estimates and otolith measurements using R and looked for statistical groups and identification error. Each agency is currently working to address specific concerns for identifying these species and a summary was provided to the group.

C. Age Structure Exchanges

Age structure exchanges occur periodically to assess calibration among CARE age-reading agencies. Depending on results, specimens of interest (e.g. demonstrated biases) are then reviewed and discussed. Exchanges are tracked by the CARE Vice-Chair. Data from exchanges are available on the CARE website.

There were five age structure exchanges initiated in 2019 and none in 2020. A request was made to CARE members during the CARE meeting to document and finalize age structure exchanges started in 2018 and 2019. All 2018 exchanges and four of the five 2019 exchanges have been finalized and will be added to the CARE websites ‘Structure Exchange table’. See 2018 and 2019 exchanges on p. 7 and 8.

D. CARE & TSC Recommendations

In 2019 recommendations were made by CARE to CARE and TSC to CARE. Some recommendations may take more than one cycle to complete. This list contains recommendations that are still pending or provide background for those made by CARE/TSC in response to prior recommendations.

1. 2019 CARE to CARE
    a. Recommends the CARE Manual working group (Elisa Russ, Betty Goetz, Jodi Neil) finalize and add the following sections before the 2021 CARE meeting:
        i. Lingcod Otolith Ageing Procedures section (is written, needs to be added)
        ii. Sablefish Ageing Procedures section (is written, needs to be added)
        iii. Thin Sectioning Method section – add a section under the General Ageing Procedures (is written, needs to be added)
        iv. Add section on baking otoliths under General Otolith Ageing Procedures; to be written and finalized
        v. Ergonomics section including equipment checklist as appendix (is written, needs to be added)
    b. Recommends the Manual working group continue the revision and expansion of the CARE Manual on Generalized Age Determination with the following sections drafted or revised for review and addition of edits to the manual by the 2021 CARE meeting:
        i. Walleye Pollock Ageing Procedures section (use AFSC manual as starting point); not written
        ii. Spiny Dogfish Ageing Procedures section – summary of spiny dogfish age determination paper by Dr. Cindy Tribuzio; not reviewed
        iii. Rockfish Ageing Procedures section; not reviewed
            1. Edit to avoid redundancy with Thin Sectioning section;
            2. Revise/move some information to General Otolith Ageing Procedures section where appropriate;
        iv. Remove documentation sections regarding changes to CARE Manual
            1. See Recommendation C to post archived editions.
            2. Remove 2015 recommendation to add Acknowledgements section.
    c. Recommends the CARE Manual working group submit archived editions of the CARE Manual to the website working group for posting on the CARE website to preserve historical records. Most archived material may be lost, but Betty Goetz offered to retrieve old files.
    d. Recommends that the CARE Forum be updated and added to the new website.
    e. Recommends the CARE searchable publication database be discontinued and an updated version of the current endnote database be supported.
    f. Additional recommendations for the website to be completed prior to the 2019 TSC meeting are as follows:
        i. Add information at the top of the Species Information page to "Check with specific agency about changes in historical techniques"; report that "Methods listed are for most recent reporting year,"
        ii. Add table for agency contacts with e-mail address of agency leads and information on age readers and species; Add as google doc and have agencies update information by Friday April 12, 2019
        iii. Update agency production numbers annually (finalize agency updates by April 19,

2019), and

iv. Update Species Information page to include new codes;

v. Edits such as consistent capitalization on the Species Information page; find updated species list by Care 2021

vi. Agencies should work to provide links to structure inventories to be assessable on the new website before CARE 2021

g. Recommends that ongoing agency progress toward long term otolith storage issues be documented and distributed to the TSC before the 2020 meeting. Research from the IPHC, CDFO, and AFSC will be summarized and distributed.

h. Recommend posting list of maximum ages on CARE website and developing quality control processes for new maximum ages including a CARE age structure exchange between appropriate agencies (age structure exchange may be done at CARE meeting to minimize transport and maximize efficiency).

i. Recommend evaluating and updating the current CARE Age Structure Exchange invoice to potentially exclude quality control statistics and include better notation before CARE 2021.

2. 2019 CARE to TSC

a. CARE currently has no recommendations for the TSC

5. TSC to CARE 2017/2018/2019

2017

a. Recommends CARE to review yelloweye aging

2018

a. CARE did not directly respond to storage recommendations and CARE will carry this recommendation on this year and develop a working group to standardize otolith storage.

b. TSC Recommends carrying over yelloweye ageing review.

c. TSC encourages the use of otolith morphometrics to separate out cryptic species and suggests expanding the current working group to expand to other species.

d. TSC encourages CARE to evaluate the machine reading of otoliths as a valid method (near infrared), concern is that suitable criteria are met.

2019

a. The TSC supports CARE's next steps, including making video documentation on how to process and age samples in an effort to fight the brain drain of retirements.

Table 1. CARE age structure exchanges

CARE Age Structure Exchanges initiated in 2018				
Exchange ID No.	Species	Originating Agency	Coordinator	Participating Agency (Cooperators)

18-001	sablefish	NWFSC	Patrick McDonald	NWFSC, ADFG-Juneau, AFSC, CDFO
18-002	Pacific cod	ADFG-Juneau	Jodi Neil	AFSC
18-003	sablefish	AFSC	John Brogan	NWFSC, ADFG-Juneau, AFSC, CDFO
18-004	canary rockfish	WDFW	Jennifer Topping	NWFSC
18-005	canary rockfish	NWFSC	Patrick McDonald	WDFW
18-006	longnose skate	AFSC	Beth Matta/ Morgan Arrington	NWFSC
18-007	sablefish	ADF&G-Juneau	Kevin McNeel	NWFSC, ADFG-Juneau, AFSC, CDFO
18-008	sablefish	CDFO	Barb Campbell	NWFSC, ADFG-Juneau, AFSC, CDFO
18-009	yelloweye rockfish	ADF&G-Homer	Elisa Russ	ADFG-Juneau
18-010	big skate	NWFSC-PSMFC	Tyler Johnson	AFSC

CARE Age Structure Exchanges initiated in 2019

Exchange ID No.	Species	Originating Agency	Coordinator	Participating Agency (Cooperators)
19-001	Pacific cod	ADFG-Juneau	Jodi Neil	AFSC
19-002	cabezon	ODFW	Lisa Kautzi	WDFW
19-003	cabezon	WDFW	Jennifer Topping	ODFW
19-004	black rockfish	ODFW	Lisa Kautzi	ADFG-Homer
19-005	widow rockfish	WDFW	Jennifer Topping	NWFSC

C.A.R.E. 2019 MEETING MINUTES 9–11 APRIL 2019

Twentieth Biennial Meeting of the Committee of Age Reading Experts
Working Group of the Canada – US Groundfish Committee TSC
AFSC Sand Point Facility, NOAA Western Regional Center
7600 Sand Point Way, NE, Seattle, WA, USA Bldg. #4, Jim Traynor Conference Room 2076

Tuesday, April 9, 2019

I. Call to Order

2019 CARE Chairperson Kevin McNeel (ADF&G-Juneau) called the meeting to order at 8:30 am.

II. Host Statement

Dr. Tom Helser (AFSC), Age and Growth Program Manager, welcomed the group to the 20th CARE conference. He disclosed which rooms were available during the meeting and covered security issues. He invited everyone to the social which would be held at the Elliot Bay Brewing Company's Cascade Hall. Tom also mentioned the donation box for the daily refreshments.

III. Introductions

CARE attendees introduced themselves—stating which agency they worked for and giving brief summaries of their history and/or directed work (Table 1, Fig. 1: 2019 CARE Attendee List).

IV. Approval of 2019 Agenda

Kevin McNeel (ADF&G-Juneau) asked for edits to the agenda. There was a correction such that the social would be located at the Elliot Bay Brewing Company where there would be pre-ordered platters of food. Chris Gburski (AFSC) would collect the $20 fee and directions to the location would be distributed. The group photo was scheduled for Wednesday before lunch. With these changes and additions, the 2019 agenda was approved by CARE.

V. Working Group Reports

A. TSC Meeting 2018

Kevin McNeel (ADF&G-Juneau) had attended the TSC meeting in San Jose in 2018 where he gave an update on CARE activity and changes in CARE personnel. In the report he included the 13 age structure exchanges conducted in 2018. Kevin commented that CARE initiated 5 yelloweye rockfish exchanges, which addressed the 2017 TSC to CARE recommendation to review yelloweye rockfish age pattern criteria. TSC was interested in using near-infrared (NIR) spectroscopy to age otoliths and TSC suggested using tag-recapture, known-age sablefish. Kevin noted that the AFSC was already working on evaluating NIR spectroscopy for ageing walleye pollock, Pacific cod, sablefish, and sole. The AFSC was the only center that Kevin knew of on the west coast with an NIR spectrometer. Kevin then went over the 2017 CARE to TSC and TSC to CARE recommendations. The CARE to TSC recommendation recognized TSC to CARE concern about storage media and therefore CARE developed an Ad Hoc Working

Group to address the issue. The 2017 TSC to CARE recommendation was to investigate yelloweye rockfish age determination criteria; CARE had five age structure exchanges, including bomb-radiocarbon validated specimens, to compare criteria. TSC members proposed to add yelloweye rockfish criteria as a research priority to help make this species easier to study.

B. Age Structure Exchanges

Kevin McNeel (ADF&G-Juneau) thanked Barbara Campbell (CDFO) for coordinating the exchanges and preparing the 2019 CARE Structure Exchange Summary. Barbara was unable to attend the meeting. Kevin also thanked Joanne Groot (CDFO) for continuing to coordinate exchanges.

In 2017 there were 13 exchange samples/invoices:

- 5 yelloweye rockfish samples exchanged (resolved)
- 2 rougheye rockfish samples exchanged (both outstanding)
- 2 lingcod samples exchanged (1 outstanding)
- 1 blue/deacon rockfish sample exchanged (resolved)
- 2 Pacific cod samples exchanged (1 training sample and 1 resolved)
- 1 petrale sole sample exchanged (resolved)

In 2018 there were 10 exchange samples/invoices (Table 3):

- 4 sablefish samples exchanged (1 outstanding)
- 1 Pacific cod sample exchanged (resolved)
- 2 canary rockfish samples exchanged (resolved)
- 1 longnose skate sample exchanged (resolved)
- 1 yelloweye rockfish sample exchanged (resolved)
- 1 big skate sample exchanged (resolved)

In 2019 there were 4 exchange samples/invoices at the time of meeting:

- 1 Pacific cod exchange started
- 2 cabezon exchanges
- 1 black rockfish exchange

CARE members also discussed the following:

- Statistical results on invoices: Kevin McNeel questioned whether it was necessary or beneficial to include statistics given the lack of consistency across invoices. People were not using forms with active equations. If people were interested in holding individuals to a set of standards, that should be addressed in the CARE to CARE recommendations.
- Resolving ages within a lab prior to inter-agency exchanges for a sample: Kevin McNeel noted that the CARE Charter states that agencies should submit only one age for invoices. Whether this should be continued could be brought up during recommendations.
- Whether an invoice number was necessary if ages were not intended for the website: Sandra Rosenfield (WDFW) suggested that the Vice Chair could assist with coordinating CARE training sample exchanges without initiating a formal exchange with an invoice. Kevin McNeel brought up whether multiple structure comparisons should be recorded as one invoice or multiple. Kevin suggested to keep data together. Andrew Claiborne

(WDFW) suggested that the data be kept in the same invoice and that the comment section of the invoice be used to identify ages of the different structures. It was suggested that these updates be added to the CARE Charter and that the invoice template be updated so that the notes section would replace the statistics section to enable the recording of additional useful information.

C. CARE Website

Jon Short (AFSC) summarized the utility of the website and noted that the management system running the site (Joomla) was out of date. Jon pointed out the species tables, manual, and link to the forum, but noted that the links and materials may no longer be supported. Jon went through the structure of the new WordPress site and what content was available. He mentioned that CARE needed a dedicated person to check the content of the new website and to do updates. The PSMFC has server space for the site and the updates should be done preferably by one agency.

Sandra Rosenfield (WDFW) asked Jon Short how long the old site was to continue working. Jon mentioned that the site was currently not functional. Sandra mentioned that the species table was one of the most important pieces of information on the site. The new site was active at http://caredev.psmfc.org/. It was expressed that Jon could use help maintaining the MS Access database and providing the code to display the data.

D. CARE Forum

Nikki Atkins (NWFSC/PSMFC) gave updates on the old and new forum. She noted that nothing had happened on the forum for quite some time. However, with the new host for the website, the forum appeared more user friendly. Posts from the old forum would be copied and moved into the new forum as “archived” posts so the content would not be lost. Nikki would contact all current users of the forum with the new address and reminders of their usernames so they could log in to the new version.

E. CARE Manual and CARE Charter

Elisa Russ (ADF&G-Homer) was the chair for both working groups and could not attend this meeting; and Betty Goetz (AFSC) did not have updates for either working group. Kevin McNeel (ADF&G-Juneau) suggested that they go over the points in the recommendations.

Morgan Arrington (AFSC/UW) mentioned that the group processing longnose skate were working on a CARE manual chapter.

Elisa Russ (ADF&G-Homer) provided input post-workshop that she had draft/final manual chapters that have been submitted. Elisa Russ will review and coordinate with authors and other working group members as needed to finalize the manual for review by the CARE membership and update prior to the 2021 meeting. Elisa Russ has reached out to other manual working group members Barbara Campbell (CDFO) and Jodi Neil (ADF&G-Juneau) to set up a meeting. Elisa Russ has reviewed the previous and current CARE to CARE recommendations and will follow up as needed and address these prior to the CARE meeting in 2021.

Regarding the CARE Charter, Elisa Russ and Betty Goetz did review it in 2015; however, no work was done to expand the Charter as previously recommended by CARE. This will remain an item to address at the next CARE meeting along with the current CARE recommendation. Elisa Russ committed to review and provide an update in 2021. Betty Goetz will be retiring in 2020, so Elisa Russ will be seeking another CARE member to join this working group.

VI. CARE & TSC Recommendations [9:45–10:15]

A. CARE to CARE 2017 (see pages 23 & 24 in 2017 CARE Meeting Minutes): Kevin McNeel (ADF&G-Juneau) reviewed the CARE to CARE and the CARE to TSC recommendations.

1. CARE recommends that the CARE Manual Working Group finalize and add the following sections to the *CARE Manual on Generalized Age Determination* and distribute the updated version of the manual to the CARE membership by June 1, 2017 with the finalized version to be submitted to the CARE Website Working Group by June 30, 2017 for posting on the CARE website:

   a. *Lingcod Otolith Ageing Procedures* section: Kevin McNeel stated that these were finalized at the 2017 meeting.

   b. *Sablefish Ageing Procedures* section: Kevin McNeel stated that these were finalized by the 2017 meeting.

   c. *Thin Sectioning Method* section—add a section under the *General Ageing Procedures*; Charles Hutchinson (AFSC) commented that this was written.

   d. *Baking Otoliths*—add a section under *General Otolith Ageing Procedures*; not written.

   e. *Ergonomics* section including equipment checklist as an appendix; Betty Goetz (AFSC) mentioned that this was written in 2017.

   Kevin McNeel (ADF&G-Juneau) suggested following up with Elissa Russ (ADF&G-Homer) to see if these sections were added.

2. CARE recommends that the CARE Manual Working Group continue the revision and expansion of the *CARE Manual on Generalized Age Determination* with the following sections drafted or revised by May 1, 2018 for review; and the edited sections to be added to the manual by the 2019 CARE meeting:

   a. *Walleye Pollock Ageing Procedures* section (use the AFSC manual as a starting point). This was noted to likely not be finished, but Elisa Russ may have updates.

   b. *Spiny Dogfish Ageing Procedures* section—summary of the spiny dogfish age determination paper by Dr. Cindy Tribuzio.

      It was noted that we do not know if this was incorporated into the manual.

   c. *Rockfish Ageing Procedures* section

      i. Edit to avoid redundancy with the *Thin Sectioning* section.

ii. Revise/move some information to the *General Otolith Ageing Procedures* section where appropriate.

d. Remove documentation sections regarding changes to CARE manual

i. See recommendation C to post archived editions.

ii. Remove 2015 Recommendation to add *Acknowledgements* section.

It was noted that documentation from the 2015 and 2017 working group meetings may be missing. Betty Goetz (AFSC) mentioned that she might have time to get some of these documents together.

3. CARE recommends that the CARE Manual Working Group submit archived editions of the CARE manual to the CARE Website Working Group for posting on the CARE website to preserve historical records.
   Kevin McNeel (ADF&G-Juneau) suggested that any archived additions of the manual be submitted to Jon Short (AFSC) to be added to the website.
4. CARE recommends that the CARE Forum be continued.

5. CARE recommends that the CARE Website Working Group continue to refine the searchable publication database to be housed at ADF&G-Juneau, so that relevant information is more accessible to the age reading community and stock assessors. Recommends that CARE members enter publications into the database using the online form. Recommends that the publications page includes the following, 1) a full list of publications, 2) a searchable feature at the top of the page, 3) a link to the publication entry form—the above to be completed before the 2019 CARE meeting. CARE members suggested that posters should verify what publication information or material could be added to the CARE website without violating online publication permissions, especially prior to adding a full publication or abstract.
   Kevin McNeel (ADF&G-Juneau) brought up the CARE website literature database. Kevin mentioned that ADF&G did not want to support the database and that no one has added submissions. He suggested that CARE vote on removing the online database in favor of supporting the Endnote file at the end of the meeting.

6. Additional CARE recommendations for the website to be completed prior to the 2019 meeting are as follows:
   a. Add information at the top of the *Species Information* page to “Check with specific agency about changes in historical techniques”; report that “Methods listed are for most recent reporting year,” or adjust in conjunction with changes incorporated in recommendation G.

   This change was not made and Kevin McNeel (ADF&G-Juneau) offered to send the quotes to Jon Short (AFSC).

   b. Add a table for agency contacts with e-mail addresses of agency leads and information on age readers and species (to be completed by April 30, 2017).

Kevin McNeel added the list as a Google Doc and recommended that agencies update information by the end of Friday.

c. Update agency production numbers annually (update the website with current production numbers by April 30, 2017). Kevin McNeel added the production number template to a CARE-wide email. Ask that production numbers be submitted by the following Friday.

d. Include methods for current year and use appropriate codes (B&BN = break-and-burn, B&BK = break-and-bake):
Kevin sent the definitions to Jon Short. Agencies will have to retroactively assign methods to historical production numbers to qualify if they are bakes or burns.

e. Edits such as consistent capitalization on the *Species Information* page:
Kevin offered to find the updated species list and email that to Jon.

7. CARE recommends that the website subcommittee continue to research the possibility of converting the CARE website and CARE forum to a different technology (Joomla is out-of-date, and it requires a major undertaking to update to a new version). The Website Working Group will research software options and make a recommendation (e.g., WordPress, Drupal, or a new version of Joomla).
The Website Working Group updated the CARE website to WordPress and the transition to the new website is in process. The updated website is housed at http://caredev.psmfc.org/.

8. CARE recommends that an Otolith Storage Ad Hoc Working Group be created to address the issues of short and long-term storage of otoliths with a complete report reviewed by membership for the 2019 CARE meeting. This is in response to prior TSC to CARE recommendations and due to the issue of otolith storage becoming a 2017-2021 research priority for the North Pacific Fishery Management Council. It is imperative that the historical archive of age structures be preserved.
There was no working group developed yet. Stephen Wischniowski (CDFO) said that their agency was cleaning their historical otoliths of glycerin and moving them to dry storage. Stephen noted that a lack of climate-controlled storage and a lack of consistency with the glycerin solution caused issues with the otoliths. The CDFO was now storing all otoliths dry. There were inconsistencies in which otoliths were degraded.

Joan Forsberg (IPHC) noted that the IPHC were still storing otoliths in glycerin but acknowledged that incorrect preparation of the solution was an issue. The IPHC has climate-controlled storage and they mix their own glycerin solutions.

Delsa Anderl (AFSC) commented that the AFSC continued to store otoliths in glycerin. The AFSC sent samples with both degraded and intact otoliths to Seattle University for analysis with the goal of determining the reasons for the degradation.

10:19 (15-minute break)

9. CARE recommends that the Charter Working Group revise the Charter and submit it to CARE membership for approval by the 2019 meeting; changes to include information on timelines including the preparation of the TSC report following the same year CARE meeting:

   Kevin McNeel noted that this was resolved by including an executive summary to TSC of the previous meeting. CARE could consider adding a due date of April 20th to the Charter for the executive summary.

   b. Submission of production numbers (species aged table); to include timelines above.

      Kevin suggested adding to the Charter a deadline of the Friday after a CARE meeting for submitting production numbers.

   c. Chair coordination with host agency regarding meeting logistics.

      CARE needed to follow up with the Charter Working Group to see if this was added and CARE should consider not including it.

10. CARE recommends that the Sablefish Ad Hoc Working Group produce a final report summarizing their work to be published on the CARE website by the 2019 meeting with possible publication as a formal report.
    This report was not written.

11. CARE recommends that a Skate Ad Hoc Working Group be created for standardization of age determination methods; this project already has funding through NOAA Fisheries.
    This working group was formed, and work was completed.

12. CARE recommends that a Rougheye/Blackspotted/Shortraker Rockfish Ad Hoc Working Group be created for addressing mixed sample issues involving these three, long-lived species and possibly other slope rockfish species.
    Betty Goetz (AFSC) offered to write a report summarizing progress, and the working group planned to meet at the 2019 CARE meeting to discuss progress.

13. CARE recommends posting a list of maximum ages on the CARE website (or link to lists on AFSC and ADF&G/ADU-Juneau, websites). Recommends developing a process to update maximum ages including a CARE age structure exchange between appropriate agencies (age structure exchange may be done at CARE meetings to minimize transport and maximize efficiency).
    Kevin McNeel (ADF&G-Juneau) offered to email a link to the ADF&G maximum age website and suggested that CARE members could send maximum ages data to update the site.

B. CARE to TSC 2017 (see page 25 in the 2017 CARE Meeting Minutes)

1. CARE recognizes that otolith storage was approved as a 2017–2021 research priority for the North Pacific Management Council. CARE appreciates that TSC recognizes that CARE

members are experts in the field of otolith reading and otolith storage and are thus best suited to develop and use best practices. As requested by TSC, CARE has initiated this process to document structures and storage methods currently in use (by species and agency) with information on their benefits and deficits. This request has been addressed by creating an ad hoc working group to report on current procedures for short and long-term storage of otoliths by CARE agencies and produce a document to support this research priority.
CARE should document the agency progress noted above and present that to TSC.

C. TSC to CARE 2017/2018 (see pages 23 and 533 in 2018 TSC Meeting Minutes)

2017

1. Ask CARE to review yelloweye rockfish ageing again.

2018

1. Progress on 2017's Recommendations from TSC to CARE: CARE did not directly respond to storage recommendations and CARE will carry on with this recommendation this year and develop a working group to standardize otolith storage.

2. 2018 Recommendation: carryover the review of yelloweye ageing. Encourage the use of otolith morphometrics to separate out cryptic species and expand the current working group to extend to other species. Encourage CARE to evaluate the machine reading of otoliths as a valid method (i.e., NIR), with the concern that suitable criteria are met.

VII. Agency Reports [10:30–12:00] Representatives from each agency gave updates on activity since CARE 2017

A. AFSC – (Tom Helser)

Tom noted that two NPRB projects were underway:

1. Latitudinal variance of growth and reproduction of flatfish in the Bering Sea. This project was looking at far north areas not covered by surveys and asking the question, "is this new area changing the status of flatfish?" This project was wrapping up with publications coming soon.

2. NIR ageing of Bering Sea and Aleutian Island Pacific cod. This study was in progress with the University of Washington School of Fisheries, assessing the possible separation of Bering Sea and Aleutian Islands Pacific cod into separate stocks. The Aleutian Islands data was coming both from fisheries and from otoliths not historically aged. The study also was trying to gain efficiencies in generating rapid age assays. This study was underway and in its second year. Jordan Healy's presentation was scheduled for Thursday. Initial results were good—not sure if NIR will supplant or supplement traditional methods. The method has promise, but there is no plan in place for changing the production model, which will need a 4- to 5-year plan to investigate.

Improve a stock assessment study—NOAA HQ approved this 2 years ago. Life history variation, NIR for longnose skates, bycatch is an issue. Not enough ages at the moment for a full assessment; NIR might assist with building a full stock assessment.

NOAA every 5 years funds new research and technology. This year operationalization of NIR was funded. This made available $1.2 million between this and another project to develop and implement the technology to improve efficiencies in collection and data production. After the funding was received, NOAA formed a Strategic Initiative Development Team and hosted a workshop. The purpose of the initiative and workshop was to look across species and ecosystems to find where NIR technology could be applied. The team is concurrently working with CARE and is testing how predictive data will fare. Current progress is going to be presented on Friday.

Published a paper on ancient Pacific cod otoliths discovered in middens at two sites. The otoliths retrieved from archaeological digs retain their integrity and analyses were successful. From these collections, we are reconstructing Gulf of Alaska sea surface temps ~200 yrs (this includes the Little Ice Age) and work will be published in the Journal of Archaeological Science. We are now looking into another study that could reconstruct ~6000 years from layered middens. With laser ablation, they tracked warming periods using stable isotope studies which give sea surface temperatures over time.

Essential fish habitat work. Coastal Alaska sampling of Pacific cod cohorts bimonthly. Measure change in cohort strength through time and examine otoliths with oxygen isotopes. Look at change in growth over winter, thermal refuge areas.

The Age and Growth lab has roughly 15 employees on top of graduate students and a prospective contractor to help with lab work and FT-NIR scanning. Dustin Nadjkovic is a new employee, Todd TenBrink was made full-time, Irina Benson was made a ZP3, and Kali Stone was made an FTE.

B. CDFO – (Steve Wischniowski)

2018
7 Full time agers
1 term
1 salmon data entry person
1 program manager

2019
7 Full time agers
0 term (potential term by April)
0 salmon data entry person
1 program manager
Darlene Gillespie and Shayne MacLellan alumnus status
1 extra position asked for

Retirement schedule
2019 Nora Crosby and Karen Charles
2021 Joanne Groot
2021 Mary-Jane Hudson
2023 Judy MacArthur

Species aged since last CARE meeting (2017):

Sebastes aleutianus (rougheye rockfish)	5,479
Sebastes entomelas (widow rockfish)	3,460
Sebastes maliger (quillback rockfish)	2,257
Sebastes pinniger (canary rockfish)	4,303
Sebastes proriger (redstripe rockfish)	667
Sebastes ruberrimus (yelloweye rockfish)	6,250
Anoplopoma fimbria (sablefish)	4,211
Microstomus pacificus (Dover sole)	1,346
Ophiodon elongatus (lingcod	)222
Merluccius productus (Pacific hake)	3,724
Oncorhynchus tshawytscha (Chinook salmon)	68,653
Oncorhynchus keta (chum salmon)	18,744
Oncorhynchus kisutch (coho salmon)	11,671
Oncorhynchus nerka (sockeye salmon)	38,905
Clupea pallasii (Pacific herring)	47,532
Panopea generosa (Pacific geoduck)	951
Total	218,375

Sclerochronology Lab (SCL) Otolith Washing Reference Collection

- SCL began to wash all otoliths in response to the deterioration issue

- ~14,000 of the 1.6 million have been washed so far—lots to go
- Reserved for term or casual employees

Validation Research
- eulachon—SIMS ^{18}O validation was inconclusive, requires more statistical evaluation potential false negatives
- the initial concern of the utility of oxygen isotopes as a validation technique for a species documented as having a deep-water profile seem to be valid with the results of this study
- small otolith exchange with WDFW (Andrew Claiborne)
- Rocky Mountain ridged mussels—SIMS ^{18}O validation completed and successful
- northern abalone, Olympia oysters, and spiny and smooth scallops to be SIM'ed
- Pacific cod-SIMS ^{18}O validation—early life history
- shortspine/longspine thornyhead, rougheye rockfish, shortraker rockfish
- isotopic oxygen to measure relative temperature difference
- isotopic carbon to measure change in metabolic rate
- isotopic nitrogen to measure trophic fractionation
- Potentially, these isotopes in harmony can identify a change in environmental condition and the influence it has on the on the growth and metabolic activity of the growth zones under scrutiny when compared to growth zones that reflect a "normal"* pattern that is typical for a specimen of this age at these depths
- Chinook salmon/coho salmon freshwater ageing issues
- Validation Technique: isotopic oxygen, elemental Ca:Sr and Ca:Br ratios

SCL Client Joint Research
* Rougheye/Blackspotted Rockfish—Species Discrimination by way of Otolith-Shape Analysis
* Canceled—a lack of funding and the lack of structures from the central coast prevents the study from progressing.

C. IPHC – (Joan Forsberg)

Four halibut readers on site. Linda Gibbs retired. Primary ageing season June–October. Last year genetics lab added. Physiology study, reproductive study.
Genetics—fin clips taken with otoliths. Using these to ID sex to match to otolith ages.
Read 30k per year, most from commercial catch.
Storage—all in glycerin thymol. 9,400 clean pairs stored dry as a "clean" collection. Waiting for elemental analysis.
Using break and bake. Bake posterior ½. 4 years and under, use surface to age.
Two staff members went to IOS last year and presented. Those studies are being updated as well.

D. ADF&G – (Kevin McNeel)

There are four main groundfish age determination programs within the Alaska Department of Fish and Game: the Age Determination Unit or ADU (based in Juneau), the Kodiak ADF&G age lab, and the Homer commercial and sport age labs. Unfortunately, representatives from the other three labs were not able to attend. Kodiak was able to give a written update and Kevin McNeel presented that.

ADF&G-Kodiak

The Kodiak ADF&G age lab update was written by Sonya El Mejjati. The dockside program samples state managed groundfish and shellfish species that are harvested in Kodiak, Chignik, and South Alaska Peninsula areas. Groundfish species aged in Kodiak include Pacific cod (about 2,000 otolith samples for all management areas), black rockfish (1000 otoliths mainly from Kodiak), dark rockfish (500 otoliths mainly from the Kodiak), lingcod (opportunistic sampling) and a few miscellaneous rockfish species.

All age readers are generally employed within December and April (3–4 months season). In 2017, 2018, and 2019 there were three age readers: Joan Brodie (38 seasons), Mike Knutson (5 seasons), and El Mejjati (11 seasons).

Precision testing is done on 40% of all samples and on 100% of samples that are aged by new readers. All differences are resolved. The lab uses the break and burn method for rockfish. For Pacific cod, one otolith is broken, and the other is cut with an Isomet saw; halves of each otolith are baked rather than burned for 12 minutes at 400°F using a standard toaster to prevent otoliths from spitting material (a.k.a., bursting). The cutting and baking process is time consuming in general, but it ultimately saves time during age reading compared to burning individual otoliths.

Starting in 2017, morphometric measurements have been collected for all species (otolith length, width, and weight, excluding crystalized or broken otoliths). This information has helped identify outliers and errors in the age, species ID, or typos. At the 2018 CARE meeting, the Kodiak lab noted that Pacific cod otoliths are frequently difficult to age with incomplete and irregular material comprising the ageing surface of the otolith, and because of this contemplated switching to fin rays. After talking to other agencies that have used Pacific cod fin rays and attending a workshop on fin ray preparation at the 2018 CARE meeting, it was decided that logistically the fin ray method would take too much time given the limited seasonal work in the Kodiak lab. Additionally, after looking at a few fin ray slides and communicating with fin ray age readers, it appeared that there were as many uncertainties with the early years due to material reabsorption. The Kodiak lab will continue processing otoliths for Pacific cod.

ADF&G-Juneau

The ADF&G Age Determination Unit (ADU) is the statewide groundfish and invertebrate age reading program based in Juneau, Alaska. The ADU currently has two permanent staff, two seasonal staff, and interim personnel borrowed from adjacent ADF&G projects. Jodi Neil and Chris Hinds are the lab’s dedicated age readers and Peter Fasolino is currently focused on weathervane scallop processing.

In 2017 and 2018, the ADU received approximately 10,000 otolith sets per year from Central and Southeast Gulf of Alaska commercial fisheries and survey samples. These collections represented approximately 15 species. During the 2017 and 2018 period, the ADU processed sablefish, lingcod, Pacific cod, yelloweye rockfish, black rockfish, shortraker rockfish, and rougheye rockfish and distributed approximately 8,200 ages per year.

For quality control, readers calibrate annually prior to processing samples. The samples are tested with a 30% second read and outlying fish and otolith size-at-age checks. Currently, the ADU uses modeled fish length and otolith weight-at-age for lingcod, yelloweye rockfish, rougheye rockfish, shortraker rockfish, shortspine thornyhead, and sablefish. During 2017 and 2018, the ADU participated in rougheye rockfish exchanges with AFSC; yelloweye rockfish exchanges with WDFW, NWFSC, CDFO, and ADF&G-Homer; sablefish exchanges with the AFSC, NWFSC, and CDFO; a Pacific cod exchange with AFSC for training; and a lingcod exchange with WDFW.

For age related research, we completed the review of potential age structures for crustaceans (red king crab, snow crab, tanner crab, and spot shrimp). We found that band counts were near expected ages estimated based on size, and that a calcium binding dye (calcein) was retained in structures across molting. However, counts did not increase for crabs that no longer molted, the proportion of readable structures was low, and recent literature found that the entire structure was digested during molting in similar species. We are currently doing some histology work on the structures through molting, but further validation needs to be done. The ADU is continuing work on a Prince William Sound shortraker rockfish chronology and a shortraker/rougheye rockfish otolith shape analysis. We worked with Bryan Black (University of Arizona) on cross-dating specimens and are waiting for time to collect more data. The ADU also initiated a North Pacific Research Board funded project on reconstructing reproductive histories of yelloweye rockfish through opercular hormone profiles in 2018. We sampled opercula and otoliths from female yelloweye rockfish collected during the NMFS Sablefish Longline Survey and are working with Baylor University to analyze increment progesterone, cortisol, and estradiol concentrations.

E. NWFSC – (Patrick McDonald)

Personnel

- Lance Sullivan left the ageing lab last fall (2018)
- We have 4 full time age readers and one team lead (myself)
- There are no plans at the moment to fill the last two age reader position that we lost

Travel/Meetings/Workshops –

  - We hosted WDFW to review yelloweye rockfish ageing (Sandra Rosenfield, Jennifer Topping, and Andrew Claiborne)
  - Tyler Johnson and I visited the AFSC to work with Beth Matta, Chris Gburski, and Morgan Arrington to learn how to age big skate.

Ageing species and numbers:

Species	Common Name	Year	N
Atheresthes stomias	arrowtooth flounder	2017	1,200
Sebastes melanops	black rockfish	2017	14
Beringraja binoculata	big skate	2018	636
Sebastes pinniger	canary rockfish	2017	4,534
Sebastes crameri	darkblotched rockfish	2017	863
Ophiodon elongatus	lingcod	2017	2,487
Sebastes alutus	Pacific Ocean perch	2017	2,861
Eopsetta jordani	petrale sole	2017	1,934
Merluccius productus	Pacific hake	2017	7,423
Merluccius productus	Pacific hake	2018	5,235

Anoplopoma fimbria	sablefish	2018	5,857
Scorpaena guttata	California scorpionfish	2017	95
Sebastes ruberrimus	yelloweye rockfish	2017	977
Sebastes flavidus	yellowtail rockfish	2017	761
Totals		2017/18	34,877

We double read over 11,000 structures in 2017 and 2018.
Projects:

- Tyler Johnson did some initial examinations looking at big skate caudal thorns (n=100) to determine the viability of their potential use for age determination. Due to the stock assessment cycle we spent a limited time on this project.
- We cored n=43 canary rockfish for ^{14}C analysis.
- We collected ~300 paired otoliths/fin-ray structures to explore using only otoliths to age lingcod.

We were participants or initiators of several exchanges since the last CARE meeting (2017). These include:
yelloweye rockfish—WDFW, ADF&G-Juneau, ADF&G-Homer, CDFO
canary rockfish—WDFW (18-005)
petrale sole—WDFW
sablefish—ADF&G-Juneau, AFSC, CDFO
big skate—AFSC
longnose skate—AFSC

F. WDFW – (Andrew Claiborne)

6 members on different species. John Sneva 1 day/week. Lucinda Morrow retired this year.
120k/year salmon, groundfish.
Exchanges, Pacific cod, petrale sole, yelloweye rockfish, lingcod, canary rockfish.
Taking on Cabezon and getting a bead on how to age and training on white sturgeon
New projects: population productivity, hatchery population forecast, data entry access to have data on hand.
1 temporary hire to enter historical ages.

WDFW's Fish Ageing Lab
Lance Campbell—Unit Lead
Andrew Claiborne—Age Lab Team Lead
Anna Hildebrandt—Age Lab and Otolith Lab
Sandra Rosenfield—Age Lab
Jenny Topping—Age Lab
John Sneva—Age Lab (part time)
Lucinda Morrow—Age Lab (retired July 2018)

Generally, business as usual. We are ageing approximately 120k samples per year and are primarily a production lab. Approximately 100k salmon and steelhead, and 20k groundfish. We received two new grants for 2019 including a project to investigate the relationship between marine growth, oceanographic factors, and productivity of Puget Sound chum salmon. Another grant is to explore early marine growth (from scales) as predictor of adult survival for Chinook salmon. We also will be populating a salmon age database with historical ages. We are exploring ageing of cabezon and white sturgeon.

Exchanges: Pacific cod, petrale sole, yelloweye rockfish, lingcod, canary rockfish.

G. ODFW – (Lisa Kautzi)

Oregon Dept. Fish & Wildlife

- I'm the only age reader

2017—Focus on blue and deacon rockfish.

- An exchange of blue and deacon rockfish was made with the SWFSC
- We aged, imaged, and used shape analysis software to analyze deacon rockfish otoliths. The project compares otolith shape of near and offshore locations and will be combined with genetics analysis.

2018—Focus on cabezon

- I experimented with different preparation methods for cabezon to try and improve the readability of the otolith. I found it best to soak the otolith in 50% ethanol for at least a week and using break and burn to age them.
- A report draft was created comparing the ages of thin sections and break and burns, and the growth curve fits.

A total of 8,352 commercial, recreation, and special project fish were aged since the last CARE meeting. Species aged were:

- black rockfish: 3,132
- cabezon: 1,548
- blue/deacon rockfish: 3,672
- approximately 20% of samples are self-tested to check for consistency

Lunch 12:00–1:15

VIII. Scientific PowerPoint Presentations [2:00–2:30]

1. Andrew Claiborne—*Results of the Yelloweye Rockfish Exchanges: Comparison of Age Determinations From Alaska, British Columbia, and the Coasts of Washington and Oregon* (15 minutes)
2. Chris Hinds—*Importance of Juvenile Sablefish Growth and Methods of Estimation* (15 minutes*)*

IV. Topics for Discussion/New Business [1:15–2:00]

A. Symposia/Conferences since CARE 2017 meeting & upcoming

CARE members mentioned the meetings and symposia that they attended since the last meeting.

- Representatives from AFSC went to 2018 Western Groundfish
- Representatives from AFSC and IPHC went to 2018 International Otolith Symposium
- Representatives from Juneau Auke Bay Lab and ADF&G-Juneau went to 2018 Sablefish Summit
- Representatives from AFSC presented otolith growth research at the 2017 Wakefield

Symposium

Break 2:30–2:45

IX. Workshops, Working Groups, Hands-On Microscope Work [2:45–5:30]

A. Yelloweye Working Group

Tuesday, April 9, 2019, 2:45 pm to 5:30 pm
AFSC, Seattle, WA, Traynor Room

Participants:
Joanne Groot (CDFO)
Michele Mitchell (CDFO)
Chris Hinds (ADF&G-Juneau)
Jodi Neil (ADF&G-Juneau)
Sandy Rosenfield (WDFW)
Andrew Claiborne (WDFW)
Patrick McDonald (NWFSC)
Kevin McNeel (ADF&G-Juneau)

Age readers from CDFO, WDFW, ADF&G-ADU, and PSMFC aged specimens from the radiocarbon sample using images. Specific features discussed were identification of the 1st year, preferred aging axis, edge interpretation, splitting vs. banding of fine annuli in older specimens, and the importance of tracing annuli from the surface onto the cross-section to help identify checks and annuli.

B. Hands-On Microscope Work and Calibration (Traynor Room)

A total of 32 CARE attendees reviewed criteria for 5 different species across the three-day meeting. See Table 2 for a summary of the participants and targeted species.

Wednesday, April 10, 2019

X. Workshops, Working Groups, Hands-On Microscope Work [8:30–12:00]

A. Pacific Cod Working Group

Wednesday, April 9, 2019, 8:30 am to 10:30 am
AFSC, Seattle, WA, Room 2011

Participants:
Delsa Anderl (AFSC)
John Brogan (AFSC)
Charles Hutchinson (AFSC)
Beth Matta (AFSC)
Dustin Nadjkovic (AFSC)
Kali Stone (AFSC)
Chris Hinds (ADF&G-Juneau)
Jodi Neil (ADF&G-Juneau)
Kevin McNeel (ADF&G-Juneau)
Sandra Rosenfield (WDFW)

The Pacific Cod Working Group evaluated ages and images from the last exchange of ADF&G Pacific cod otoliths. Specifically, the group evaluated last annulus on/before the edge and whether spacing made sense compared to the spacing between the rest of the annuli. Participants also looked at different transects and the 1–2 check spacing.

B. Sablefish Working Group

Wednesday, April 9, 2019, 10:30 am to 12:00 pm
AFSC, Seattle, WA, Room 2011

Participants:
Delsa Anderl (AFSC)
John Brogan (AFSC)
Dustin Nadjkovic (AFSC)
Kali Stone (AFSC)
Nikki Atkins (NWFSC)
Jamie Hale (NWFSC)
Tyler Johnson (NWFSC)
Patrick McDonald (NWFSC)
Joanne Groot (CDFO)
Michele Mitchell (CDFO)
Chris Hinds (ADF&G-Juneau)
Kevin McNeel (ADF&G-Juneau)
Jodi Neil (ADF&G-Juneau)

The Sablefish Working Group reviewed images and ages of the resent sablefish exchanges between AFSC, CDFO, NWFSC, and ADF&G-Juneau. Also, the group came up with a plan to distribute the current collection of known-age sablefish otoliths in a larger exchange sample to prevent potential bias due to the specimens being known-age.

C. Big and Longnose Skate Working Group

Wednesday, April 10, 2019, 4:00 pm to 5:00 pm
AFSC, Seattle, WA, Imaging Room 1110

Participants:
Morgan Arrington (AFSC, UW)
Chris Gburski (AFSC)
Tyler Johnson (NWFSC)
Beth Matta (AFSC)
Patrick McDonald (NWFSC)

The Big and Longnose Skate Working Group began the skate ageing session viewing thin section images from vertebral centra on the imaging PC monitor which had been prepared by Morgan Arrington. The US west coast longnose skate (*Raja rhina*) specimen images were acquired with reflected light and image enhanced. We examined discrepancies between the AFSC and NWFSC from the CARE exchange conducted in winter 2018. Early growth years (0–1 year old) were viewed for consensus ageing. The intermedialia, corpus calcarea arms, edge, birthmark increment, translucent versus opaque growth zones, and total length were used for age determination. For west coast collected longnose skate, it was surmised that the birthmark is closer in distance to the focus when compared to longnose skate collected from the Gulf of Alaska. To explain this difference, water temperature and timing for embryo development within the skate egg case may vary from these two regions with variances in life history events. Edge growth and seasonality (summer vs. fall collected) was discussed to estimate age and edge growth. One specimen was subsequently ranged due to the difficulty in age interpretation. Skate maturity stage (mature vs. immature) with respect to how it may affect appearance of growth zones was also discussed. Ontogenetic shift in diet may affect growth and maturity stage timing. Age 1–2 years old were also viewed. The '*Young Skate*' section for '*Longnose Skate Ageing Procedures*' from the CARE ageing manual was referenced to assist with ageing. Tyler showed west coast collected big skate (*Beringraja binoculata*) unstained vertebral thin sections (n=5) that we viewed with reflected light. Both age 1 or 2-year-old and age 3 or 4-year-old specimens were looked at for a consensus age. How to interpret growth patterns including splitting versus grouping, translucent growth zones, spacing, pre-annular checks, and thin section thickness were discussed. There were 5 participants from AFSC and NWFSC.

D. Hands-On Microscope Work and Calibration (Traynor Room)

See Table 2 for summary of attendees and focused species.

Lunch 12:00–1:15

XI. Recommendations [2:00–2:30]

A. 2019 CARE to CARE

1. Recommends that the CARE Manual Working Group (Elisa Russ, Betty Goetz, Jodi Neil, and Barb Campbell) finalize and add the following sections before the 2021 CARE meeting:
   a. *Lingcod Otolith Ageing Procedures* section—written
   b. *Sablefish Ageing Procedures* section—written
   c. *Thin Sectioning Method* section under the *General Ageing Procedures*— written
   d. Add *Baking Otoliths* section under *General Otolith Ageing Procedures*—not written
   e. *Ergonomics* section including equipment checklist as appendix—written

2. Recommends that the CARE Manual Working Group continue the revision and expansion of the *CARE Manual on Generalized Age Determination* with the following sections drafted or revised for review and addition of edits to the manual by the 2021 CARE meeting:
   a. *Walleye Pollock Ageing Procedures* section (use AFSC manual as starting point)
   b. *Spiny Dogfish Ageing Procedures* section—summary of spiny dogfish age determination paper by Dr. Cindy Tribuzio, or a reference to the existing manual written by Dr. Tribuzio
   c. *Rockfish Ageing Procedures* section
   d. edit to avoid redundancy with *Thin Sectioning* section
   e. revise/move information to *General Otolith Ageing Procedures* section where appropriate

3. Recommends that the CARE Manual Working Group remove current or recommended

documentation sections regarding changes to the CARE manual and remove the 2015 recommendation to add *Acknowledgements* section. Also, CARE members should submit archived editions of the CARE manual to the CARE Website Working Group for posting on the CARE website to preserve historical records.

4. Recommends that the CARE Website Working Group update and add the CARE Forum to the new website and discontinue the CARE searchable publication database (with continued support of the current endnote database). Additional recommendations for the website to be completed prior to the 2019 meeting are as follows:
   a. Add information at the top of the *Species Information* page to "Check with specific agency about changes in historical techniques"; report that "Methods listed are for most recent reporting year," or adjust in conjunction with changes incorporated in Recommendation G.

   b. Add table for agency contacts with e-mail address of agency leads and information on age readers and species; Add as a Google Doc and have agencies update information by end of Friday.

   c. Update agency production numbers annually (update website with current production numbers by April 30, 2019), and Update *Species Information* page to include new codes for baking and burning.

   d. Edit *Species Information* pages to fix capitalization and formatting.

   e. Agencies should provide links to structure inventories to be accessible on the new website before CARE 2021

   f. Posting a list or link to current lists of maximum ages on CARE website and develop a quality control process for new maximum ages (e.g., a CARE age structure exchange between appropriate agencies, potentially done at a CARE meeting to maximize efficiency).

5. Recommends that the CARE Otolith Storage Working Group document and distribute ongoing agency progress toward long term otolith storage issues to TSC before the 2021 meeting.

6. Recommends the CARE Charter Working Group evaluate and update the current CARE Age Structure Exchange invoice to potentially exclude quality control statistics and include better notation before CARE 2021.

B. 2019 CARE to TSC

CARE currently has no recommendations for TSC

XII. CARE Administrative Business [2:30–3:30]

A. CARE Officer nominations

Chair: Delsa Anderl
Vice Chair: Andrew Claiborne
Secretary: Nikki Atkins

B. Schedule and location of 2021 meeting—Newport, OR

XIII. Workshops, Working Groups, Hands-On Microscope Work [3:30—4:30]

A. Hands-on microscope work and calibration (Traynor Room). See Table 2 for a summary of the participants and targeted species.

XIV. CARE Business Meeting Adjourns [4:30]

Thursday, April 11, 2019

XV. Working Groups and Hands-On Workshop Continuation [8:30–12:00]

A. Workshop—Rapid Estimation of Fish Age Using Fourier Transform-Near Infrared Spectroscopy (see attached schedule)

B. Shortspine Thornyhead Working Group

Participants:
Jodi Neil (ADF&G-Juneau)
Charles Hutchinson (AFSC)
Todd TenBrink (AFSC)

Goal: Discuss the otolith structure exchange between AFSC and ADF&G-ADU (initiated by AFSC) using unburned thin-sectioned specimens.
Both agencies annotated the images and we discussed these annotations as well as looked at a few additional unburned thin-sectioned specimens, and aged and annotated them as a group. The results of the annotated structure exchange suggested a slightly older pattern interpretation by AFSC age readers in comparison to the ADU age readers. We discussed the best counting pathway.(axis) to use (e.g., sulcus vs edge) and how to interpret the early years. Shortspine thornyhead growth patterns are noisy and checky in the early years so all readers agreed that using the surface was better, and that focusing on the sulcus was the best way to interpret these patterns.

A concern brought up by the AFSC age readers was whether darker areas in older specimens were compressed zones or fast growth larger zones, and how best to interpret these zones. In unburned thin sections, these zones appear as translucent bands within which the individual annuli are difficult to distinguish. We discussed the possibility that, at least for these older specimens, the thin section was not thin enough to clear up these translucent compressed areas.
We discussed the possibility of conducting a larger paired-structure exchange that would include both a broken and burned half, and an unburned thin-sectioned half from the same specimens—both agencies would contribute otoliths for the exchange. At the end of the meeting, Charles Hutchinson proposed that AFSC staff compile a list of questions and goals that they would like to achieve in the next structure exchange.

Friday, April 12, 2019

C. Rougheye/Blackspotted/Shortraker Rockfish Working Group

Participants:
Charles Hutchinson (AFSC)
Steve Wischniowski (CDFO)
Kevin McNeel (ADF&G-Juneau)

Notes from 2017 CARE meeting: several agencies are dealing with this 'mixed bag' problem. Three in particular (AFSC, ADF&G and CDFO) are aware of the potential, and others (NWFSC, WDFW) may have the problem but are currently unaware of any specific problems with species identification in their collections as they are just starting to calibrate on this species group. We have some tools to develop (Kevin's R-based approach of otolith shape discrimination and Harris/Hutchinson rougheye/blackspotted rockfish shape morphometric project) that may help with this problem. It was suggested that a Working Group could potentially address this question from a more formal perspective and perhaps gain funding/prioritization via TSC. We need to prioritize collection and analysis of more vouchered shortraker rockfish via DNA analysis. Rougheye/Blackspotted/Shortraker Rockfish Working Group = Charles Hutchinson (lead), Betty Goetz (AFSC), Irina Benson (AFSC), Tom Helser (AFSC). Other agencies: Kevin McNeel, Elisa Russ, Joanne Groot (CDFO), Stephen Wischniowski

AGENCY PROJECT STATUS REPORTS 2019

AFSC—Two projects are currently addressing this situation with Alaskan samples. Problem blackspotted/rougheye/shortraker rockfish mixed observer sample (Betty Goetz) - An observer collection of rougheye rockfish was submitted for ageing (B30713A) (n = 307) and initial testing suggested a potential problem with mixing. Some otoliths appear to have characteristics which suggested that they might be shortraker rockfish. We also knew that rougheye samples were typically mixes of blackspotted and rougheye rockfish. Although we already have a research plan to separate blackspotted rockfish from rougheye rockfish, this identification protocol requires ages and we do not yet have reliable ageing criteria for shortraker rockfish. The model developed would not assist in the separation of a third species. To address this problem, we have done the following: ImagePro morphometrics and otolith weights have been taken from all otoliths in the problem cruise. ImagePro morphometrics and otolith weights have been taken from DNA vouchered blackspotted and rougheye rockfish used in the blackspotted/rougheye rockfish separation model. A selection of smaller shortraker rockfish collected from surveys (not observer samples) have been accessed and are ready for morphometric measurement/otolith weight. Blackspotted/Rougheye Rockfish otolith separation model (Charles Hutchinson) -

ADF&G—The Alaska Department of Fish & Game has a consistent collection of shortraker rockfish and mixed rougheye and blackspotted rockfish otoliths from Prince William Sound, Alaska. Historically, the Alaska Department of Fish & Game Age Determination Unit (ADU) submitted species corrections to regional samplers based on otolith morphology and growth patterns. The ADU was seeking to automate this procedure and look for significance of species corrections using a small sample size of genetically verified species. The genetic results found a significant proportion of the rougheye rockfish were blackspotted rockfish and an automated shape analysis using R could significantly identify specimens within the genetic collection. However, use of the model for otoliths outside of the genetically verified specimens did not work, because of the small sample size. The ADU is seeking to continue this work and to verify results using results from the AFSC models and future work by CDFO to improve the current shape identification or species correction procedures done at the ADU.

CDFO—Looking at cost cutting measures to reduce DNA charges for the identification of the Blackspotted/Rougheye Rockfish complex. 704 blackspotted/rougheye rockfish otoliths were collected from all groundfish surveys in 2018, all structures were genetically identified by the Molecular Genetics Lab at Pacific Biological Station. All structures were aged, imaged, and weighed. A small subsample (~70) was tested during the 2019 CARE workshop in Seattle, WA. Both techniques were employed, i.e., Kevin McNeel's R-based approach of otolith shape discrimination and the Jeremy Harris/Charles Hutchinson rougheye/blackspotted rockfish shape morphometric project. Unfortunately, time constraints worked against us and we were unable to determine the errors that were generated in the Harris/Hutchinson approach using ImagePro software. However, the R-based approach provided results that indicate that otolith shape is a viable means of determining species within this complex for fish caught off the west coast of Vancouver Island. The SCL is looking to incorporating both otolith weight and shape imagery during the age estimation process for all its species. This as a means increase the QA/QC before submitting age estimates to its clients.

CARE Social at the Elliot Bay Brewing Company (5:30–9:00)

Table 1. Attendees of the CARE Conference, April 9–11, 2019, Seattle, Washington, U.S.A.

Last Name	First Name	Agency	Location	Country	Contact
Anderl	Delsa	AFSC	Seattle	USA	delsa.anderl@noaa.gov
Arrington	Morgan	AFSC/UW	Seattle	USA	morgan.arrington@noaa.gov
Atkins	Nikki	NWFSC/PSMFC	Newport	USA	nikki.atkins@noaa.gov
Brogan	John	NOAA/AFSC	Seattle	USA	john.brogan@noaa.gov
Claiborne	Andrew	WDFW	Olympia	USA	andrew.claiborne@dfw.wa.gov
Forsberg	Joan	IPHC	Seattle	USA	joan.forsberg@iphc.int
Gburski	Chris	AFSC	Seattle	USA	christopher.gburski@noaa.gov
Goetz	Betty	AFSC	Seattle	USA	betty.goetz@noaa.gov
Groot	Joanne	CDFO	Nanaimo	Canada	joanne.groot@dfo-mpo.gc.ca
Hale	Jamie	NWFSC/PSMFC	Newport	USA	james.hale@noaa.gov
Helser	Thomas	NOAA/AFSC	Seattle	USA	thomas.helser@noaa.gov
Hildebrandt	Anna	WDFW	Olympia	USA	anna.hildebrandt@dfw.wa.gov
Hinds	Chris	ADF&G	Juneau	USA	chris.hinds@alaska.gov
Hutchinson	Charles	NOAA/AFSC	Seattle	USA	charles.hutchinson@noaa.gov
Johnson	Tyler	NWFSC/PSMFC	Newport	USA	tyler.johnson@noaa.gov
Johnston	Chris	IPHC	Seattle	USA	chris.johnston@iphc.int
Kastelle	Craig	NOAA/AFSC	Seattle	USA	craig.kastelle@noaa.gov
Kautzi	Lisa	ODFW	Newport	USA	lisa.a.kautzi@state.or.us
Matta	Beth	AFSC	Seattle	USA	beth.matta@noaa.gov
McBride	Richard	NOAA/NEFSC	Woods Hole	USA	richard.mcbride@noaa.gov
McDonald	Patrick	NWFSC/PSMFC	Newport	USA	pmcdonald@psmfc.org
McNeel	Kevin	ADF&G	Juneau	USA	kevin.mcneel@alaska.gov
Mitchell	Michele	CDFO	Nanaimo	Canada	michele.mitchell@dfo-mpo.gc.ca
Nadjkovic	Dustin	NOAA/AFSC	Seattle	USA	dustin.nadjkovic@noaa.gov
Neidetcher	Sandi	NOAA/AFSC	Seattle	USA	sandi.neidetcher@noaa.gov
Neil	Jodi	ADF&G	Juneau	USA	jodi.neil@alaska.gov
Pearce	Julie	AFSC	Seattle	USA	julie.pearce@noaa.gov
Piston	Charlie	AFSC	Seattle	USA	charlie.piston@noaa.gov
Rasmuson	Leif	ODFW	Newport	USA	leif.k.rasmuson@state.or.us
Rosenfield	Sandra	WDFW	Olympia	USA	sandrarosenfield@dfw.wa.gov
Rudy	Dana	IPHC	Seattle	USA	dana.rudy@iphc.int
Short	Jon	NOAA/AFSC	Seattle	USA	jon.short@noaa.gov
Stone	Kali	AFSC	Seattle	USA	kali.stone@noaa.gov
TenBrink	Todd	NOAA/AFSC	Seattle	USA	todd.tenbrink@noaa.gov
Wischniowski	Stephen	CDFO	Nanaimo	Canada	stephen.wischniowski@dfo-mpo.gc.ca

Table 2. 2019 CARE Hands-On Sessions – Species Aged, Participants, and Agency.

Species	Participants	Agency	Comments
shortspine thornyhead	Charles Hutchinson	AFSC	calibration
	Jodi Neil	ADF&G-Juneau	
	Todd TenBrink	AFSC	
longnose skate	Morgan Arrington	AFSC, UW	calibration
	Chris Gburski	AFSC	
	Tyler Johnson	NWFSC-PSMFC	
	Beth Matta	AFSC	
	Patrick McDonald	NWFSC-PSMFC	
sablefish	Delsa Anderl	AFSC	calibration
	Nikki Atkins	NWFSC-PSMFC	
	John Brogan	AFSC	
	Joanne Groot	CDFO	
	Jamie Hale	NWFSC-PSMFC	
	Chris Hinds	ADF&G	
	Tyler Johnson	NWFSC-PSMFC	
	Patrick McDonald	NWFSC-PSMFC	
	Kevin McNeel	ADF&G	
	Michele Mitchell	CDFO	
	Dustin Nadjkovic	AFSC	
	Jodi Neil	ADF&G	
	Kali Stone	AFSC	
Pacific cod	Delsa Anderl	AFSC	calibration
	John Brogan	AFSC	
	Chris Hinds	ADF&G	
	Beth Matta	AFSC	
	Kevin McNeel	ADF&G	
	Dustin Nadjkovic	AFSC	
	Jodi Neil	ADF&G	
	Sandra Rosenfield	WDFW	
	Kali Stone	AFSC	
cabezon	Lisa Kautzi	ODFW	calibration
	Sandra Rosenfield	WDFW	

Table 3. CARE age structure exchanges initiated in 2018.

Exchange ID	Species	Originating Agency	Coordinator	Participating Agency
18-010	big skate	NWFSC-PSMFC	Tyler Johnson	AFSC
18-004	canary rockfish	WDFW	Jennifer Topping	NWFSC
18-005	canary rockfish	NWFSC	Patrick McDonald	WDFW
18-006	longnose skate	AFSC	Beth Matta	NWFSC
18-002	Pacific cod	ADF&G-ADU	Jodi Neil	AFSC
18-001	sablefish	NWFSC	Patrick McDonald	NWFSC, ADF&G-ADU, AFSC, CDFO
18-003	sablefish	AFSC	John Brogan	NWFSC, ADF&G-ADU, AFSC, CDFO
18-007	sablefish	ADF&G-ADU	Jodi Neil	NWFSC, ADF&G-ADU, AFSC, CDFO
18-008	sablefish	CDFO	Barb Campbell	NWFSC, ADF&G-ADU, AFSC, CDFO
18-009	yelloweye rockfish	ADF&G-Homer	Elisa Russ	ADF&G-ADU

Figure 1: Attendees of the 2019 CARE Conference, April 9–11, 2019 Group Photo

APPENDIX-I: 2019 CARE Agenda

CARE 2019 Agenda

Twentieth Biennial Meeting of the Committee of Age Reading Experts

Working Group of the Canada – US Groundfish Committee TSC AFSC Sand Point Facility, NOAA Western Regional Center

7600 Sand Point Way, NE, Seattle, WA, USA Bldg. #4, Jim Traynor Conference Room 2076 April 9 – 11, 2019

Tuesday, April 9, 2019

1. **Call to Order [8:30 am] – CARE Chair (Kevin McNeel)**
2. **Host Statement**

    7. Welcome statements & host info: safety/security orientation, refreshments, social. etc. (Tom Helser-Age & Growth Program Director)

3. **III. Introductions**

    1. Round-table intro (name, agency, location)
    2. Attendance-address, phone, email (written list distributed)

V. Approval of 2019 Agenda

4. **Working Group Reports [9:00 – 9:45] Activity since CARE 2015 (~ 5 min each)**

    XVI. TSC Meeting 2018 (Kevin McNeel)
    XVII. Age Structure exchanges (Kevin McNeel)
    XVIII. Website (Jon Short)
    XIX. CARE Forum (Nikki Atkins)
    XX. CARE Manual (TBD)
    XXI. Charter Committee (TBD)

5. **CARE & TSC Recommendations [9:45 – 10:15]**

    6. CARE to CARE 2017 (see pages 23 & 24 in 2017 CARE Meeting Minutes)
    7. CARE to TSC 2017 (see page 25 in 2017 CARE Meeting Minutes)
    8. TSC to CARE 2017/2018 (see pages 533 and 23 in 2018 TSC Meeting Minutes)

Break 10:15 – 10:30

9. **Agency Reports [10:30 – 12:00] Activity since CARE 2017 (~ 5 min each)**

    1. CDFO – (Steve Wischniowski)
    2. IPHC – (Joan Forsberg)
    3. AFSC – (Tom Helser)

4. ADF&G – (Kevin McNeel)
5. NWFSC – (Patrick McDonald)
6. WDFW – (Andrew Claiborne)
7. ODFW – (Lisa Kautzi)
8. Additional Attending Agencies

Lunch 12:00 – 1:15

10. Topics for Discussion/New Business [1:15 – 2:00]

1. Symposia/Conferences since CARE 2017 meeting & upcoming
2. Agency updates & verification of sp. info on CARE website
3. Non-agenda items

11. Scientific PowerPoint Presentations [2:00 – 2:30]

1. Andrew Claiborne, *Results of the yelloweye rockfish exchanges: comparison of age determinations from Alaska, British Columbia, and the coasts of Washington and Oregon* (15 min)
2. Chris Hinds, *Importance of juvenile sablefish growth and methods of estimation* (15 min)

Break 2:30 – 2:45

12. Workshops, working groups, hands-on microscope work [2:45 – 5:30]

1. Yelloweye Working Group [2:45 – 5:30]
2. Working Groups (Traynor Room and Room 2079)
3. Hands-on microscope work and calibration (Traynor Room)

a. Wednesday, April 10, 2019

13. Workshops, working groups, hands-on microscope work [8:30 – 12:00]

1. Sablefish Working Group [10:30 – 12:00]
2. Working Groups (Traynor Room and Room 2079 available all day)
3. Hands-on microscope work and calibration (Traynor Room)

--- Posters available for viewing during breaks from other tasks all day---

Lunch 12:00 – 1:15

14. Recommendations [2:00 – 2:30]

3. 2019 CARE to CARE
4. 2019 CARE to TSC

15. CARE Administrative Business [2:30 –3:30]

1. Officer nominations
2. Schedule and location of 2019 meeting

16. Workshops, working groups, hands-on microscope work [3:30 – 5:30]

1. Working Groups (Traynor Room and Room 2079 available all day)

2. Hands-on microscope work and calibration (Traynor Room)

--- Posters available for viewing during breaks from other tasks all day---

17. CARE Business Meeting Adjourns [4:30]

a. Thursday, April 11, 2019

18. Working groups & Hands-on Workshop Continuation [8:30 – 12:00]

1. Workshop- Rapid Estimation of Fish Age Using Fourier Transform-near Infrared Spectroscopy (see attached schedule)
2. Working Groups – additional time available to meet and schedule tasks for 2019
3. Hands-on Workshop – dual microscopes available for calibration work until noon
4. Workshops – additional time if needed

CARE Social at the Elliot Bay Public House & Brewery -see sign-up sheet and directions (5:30-9:00)

APPENDIX-II

NOAA Fisheries, Alaska Fisheries Science Center, Western Regional Center, Building 4, Traynor Room 2076, 7600 Sand Point Way, NE, Seattle WA 981093, April 11th & 12th, 2019

Thursday, April 11, 2019

9:00 Welcome, introductions and workshop purpose (T. Helser – FT-NIR SIDT Chair)
9:30 *Introduction to NIR and FT-technology*. Jason Erickson, Applications Scientist, Bruker Optics.
10:00 *Data preprocessing for quantitative and qualitative models based on NIR spectroscopy*. Barry Wise, President, Eigenvector Research, Inc.
10:30 *Applications of near infrared spectroscopy to questions in animal physiology*. Carrie Vance, Professor, Mississippi State University.
11:00 coffee Break
11:20 *Near infrared reflectance spectroscopy detection of male northern dusky salamanders (Desmognathus fuscus) response to female pheromones*. Mariana Santos-Rivera, Mississippi State University.
11:40 *Predicting fish age at the speed of light*. Brett Wedding, Principle Scientist, Agri-Science Queensland Government, Australia.
12:00 Morning discussion and wrap up
12:30 Lunch and tour of the AFSC Spectroscopy Laboratory
14:00 *Age prediction of Gulf of Mexico red snapper using near infrared spectroscopy*. Beverly Barnett, Fishery Biologist, Southeast Fisheries Science Center, Panama City Laboratory.
14:20 *Using FT-NIR to predict daily ages in juvenile red snapper*. Michelle Passerotti, Ph.D. Candidate, University of South Carolina.
14:40 *Case study of FT-NIR spectroscopy for Bering Sea Pacific cod stocks*. Jordan Healy, M.S. Candidate, University of Washington.
15:00 *Application of near FT-NIR spectroscopy for Gulf of Alaska longnose skate vertebrae*. Morgan Arrington, M.S. Candidate, University of Washington.
15:20 *Anadromous chinook salmon otoliths ageing using near infrared spectroscopy*. Andrew Claiborne, Fishery Biologist, Washington Department of Fish and Game.
15:40 Coffee Break
16:00 *FT-NIR spectroscopy ageing of Bering Sea walleye pollock: Wavelengths to population parameters*. Irina Benson, Research Fishery Biologist, Alaska Fisheries Science Center, Age and Growth Laboratory.
16:20 Discussion and session wrap up.

Workshop Social: TBD

Friday, April 12, 2019

9:00 *Precision and accuracy metrics for ageing QA/QC: what is behind the numbers.* Richard McBride, Branch Chief, Population Biology, Northeast Fisheries Science Center, Woods Hole Laboratory.

9:30 *Ageing outputs in stock assessments in Queensland-focus on fisheries concerns moving the technology forward*. Julie Robins, Research Scientist, Department of Fisheries and Agriculture, Queensland, Australia.

10:00 *A new paradigm of FT-NIR age estimation and challenges in U.S. stock assessments.* TBD, Stock Assessment Scientist, Resource Ecology and Ecosystem Modeling, Alaska Fisheries Science Center.

10:30 *Operationalizing FT-NIR ageing enterprise in NOAA Fisheries: A conceptual pathway forward*. Thomas Helser, Supervisory Research Fishery Biologist, Alaska Fisheries Science Center, Age and Growth Laboratory.

11:00 *Report of the week's FT-NIRS multispecies analysis by the Strategic Initiative Development Team.* Discussion facilitated by T.E. Helser.

12:30 Lunch

14:00 Discussion of detailed strategic initiative work plan and report to NOAA Fisheries Science Board.

1) Group discussion – likelihood of success for implementing FT-NIRS ageing of fish from otoliths
2) Impediments to success - Prioritization and execution of central scientific questions to be answered
3) Unique requirements of NIR technology in fisheries science and its scalability
4) Implementation timelines for strategic initiative work plan

APPENDIX-III

CARE Meeting 2019

April 9-11, 2019

NOAA, Western Regional
Center, Alaska Fisheries Science
Center, Sand Point, Seattle, WA

CALL FOR PRESENTATIONS & POSTERS

The Committee of Age Reading Experts is pleased to announce the Call for Presentations and Posters for the 2019 CARE Meeting.

While no specific theme has been designated, topic sessions can focus on current research and the 2018 TSC recommendations: yelloweye rockfish, differentiating cryptic species, and evaluating machine reading of otoliths.

Please submit abstracts by Friday, March 8, 2019 to Kevin McNeel, CARE Chair:

kevin.mcneel@alaska.gov

Submit abstract as a Word document (preferably) and include the following information:

- Type of presentation (oral or poster)
- Title
- First and Last Name of Author(s)
  - Include any preferred appellation (e.g. Dr. or Ph.D.)
  - Name of Presenter (if more than one author)
  - Include any affiliations (spell out agency), city, country, and e-mail
- Text of abstract in 250 words or less
- Amount of time needed for presentation (maximum of 20 minutes-including questions)

The CARE meeting includes presentations, age reader calibration, workshops and workgroup meetings, held April 9-11, 2019. Presentation titles and abstracts will be published online in CARE the minutes.

- Oral presentations-Tuesday (afternoon), April 9th
- Poster presentation- will be displayed throughout the meeting

CARE Website: http://care.psmfc.org

APPENDIX-IV

Nineteenth Biennial Meeting of the Committee of Age Reading Experts

Working Group of the Canada – US Groundfish Committee TSC
AFSC Sand Point Facility, NOAA Western Regional Center
April 4 – 6, 2017

Abstracts

Type of Presentation: Oral

Title: Results of the yelloweye rockfish exchanges: comparison of age determinations from Alaska, British Columbia, and the coasts of Washington and Oregon

Authors and affiliation:
Andrew Claiborne[1]
[1]Washington Department of Fish and Wildlife, 1111 Washington St SE Olympia WA, 98501

Abstract:
Yelloweye rockfish are an ecologically and commercially important species from Alaska to central California and one of the longer-living rockfish with a reported maximum age of 147. Several agencies and members of the Committee of Age Reading Experts (CARE) produce age estimates for yelloweye rockfish across their range, yet few CARE sample exchanges have occurred in the last two decades. Here we compare age estimates independently made between 5 laboratories with samples originating from Alaska to California. Overall, age estimates agreed between readers for yellow eye up to age-30. However, bias between labs was clear for ages ranging from 40 to 120. CARE exchange results are discussed in the context of the 2017 stock assessment of yellow eye in the federal and state waters of Washington, Oregon, and California, and recommendations to further validate ages of yelloweye rockfish.

Type of Presentation: Oral

Title: The importance of juvenile sablefish growth and methods of estimation

Authors and affiliation:
Wess Strasburger[1], Chris Hinds[2]
[1] Auke Bay Laboratories, Alaska Fisheries Science Center, National Oceanic and Atmospheric Administration, United States Department of Commerce, 17109 Point Lena Loop Road, Juneau, AK 99801
[2]Alaska Department of Fish & Game, Division of Commercial Fisheries, Mark, Tag and Age Laboratory, Juneau, AK 99811

Abstract:

Gulf of Alaska sablefish biomass has declined since 1988 with only a few strong year classes supporting the fishery. Studies suggest that juvenile sablefish growth may be a better indicator of recruitment than spawning stock biomass, but that has not been studied in Alaska. To compare juvenile growth with recruitment and environmental factors, we developed three objectives: (1) compare daily increment counts between the lapillus

and sagitta otoliths to ensure that results using either otolith are comparable; (2) compare objective fish and otolith measurements to highlight growth differences across conditions; and (3) model growth rates across environmental and ecological conditions using daily increment widths and relate that to recruitment events. To compare lapillus and sagitta otoliths, samples from the 2014, 2016, 2017 National Marine Fisheries Surface Trawl were mounted to petrographic slides and polished using sandpaper and lapping film to image daily growth bands. Using image analysis software, we found no difference between lapillus and sagitta daily growth counts (-0.75 + 7.2 SD differences between structures) and estimated an average hatch date of April 12th. Our preliminary analysis supports that there is no difference between daily counts for each structure and we will focus on the lapillus for the remainder of the study. To preliminarily compare objective otolith measurements, we took images of unpolished otoliths from the trawl samples and measured lapillus and sagitta otolith length and height using image analysis. We found a positive relationship between lapillus and sagitta otolith diameters and fish length and will further investigate this relationship across controlled environmental factors (temperature and food ration) to look for objective differences in otolith growth using fish that were reared at Auke Bay Laboratories. To model growth rates, juvenile sablefish otoliths from 1997-2018 Middleton Island rhinoceros auklet bill loads will be processed to estimate juvenile growth spanning over 20 years and juveniles reared at Auke Bay Laboratories in a controlled temperature and feeding study will be used to interpret and validate results. Given preliminary results from objectives 1 and 2, we will focus on processing lapillus from bill load samples and will continue to collect daily increment counts, otolith length and height measurements, and otolith increment widths to improve evaluation of objectives 2 and 3.

APPENDIX-V

Rougheye/Blackspotted/Shortraker Rockfish Working Group Report 2019

Notes from 2017 CARE meeting: Several agencies are dealing with this 'mixed bag' problem. Three in particular (AFSC, ADF&G and CDFO) are aware of the potential, and others (NWFSC, WDFW) may have the problem but are currently unaware of any specific problems with species identification in their collections as they are just starting to calibrate on this species group. We have some tools to develop (Kevin's R-based approach of otolith shape discrimination and Harris/Hutchinson rougheye-blackspotted shape morphometric project) that may help with this problem. It was suggested that a working group could potentially address this question from a more formal perspective and perhaps gain funding/prioritization via TSC. We need to prioritize collection and analysis of more vouchered shortraker via DNA analysis. RE/BS/SR RF Working Group = Charles Hutchinson (lead), Betty Goetz, Irina Benson, Tom Helser. Other agencies: Kevin McNeel, Elisa Russ, Joanne Groot, Stephen Wischniowski

AGENCY PROJECT STATUS REPORTS 2019

AFSC – Two projects are currently addressing this situation with Alaskan samples.
Problem Blackspotted/rougheye/shortraker mixed observer sample (Betty Goetz) - An observer collection of rougheye rockfish was submitted for ageing (B30713A) (n = 307) and initial testing suggested a potential problem with mixing. Some otoliths appear to have characteristics which suggested that they might be shortraker rockfish. We also knew that rougheye samples were typically mixes of blackspotted and rougheye rockfish. Although we already have a research plan to separate blackspotted rockfish from rougheye rockfish, this identification protocol requires ages and we do not yet have reliable ageing criteria for shortraker rockfish. The model developed would not assist in the separation of a third species. To address this problem, we have done the following:

(1) ImagePro morphometrics and otolith weights have been taken from all otoliths in the problem cruise.
(2) ImagePro morphometrics and otolith weights have been taken from DNA vouchered blackspotted and rougheye rockfish used in the Blackspotted/rougheye rockfish separation model.
(3) A selection of smaller shortraker rockfish collected from surveys (not observer samples) have been accessed and are ready for morphometric measurement/otolith weight.

Blackspotted/Rougheye Rockfish otolith separation model (Charles Hutchinson) -

ADF&G – The Alaska Department of Fish & Game has a consistent collection of shortraker and mixed rougheye and blackspotted otoliths from Prince William Sound, Alaska. Historically, the Alaska Department of Fish & Game Age Determination Unit (ADU) submitted species corrections to regional samplers based on otolith morphology and growth patterns. The ADU was seeking to automate this procedure and look for significance of species corrections using a small sample size of genetically verified species. The genetic results found a significant proportion of the rougheye rockfish were blackspotted rockfish and an automated shape analysis using R could significantly identify specimens within the genetic collection. However, use of the model for otoliths outside of the genetically verified specimens did not work, because of the small sample size. The ADU is seeking to continue this work and to verify results using results from the AFSC models and future work by CDFO to improve the current shape identification or species correction procedures done at the ADU.
CDFO – Looking at cost cutting measures to reduce DNA charges to groundfish for the identification of the Blackspotted/Rougheye Rockfish complex. 704 Blackspotted/Rougheye otoliths were collected from all groundfish surveys in 2018, all structures were genetically identified by the Molecular Genetics Lab at PBS. All structures were aged, imaged and weighed. A small subsample (~70) was tested during the 2019 CARE workshop in Seattle, WA. Both techniques were employed, Kevin's R-based approach of otolith shape discrimination and Harris/Hutchinson rougheye-blackspotted shape morphometric project.

Unfortunately, time constraints worked against us and we were unable to determine the errors that were generated in the Harris/Hutchinson approach using ImagePro software. However, the R-based approach provided results that indicate that otolith shape is a viable means of determining species within this complex for fish caught of West Coast Vancouver Island.

The SCL is looking at the incorporation of both otolith weight and shape imagery during the age estimation process for all its species. This as a means increase the QA/QC before submitting age estimates to its clients.