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

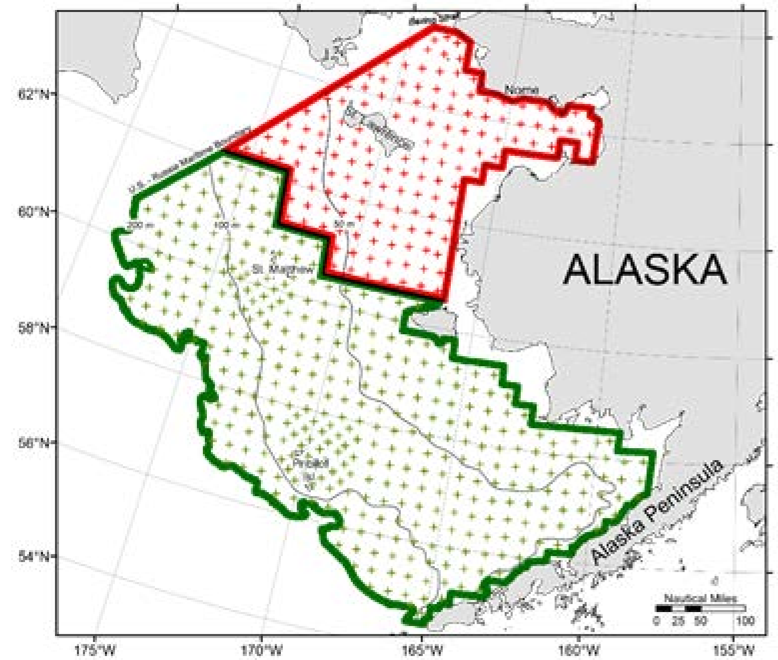

Fig. 1. Map showing survey stations sampled during the 2019 eastern and northern Bering Sea shelf bottom trawl survey.

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 biomas 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.

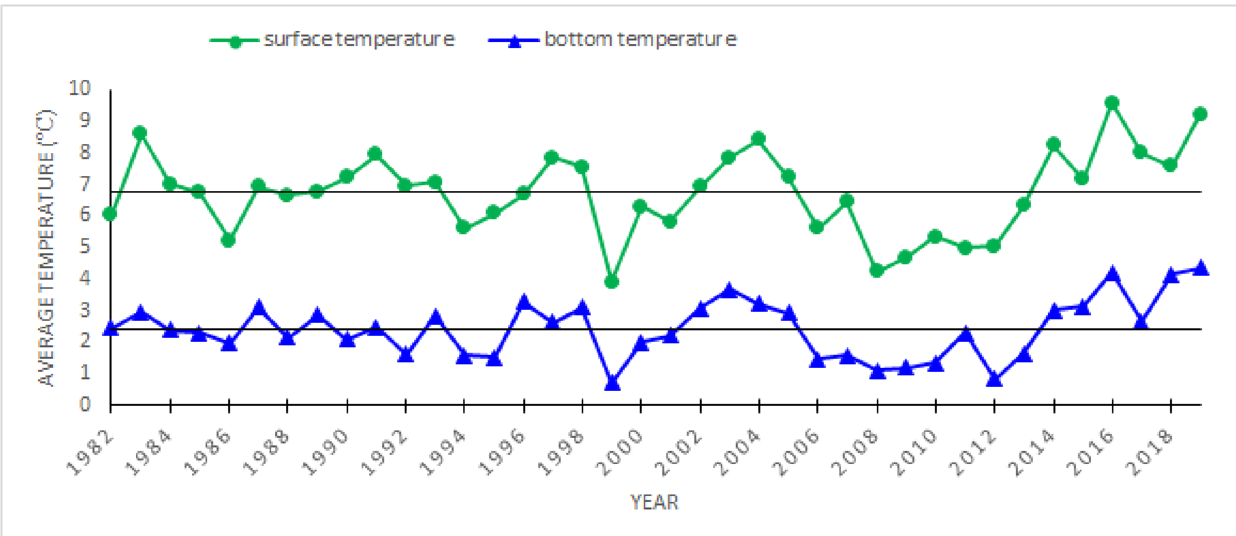

Figure 3: Average annual surface and bottom temperature during the survey period for the eastern Bering Sea shelf survey with the survey mean temperature (1982-2019).

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.

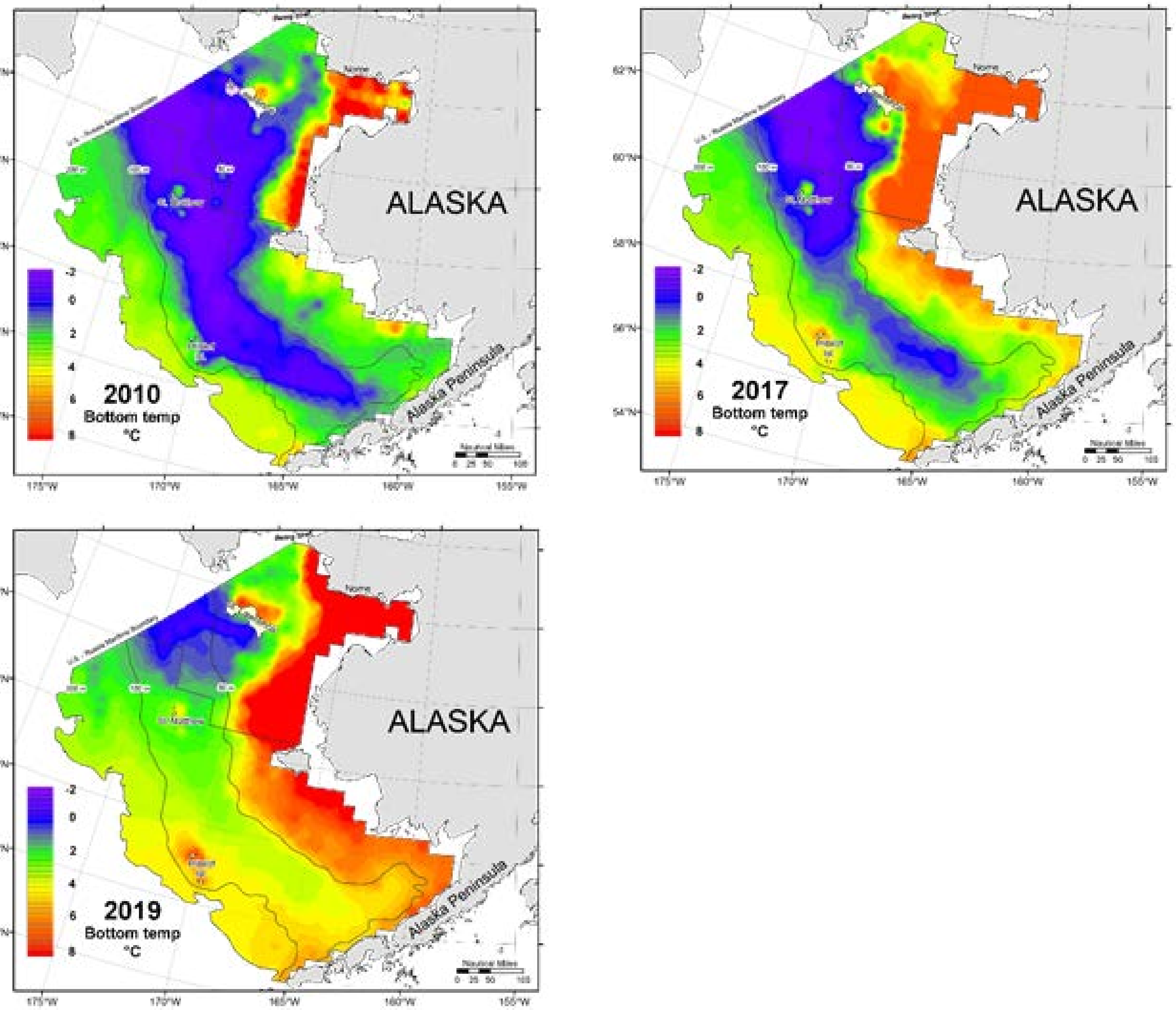

Figure 4: Distribution of survey bottom temperatures for 2010 (top left), 2017 (top right), and 2019 (lower left), the three years that the EBS survey was expanded to comprehensively include the northern Bering Sea shelf.

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 others 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).

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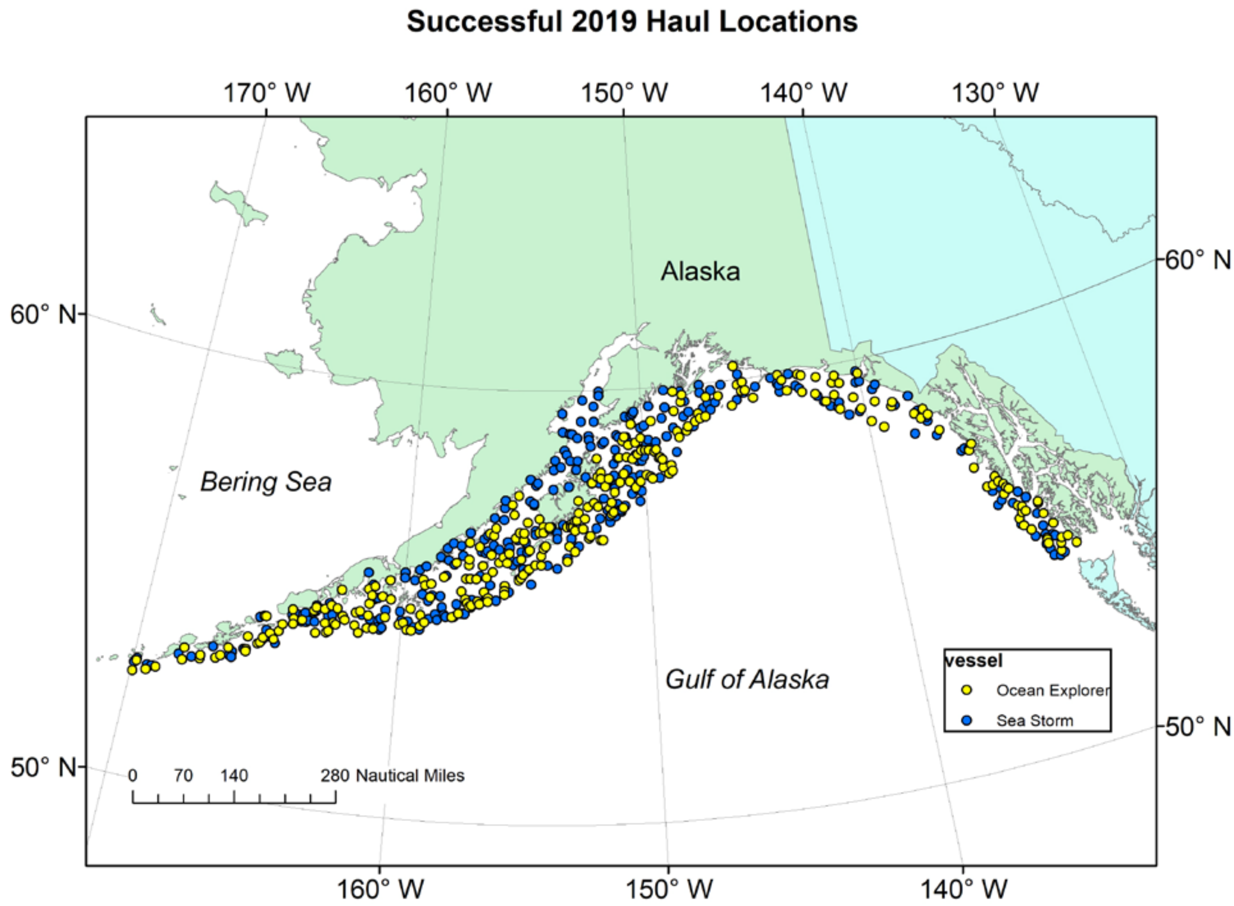

Figure 1. Successful stations occupied during the 2019 Gulf of Alaska Biennial Bottom Trawl Survey by vessel.

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 was 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:

Laurel, B. and L.A. Rogers (2020). Loss of spawning habitat and pre-recruits of Pacific cod during a Gulf of Alaska heatwave. Canadian Journal of Fisheries and Aquatic Sciences. https://doi.org/10.1139/cjfas-2019-0238.

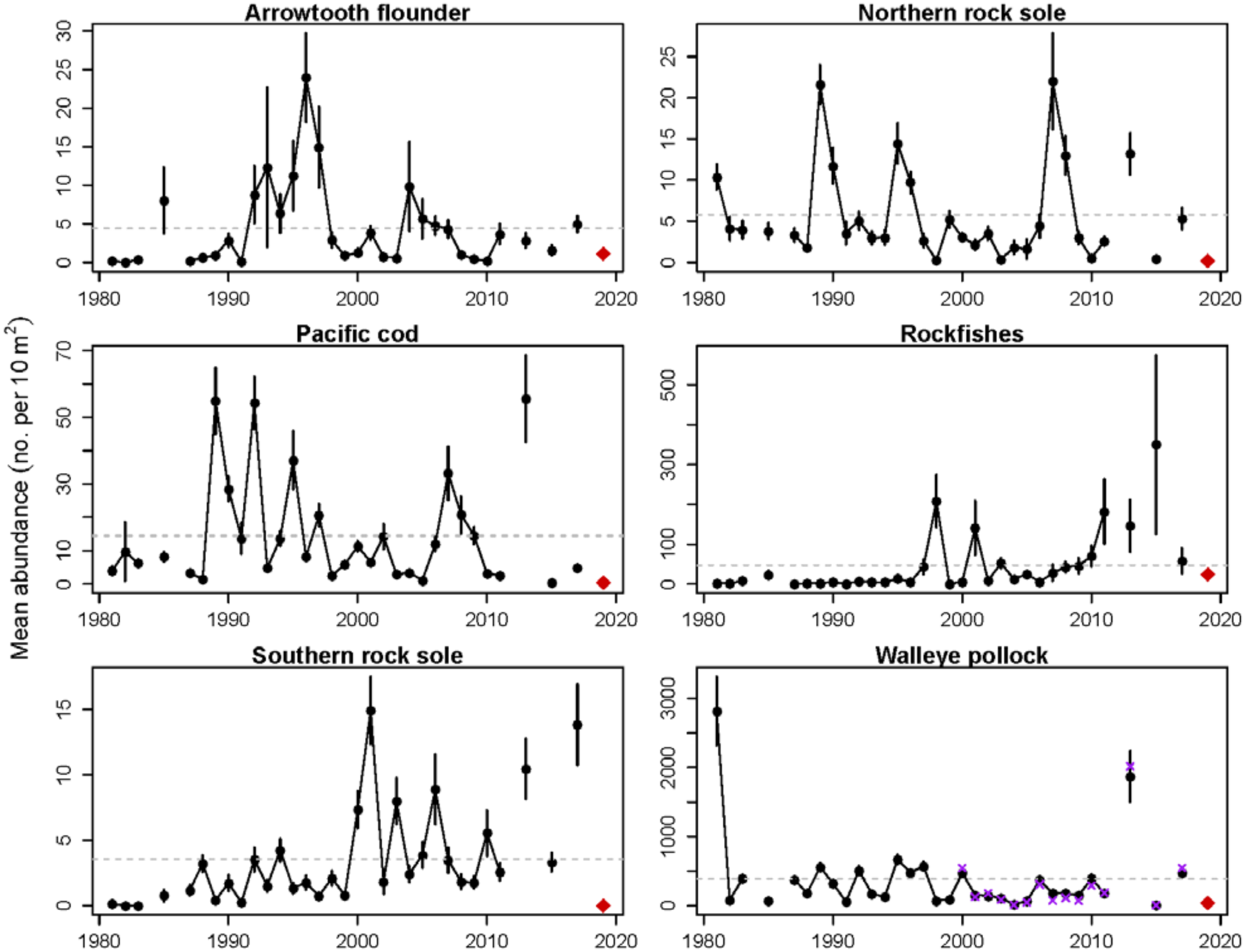

Figure 1. Time-series of mean abundance within the main grid area for species included in the Rapid Larval Assessment (RLA) for 2019. Laboratory counts are denoted by black circles; the RLA estimate is the red diamond. Purple x's denote historical at-sea rough count estimates for Pollock.

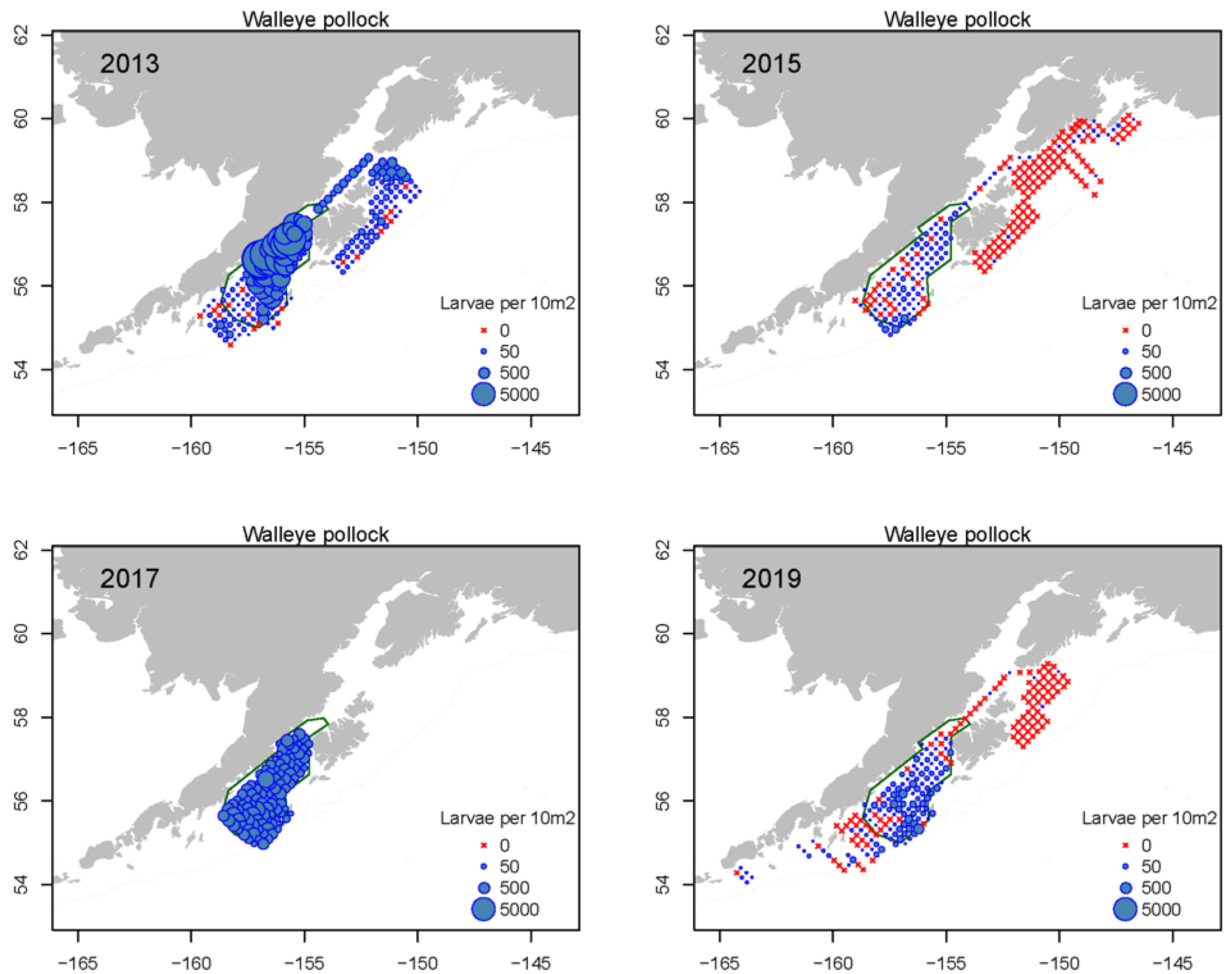

Figure 2. Abundance of larval Pollock on the EcoFOCI spring larval survey for 2013-2019. The at-sea rough counts were used to generate the distribution for 2019 whereas laboratory data are shown for previous years. Main grid area delineated by the green line.

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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%).

Literature Cited

Honkalehto, T.H., P.H. Ressler, R.H. Towler, and C.D. Wilson. Using acoustic data from fishing vessels to estimate walleye pollock abundance in the eastern Bering Sea. Canadian Journal of Fisheries and Aquatic Sciences 68(7): 1231–1242.

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 passowrd 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.

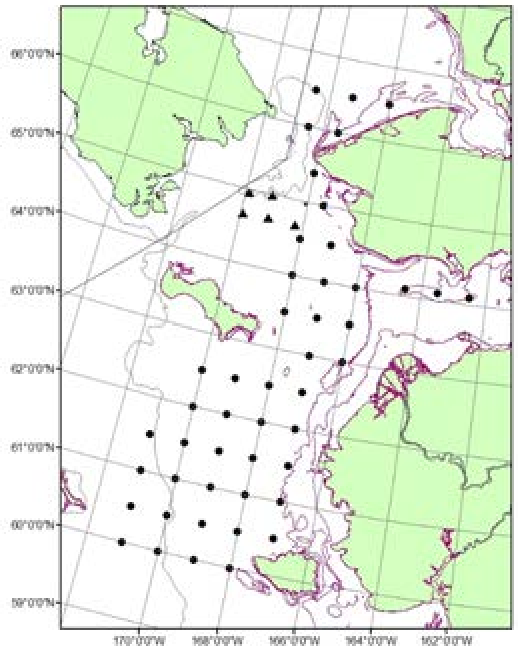

Figure 1. Stations sampled during the August 27 to September 20, 2019 surface trawl survey in the northern Bering Sea.

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

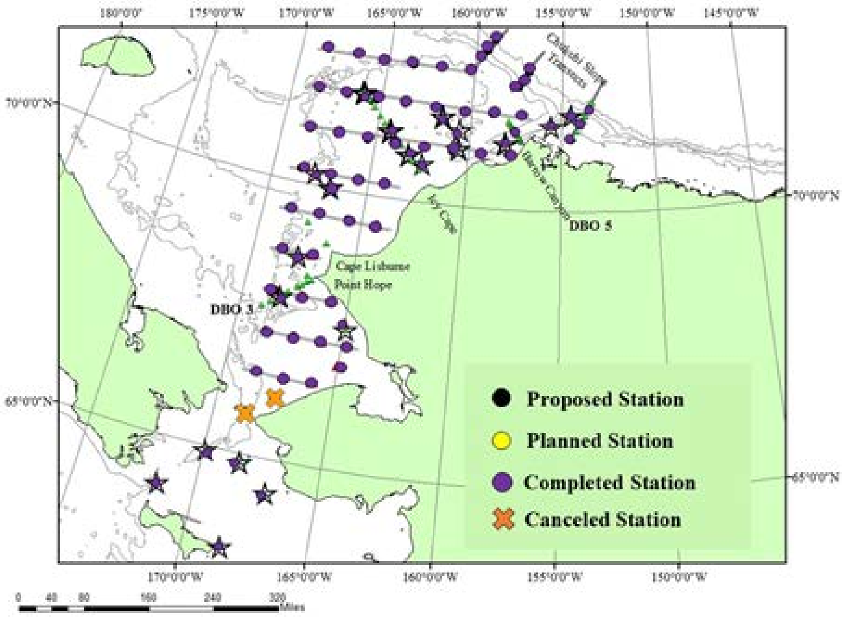
BASIS fisheries-oceanographic surveys in the southeastern Bering Sea have been conducted annually since 2002 (with the exception of 2013) and biennially since 2016. In 2019 there was no survey and results of the 2020 survey will be provided next year.

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.

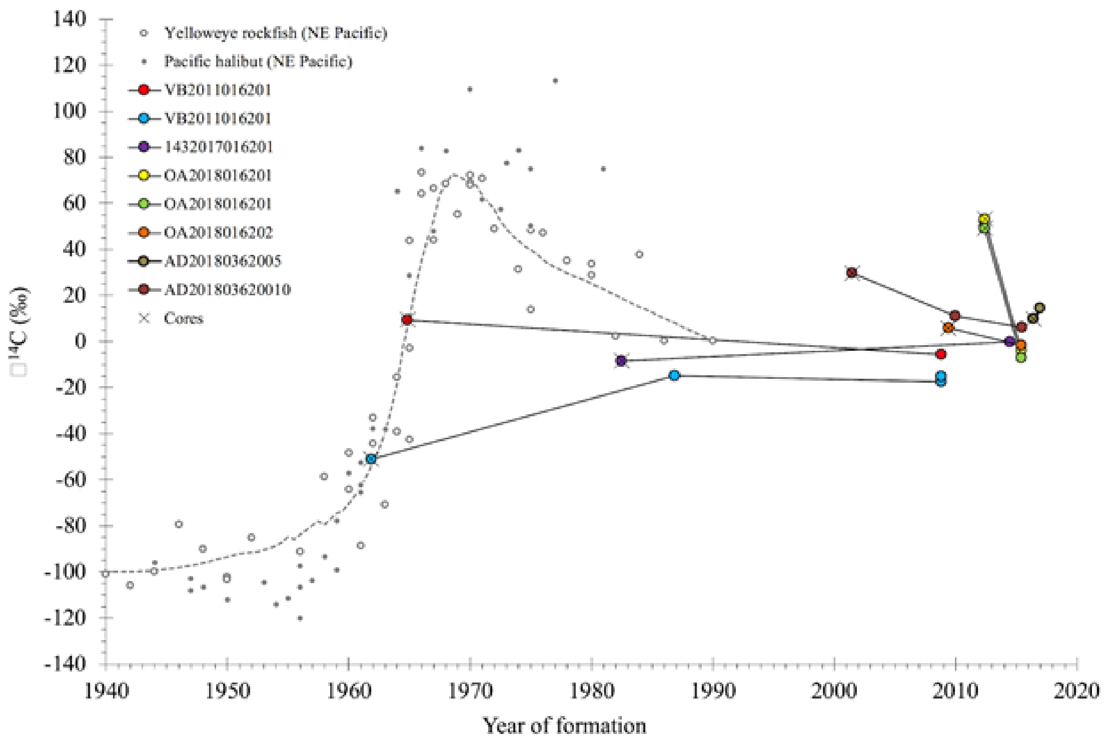


Figure 1. 14C values of the Pacific sleeper shark sampled for the pilot study, the cores are in "x". Each animal is a different color, some animals had just the core, others had the core and 1-2 layers analyzed. The reference chronologies from yelloweye rockfish and Pacific halibut are included and were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

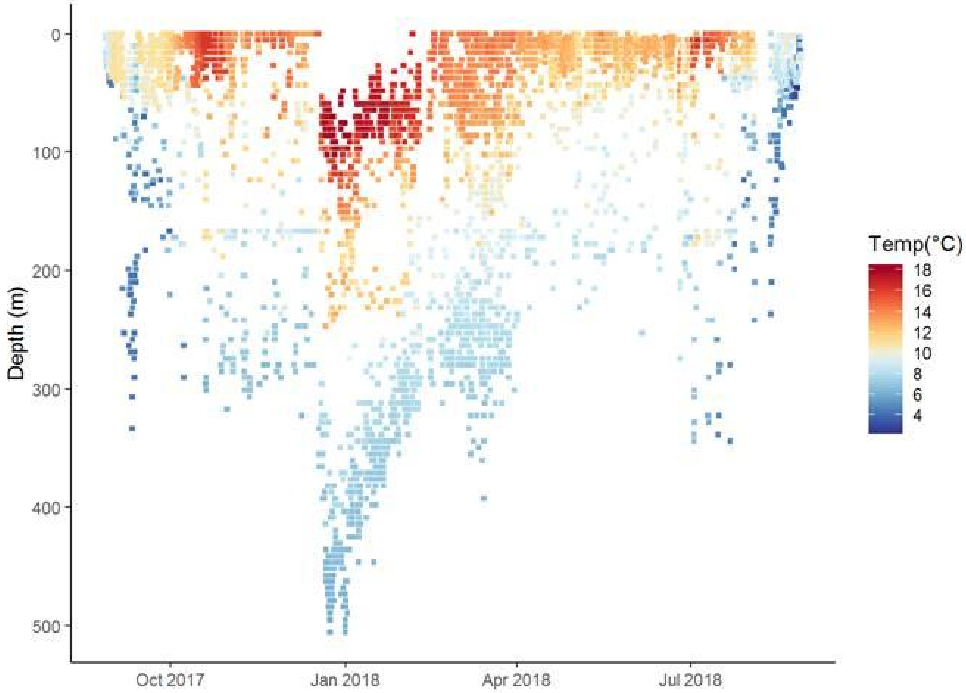


Figure 1. Salmon shark track depth and temperature record for 12 months after being tagged with an X-Tag (Microwave Telemetry, Inc.) on 27 August 2017. Each point represents the average depth and temperature for hourly data where both temperature and depth were recorded.

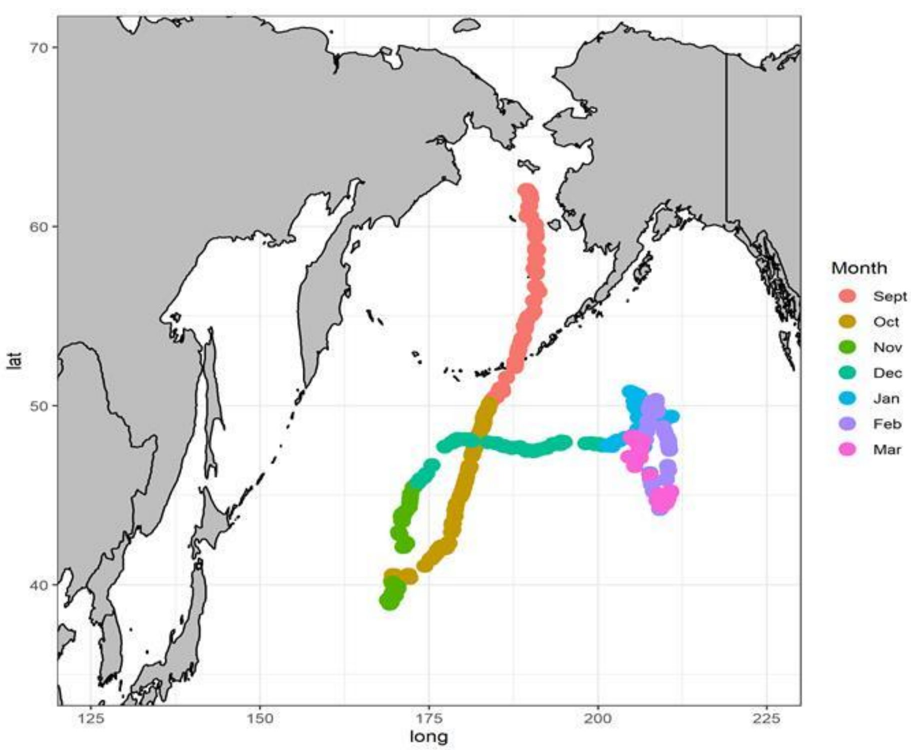


Figure 2. Salmon shark track after being tagged on 7 September 2019. Each point is a GPS location detected when the tag on the shark breaks the surface of the water, providing real-time, nearly daily observations.

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.

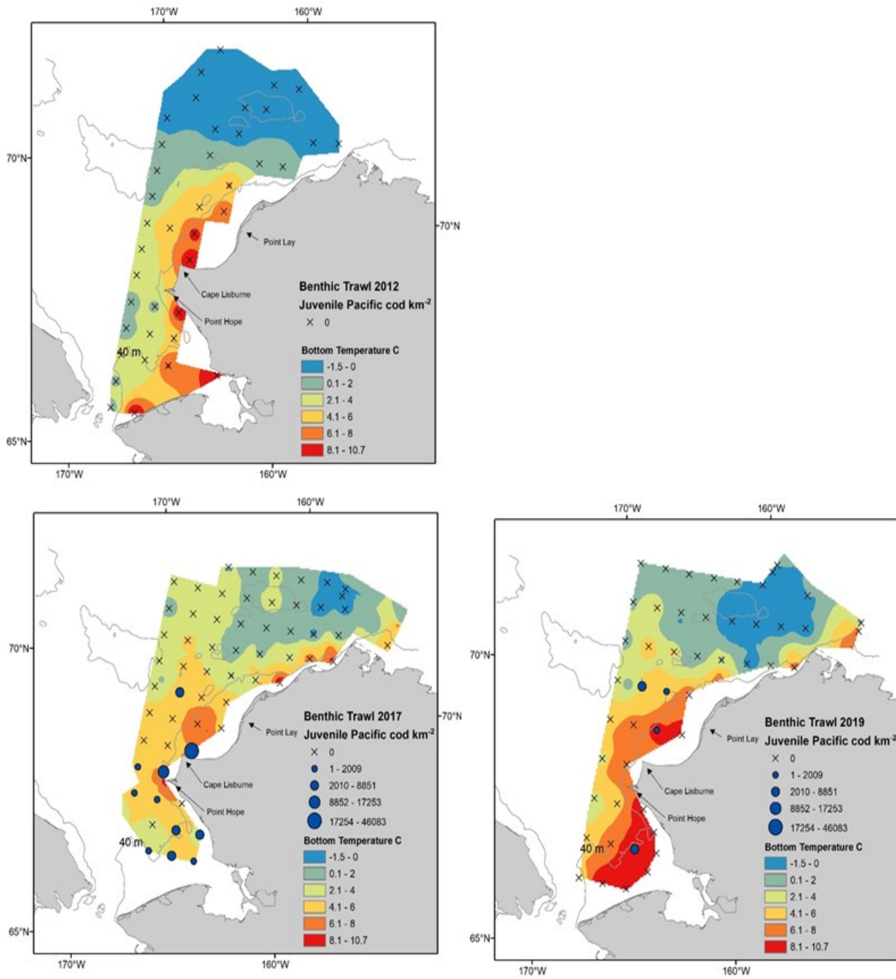


Figure 1. Pacific cod catch per unit effort and bottom temperature interpolations from 2012, 2017, and 2019.

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

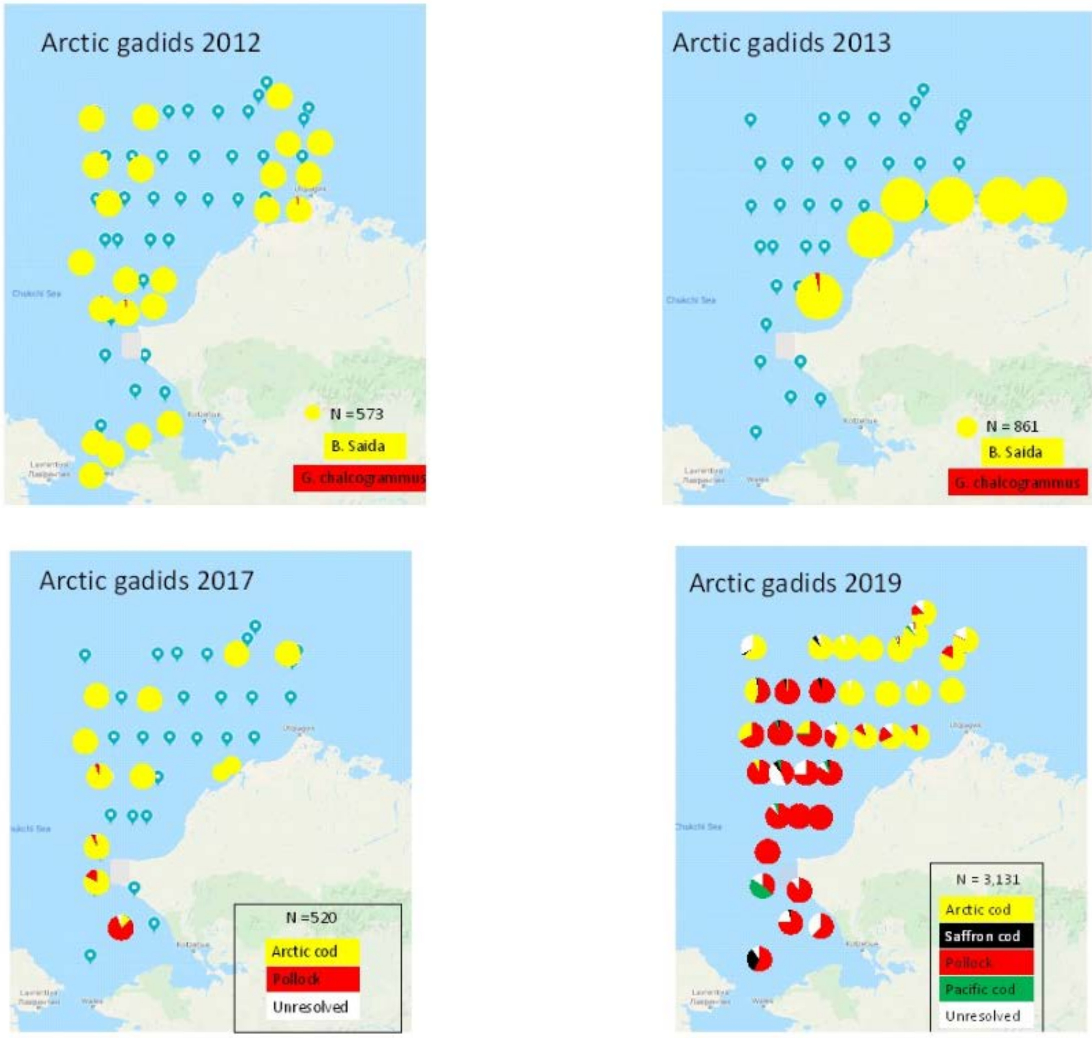
Poleward species range shifts have been predicted to result from climate change, and many observations have confirmed such movement. The abundant center hypothesis predicts that range shifts will take place by movement of individuals from core habitat to marginal habitat. However, poleward shifts may 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.

Literature Cited

Coyle K.O., L.B. Eisner, F.J. Mueter, A.I. Pinchuk, M.A. Janout, K.D. Cieciel, E.V. Farley, and A.G. Andrews. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. Fisheries Oceanography 20(2):139-56.

R Core Team (2016). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Thorson, J.T., A.O. Shelton, E.J. Ward, and H.J. Skaug. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science 72(5):1297-1310. doi:10.1093/icesjms/fsu243

Thorson, J.T., and K. Kristensen. 2016a. Implementing a generic method for bias correction in statistical models using random effects, with spatial and population dynamics examples. Fisheries Research 175:66-74. doi:10.1016/j.fishres.2015.11.016. url: http://www.sciencedirect.com/science/article/pii/S0165783615301399

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

Thorson, J.T., A. Rindorf, J. Gao, D.H. Hanselman, and H. Winker. 2016c. Density-dependent changes in effective area occupied for sea-bottom-associated marine fishes. Proceedings of the Royal Society B 283(1840):20161853.

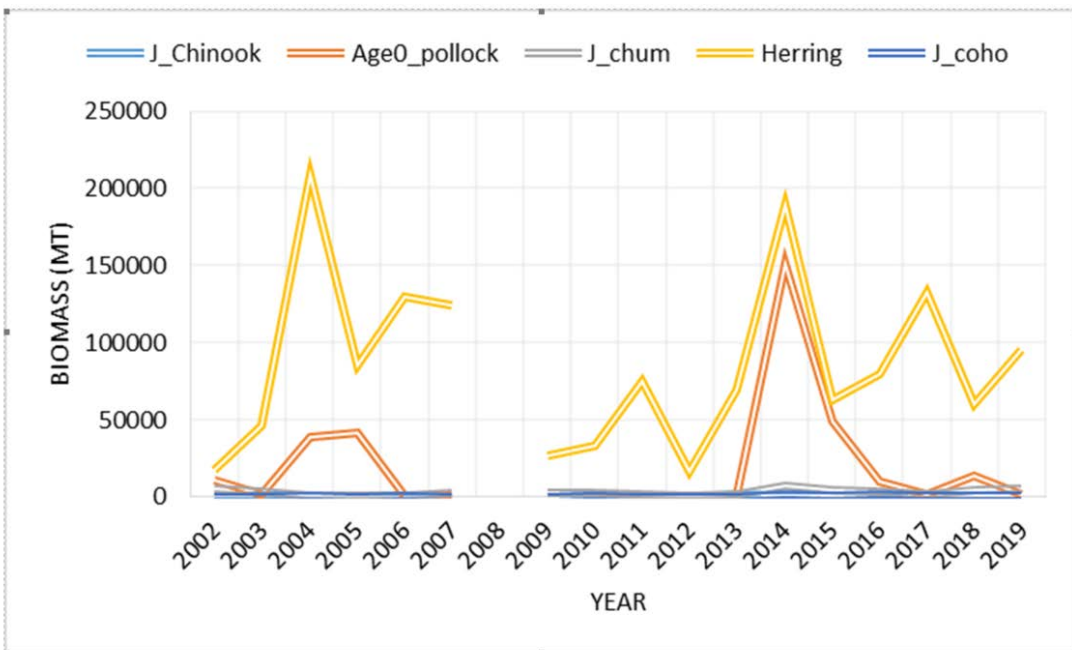


Figure 1. Estimated biomass (metric tonnes) of fish in pelagic waters of the northern Bering Sea, 2002-2019, less 2008.

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.

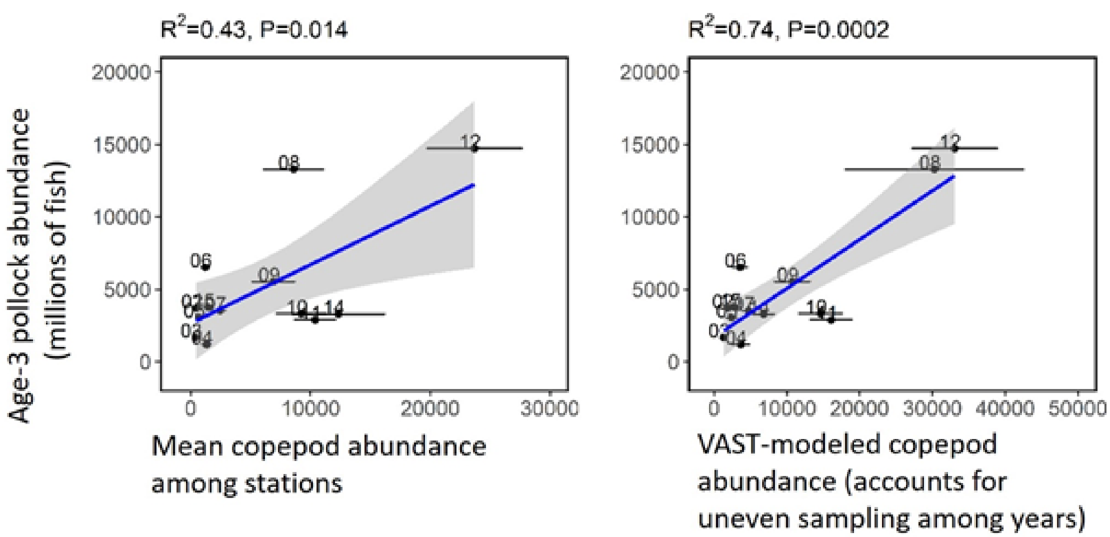


Fig. 1. Linear least squares regressions relating age-3 pollock abundance to sample-based and VAST model-based estimates of large copepod mean abundance in the southeastern Bering Sea, 2002–2015 (excluding 2013).

Literature Cited

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.

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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.

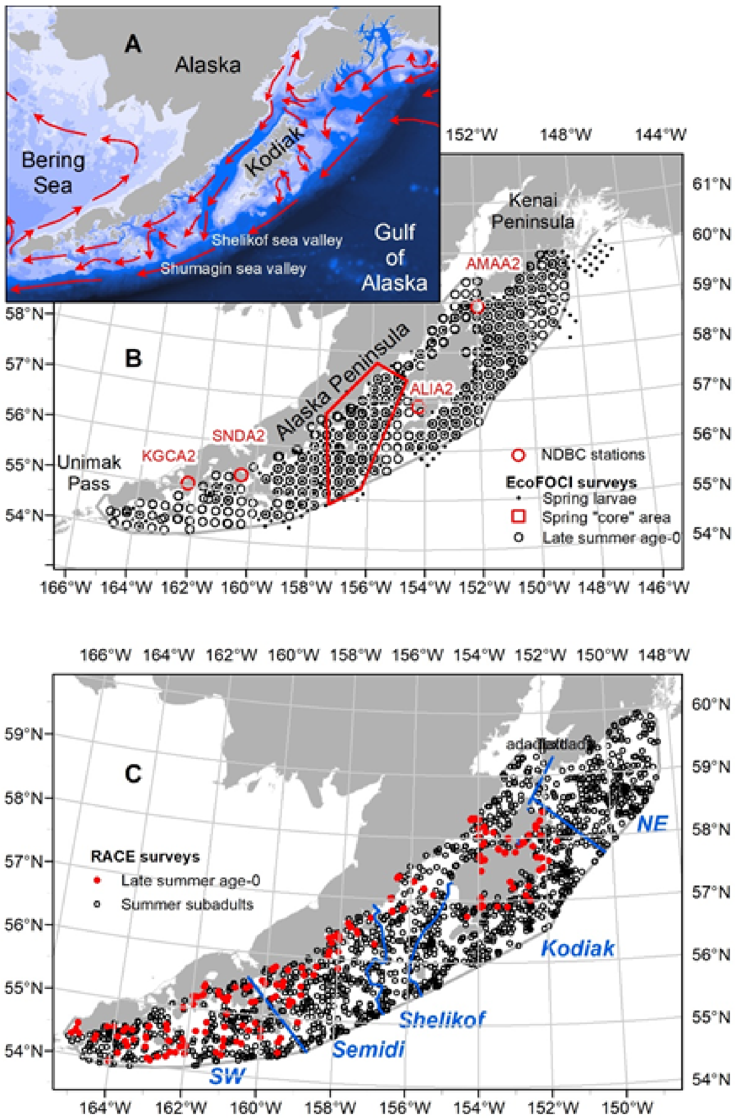

Figure 1. (A) Generalized flow over and along the shelf in the western Gulf of Alaska (Reed and Schumacher, 1986). (B) Location of four NDBC stations where wind vectors were recorded, and of EcoFOCI stations sampled during spring (larval walleye pollock, red polygon represents the “core” area) and late-summer (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).

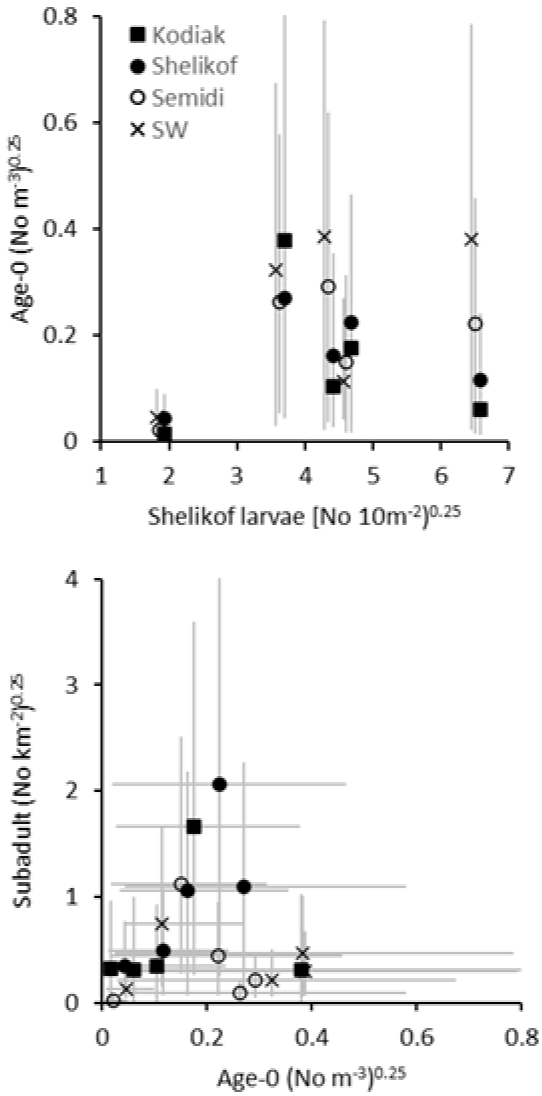

Figure 2. Region- and year-specific mean (± se) population density of age-0 juvenile walleye pollock during late summer in relation to population density of larvae in the EcoFOCI "core" area from Dougherty et al. (2019) (top, points are offset to show error bars), and to region- and year-specific mean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

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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.

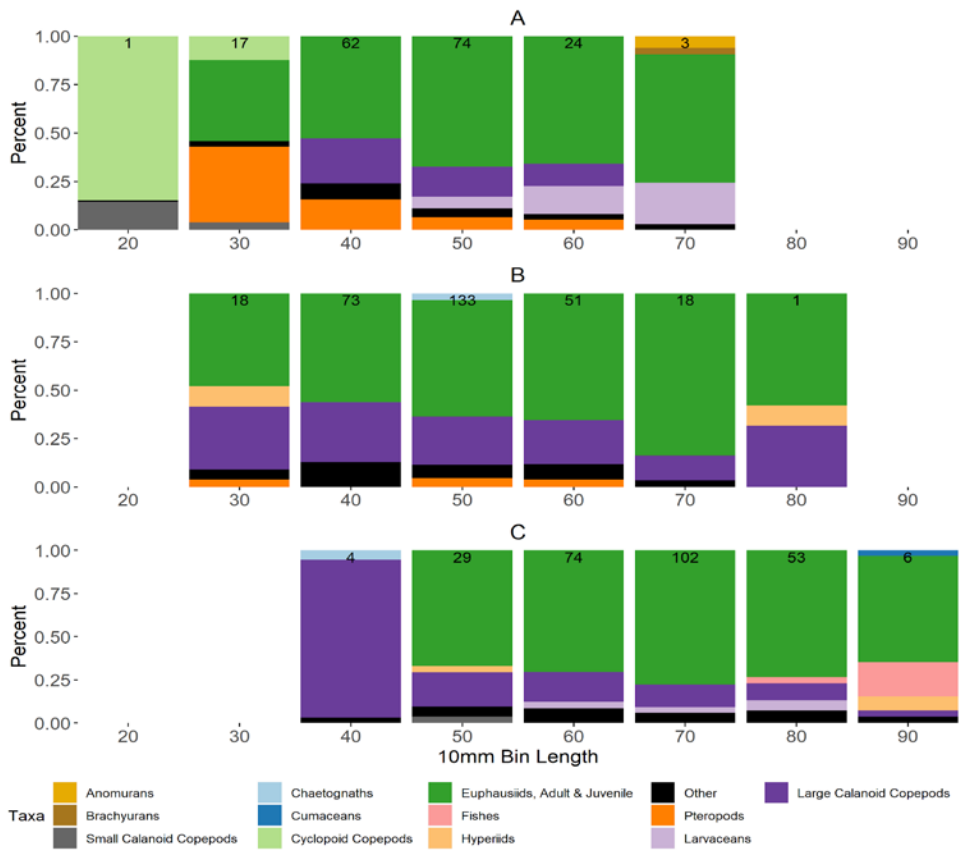


Figure 1. Age-0 pollock diet composition (percent weight) by 10mm length bins. The “Other” prey category was the sum total of prey categories that comprised less than 3% of the total prey weight in both regions.

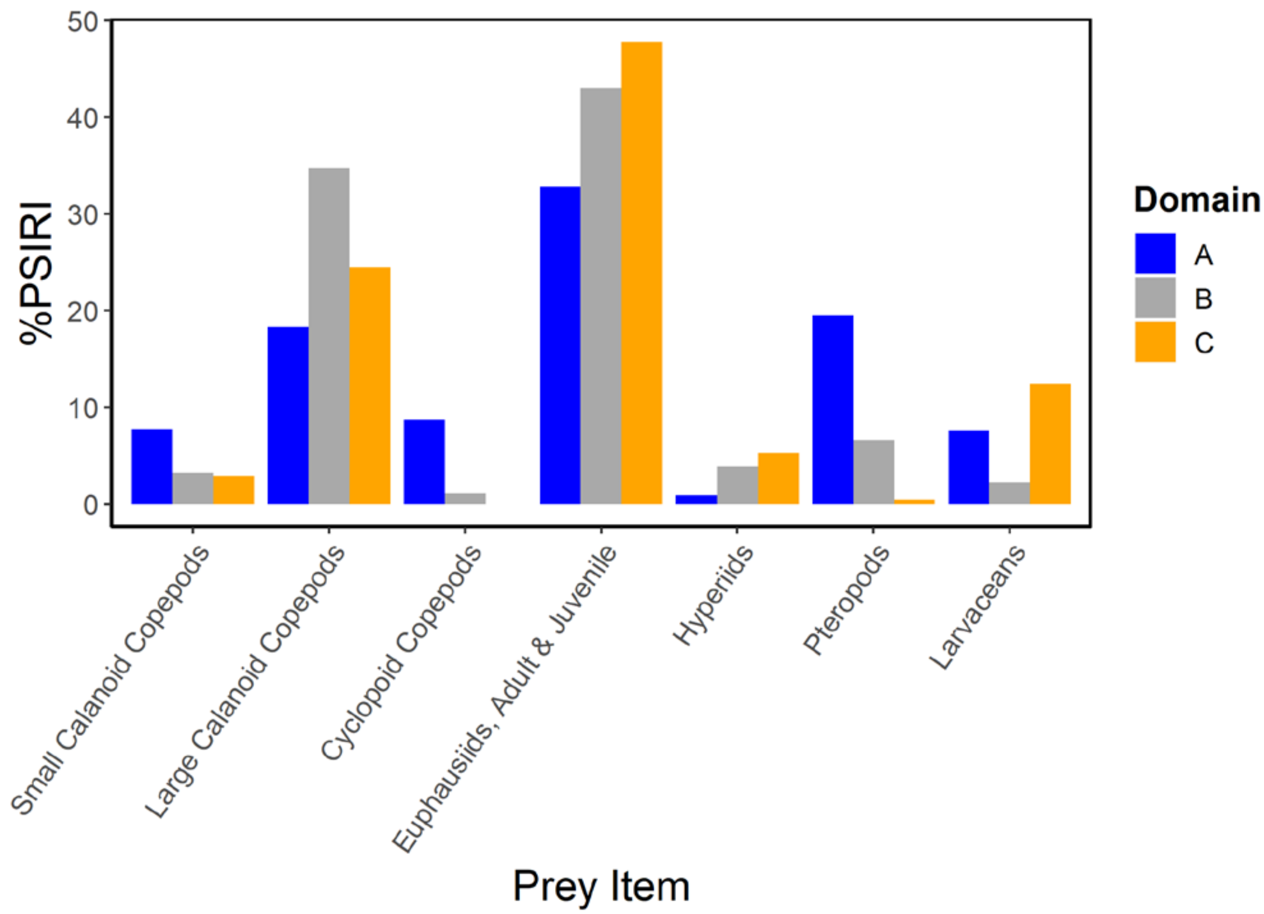


Figure 2. The top five selected prey taxa as determined by the PSIRI for stations southwest of Shumagin Is. (Domain A), between the Shumagin Is. and Kodiak Is. (Domain B) and stations surrounding and to the northeast of Kodiak Isl. (Domain C).

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.

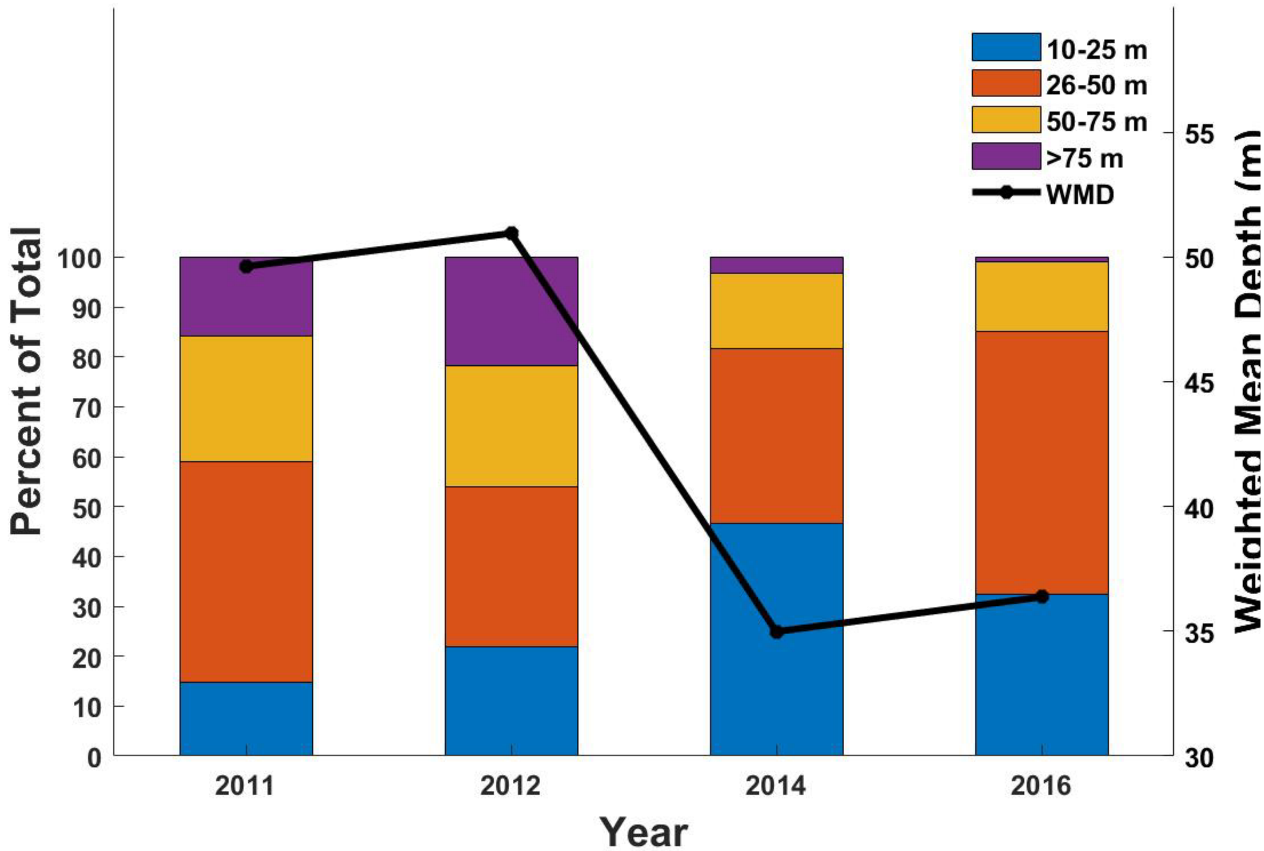


Figure 1. Depth distribution as percent of total abundance (fish nmi^{-2}) and weighted mean depth of age-0 pollock estimated by acoustic-trawl methods in 2011,2012, 2014,2016.

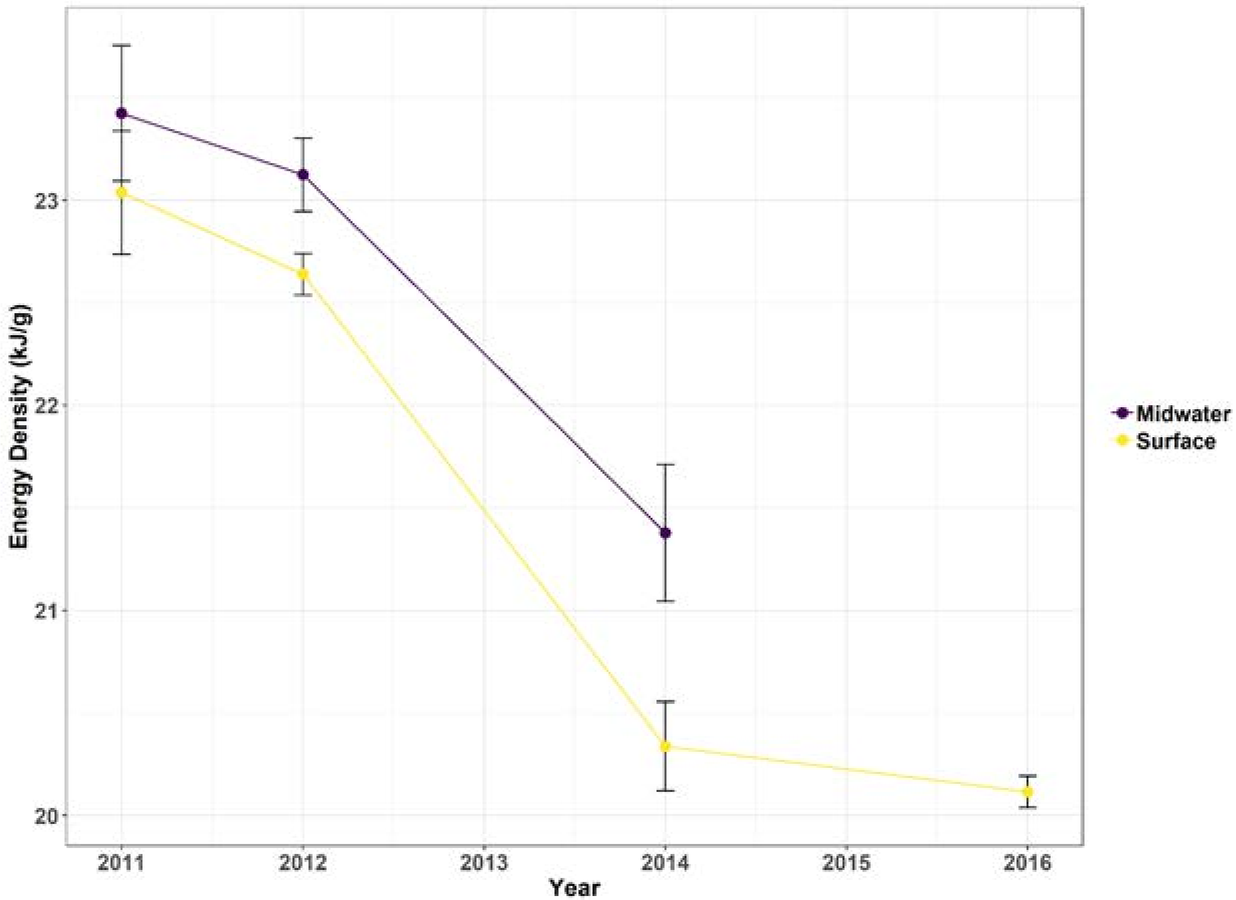


Figure 2. Energy density (± S.E.) for age-0 pollock caught in surface and midwater trawls.

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. <u>Rockfish</u>

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, s 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 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.

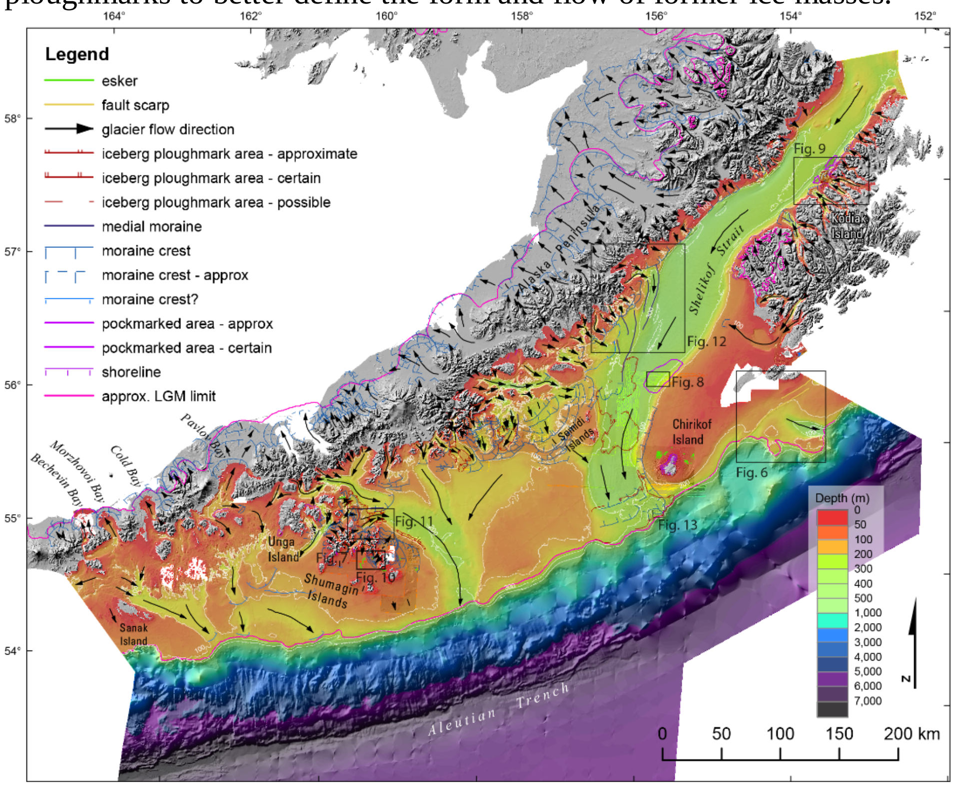
Support of Industry Innovation
In 2019 CE organized, with the help of a steering committee, the third Fisheries Innovation for Sustainable Harvest (F.I.S.H.) Workshop. Approximately 100 people participated from three NOAA Alaska Fisheries Science Center (AFSC) locations (Newport, OR; Seattle, WA; Kodiak, 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.

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References:

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.

2019 Groundfish ESPs:

Shotwell, S.K., B. Fissel, and D. Hanselman. 2019. Ecosystem and Socioeconomic Profile of the Sablefish stock in Alaska. Appendix 3C *In* Hanselman, D.H., C.J. Rodgveller, K.H. Fenske, S.K. Shotwell, K.B. Echave, P.W. Malecha, and C.R. Lunsford. 2019. Assessment of Sablefish stock in Alaska. Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea Aleutian Islands and Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501. 263 pp. Available online at: https://archive.afsc.noaa.gov/refm/docs/2019/sablefish.pdf

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:

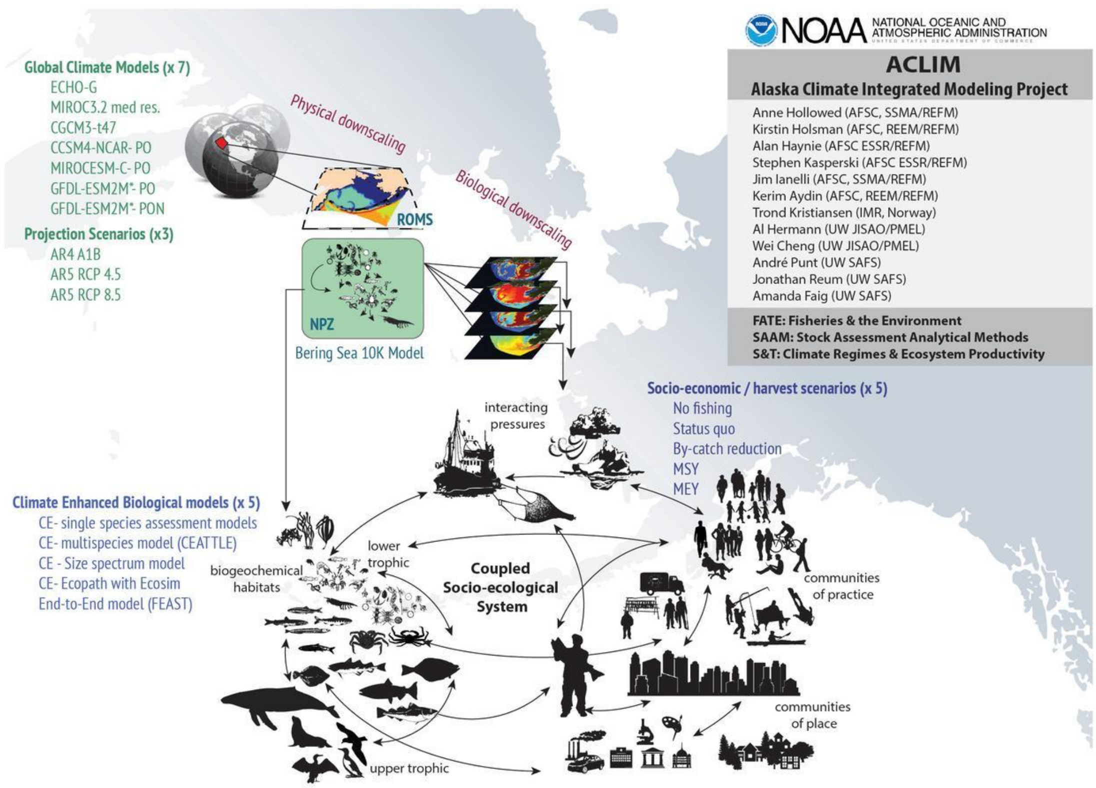
Fedewa, E., B. Garber-Yonts, K. Shotwell, and K. Palof. 2019. Ecosystem and Socioeconomic Profile of the Saint Matthew Blue King Crab stock in the Bering Sea. Appendix E *In* Palof, K., J. Zheng, and J. Ianelli. 2019. Saint Matthew Island Blue King Crab Stock Assessment 2019. Stock assessment and fishery 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 CO_2 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.

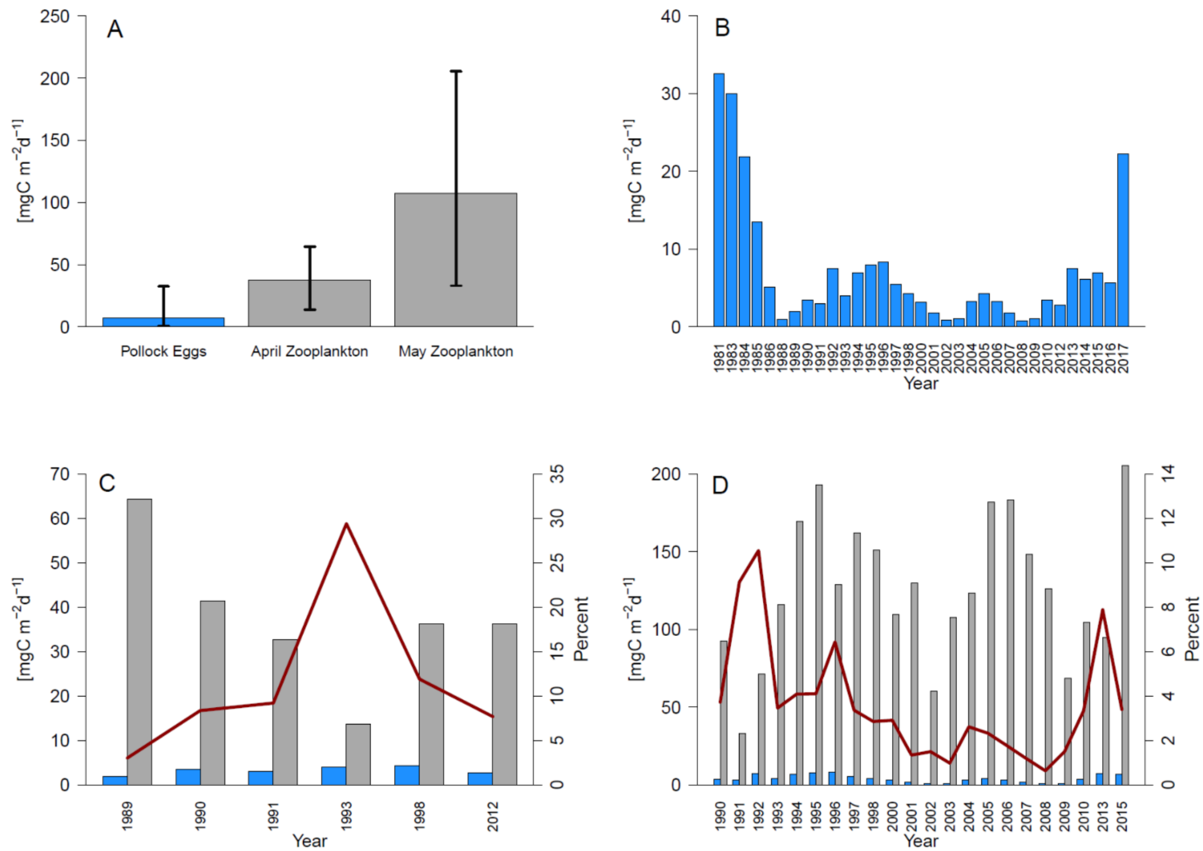


Fig 1: Estimates of, **A**) average production [mgC m^{-2} m^{-1}] of Walleye Pollock eggs deposited as energy, April and May zooplankton, **B**) annual egg production, and comparison of yearly Walleye Pollock egg production (blue) with **C**) April zooplankton (grey) and **D**) May (grey) zooplankton 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.

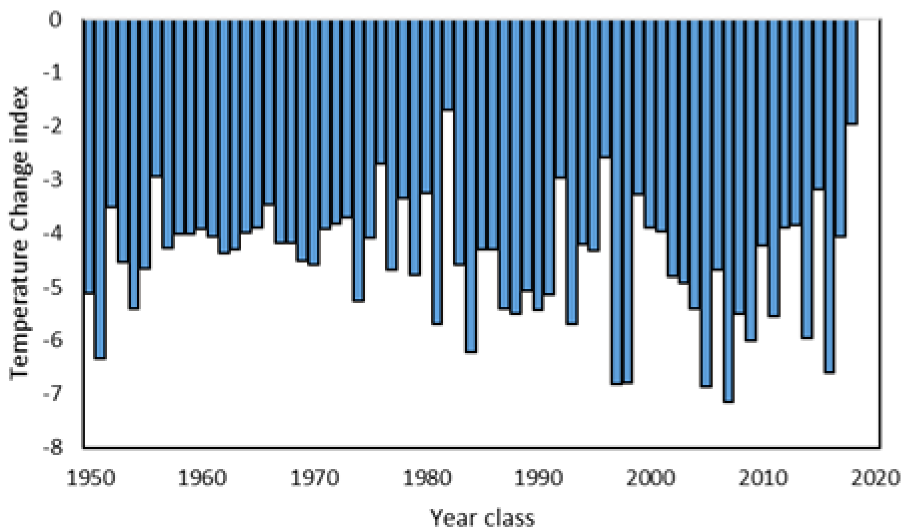


Figure 1: The Temperature Change index values from 1950 to 2019. Values represent the differences in sea temperatures on the south eastern Bering Sea shelf experienced by the 1949-2018 year classes of pollock. Less favorable conditions (more negative values) represent a warm summer during the age-0 life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

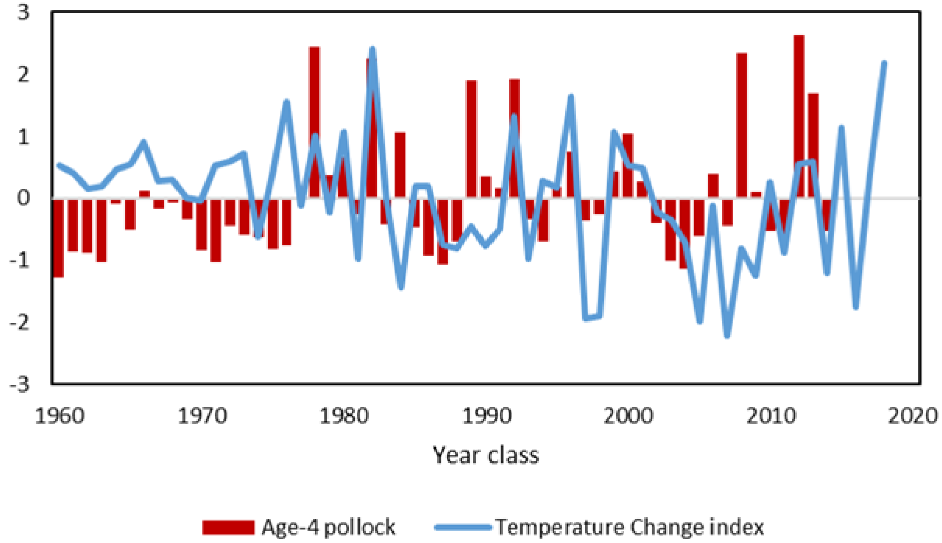


Figure 2: Normalized time series values of the temperature change index indicating conditions experienced by the 1960-2018 year classes of pollock during the summer age-0 and spring age-1 life stages. Normalized values of the estimated abundance of age-4 walleye pollock in the eastern Bering Sea from 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).

Literature Cited

Coyle, K. O., Eisner, L. B., Mueter, F. J., Pinchuk, A. I., Janout, M. A., Cieciel, K. D., ... & Andrews, A. G. (2011). Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. *Fisheries Oceanography, 20*(2), 139-156.

Heintz, R. A., Siddon, E. C., Farley, E. V., & Napp, J. M. (2013). Correlation between recruitment and fall condition of age-0 pollock (*Theragra chalcogramma*) from the eastern Bering Sea under varying climate conditions.*Deep Sea Research Part II: Topical Studies in*

Oceanography, *94*, 150-156.

Hunt Jr, G. L., Stabeno, P., Walters, G., Sinclair, E., Brodeur, R. D., Napp, J. M., & Bond, N. A. (2002). Climate change and control of the southeastern Bering Sea pelagic ecosystem. *Deep Sea Research Part II: Topical Studies in Oceanography*, *49*(26), 5821-5853.

Hunt, G. L., Coyle, K. O., Eisner, L. B., Farley, E. V., Heintz, R. A., Mueter, F., ... & Stabeno, P. J. (2011). Climate impacts on eastern Bering Sea foodwebs: a synthesis of new data and an assessment of the Oscillating Control Hypothesis. *ICES Journal of Marine Science: Journal du Conseil*, fsr036.

Ianelli, J. N., Kotwicki, S., T. Honkalehto, A. McCarthy, S. Stienessen, S., Holsman, K. Siddon, E., and 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, pp. 55–183.

Kalnay, E., Kanamitsu, M., Kistler, R., Collins, W., Deaven, D., Gandin, L., Iredell, M., Saha, S., White, G., Woollen, J. and Zhu, Y., 1996. The NCEP/NCAR 40-year reanalysis project. *Bulletin of the American meteorological Society*, *77*(3), pp. 437–471.

Martinson, E. C., Stokes, H. H., & Scarnecchia, D. L. 2012. Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0 yr class strengths in the Gulf of Alaska and eastern Bering Sea. *Fisheries Oceanography*, *21*(4), 307-319.

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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

Published January 2019 through December 2019 (AFSC authors in bold text)

ALASKA FISHERIES SCIENCE CENTER and ALASKA REGIONAL OFFICE. 2019. North Pacific Observer Program 2018 Annual Report. AFSC Processed Rep. 2019-04, 148 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

ARKEMA, K. K., L. A. ROGERS, J. TOFT, A. MESHER, K. H. WYATT, S. ALBURY-SMITH, S. MOULTRIE, M. H. RUCKELSHAUS, and J. SAMHOURI. 2019. Integrating fisheries management into sustainable development planning. Ecol. Soc. 24(2):1. https://www.ecologyandsociety.org/vol24/iss2/art1/

Beaudreau A. H., E. W. Ward, R. E. Brenner, A. O. Shelton, J. T. Watson, J. C. Womack, S. Anderson, A. C. Haynie , K. N. Marshall, B. C. Williams. 2019. Thirty years of change and the future of Alaskan fisheries: Shifts in fishing participation and diversification in response to environmental, regulatory, and economic pressures. Fish. Fish. Early Online. https://doi.org/10.1111/faf.12364

BENSON, I. M., C. R. KASTELLE, T. E. HELSER, J. A. SHORT, and D. M. ANDERL 2019. Age interpretation in eulachon (Thaleichthys pacificus) as suggested by otolith microchemical signatures. Environ. Biol. Fish. Early Online. https://doi.org/10.1007/s10641-019-00858-7

BLAKE, R. E., C. L. WARD, M. E. HUNSICKER, A. O. SHELTON and A. B. HOLLOWED. 2019. Spatial community structure of groundfish is conserved across the Gulf of Alaska. Mar. Ecol. Prog. Ser. 626:145-160. https://doi.org/10.3354/meps13050

BOSLEY, K. M., D. R. GOETHEL, A. M. BERGER, J. J. DEROBA, K. H. FENSKE, D. H. HANSELMAN, B. J. LANGSETH, and A. M. SCHUELLER. 2019. Overcoming challenges of harvest quota allocation in spatially structured populations. Fish. Res. 220:105344. https://doi.org/10.1016/j.fishres.2019.105344

COCKERHAM, S., R. ORBEN, B. LEE, H. YOUNG, L. TORRES, P. WARZYBOK, R. BRADLEY, R. SURYAN, C. OUVERNEY, S. SHAFFER. 2019. Microbial ecology of western gulls (Larus occidentalis). Microb. Ecol. https://doi.org/10.1007/s00248-019-01352-4

COOPER, D. J., and C. A. TRIBUZIO. 2019. Analysis of catch per unit effort estimates based on hooking order when more than one fish is caught on a hook. AFSC Processed Rep. 2019-07, 22 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., Auke Bay Laboratories, 17109 Point Lena Loop Road, Juneau, AK 99801.

De ROBERTIS, A., C. BASSETT, L. N. ANDERSEN, I. WANGEN, S. FURNISH, and M. LEVINE. 2019. Amplifier linearity accounts for discrepancies in echo-integration measurements from two widely used echosounders. ICES J. Mar. Sci. Early online. https://doi.org/10.1093/icesjms/fsz040

DUFFY-ANDERSON, J. T., P. STABENO, A. G. ANDREWS III, K. CIECIEL, A. DEARY, E. FARLEY, C. FUGATE, C. HARPOLD, R. HEINTZ, D. KIMMEL, K. KULETZ, J. LAMB, M. PAQUIN, S. PORTER, L. ROGERS, A. SPEAR and E. YASUMIISHI. 2019. Responses of the northern Bering Sea and southeastern Bering Sea pelagic ecosystems following record-breaking low winter sea ice. Geophys. Res. Let. 46. https://doi.org/10.1029/2019GL083396

EILER, J. H., T. M. GROTHUES, J. A. DOBARRO, and R. SHOME. 2019. Tracking the movements of juvenile Chinook salmon using an autonomous underwater vehicle under payload control. Appl. Sci. 9: 2516. https://doi.org/10.3390/app9122516

FENSKE, K. H., A. M. BERGER, B. CONNORS, J.M. COPE, S. P. COX, M.A. HALTUCH, D. H. HANSELMAN, M. KAPUR, L. LACKO, C. LUNSFORD, C. RODGVELLER, and B. WILLIAMS. 2019. Report on the 2018 International Sablefish Workshop. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-387, 107 p.

GANZ, P., and C. FAUNCE. 2019. Alternative sampling designs for the 2019 Annual Deployment Plan of the North Pacific Observer Program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-394, 29 p.

GANZ, P., and C. FAUNCE. 2019. An evaluation of methods used to predict commercial fishing effort in Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-395, 19 p.

GANZ, P., S. BARBEAUX, J. CAHALAN, J. GASPER, S. LOWE, R. WEBSTER, and C. FAUNCE. 2019. Deployment performance review of the 2018 North Pacific Observer Program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-397, 64 p.

GUTHRIE III, C. M., HV. T. NGUYEN, M. MARSH, and J. R. GUYON. 2019. Genetic stock composition analysis of Chinook salmon bycatch samples from the 2017 Gulf of Alaska trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-390, 30 p

GUTHRIE III, C. M., HV. T. NGUYEN, M. MARSH, J. T. WATSON, and J. R. GUYON. 2019. Genetic stock composition analysis of the Chinook salmon bycatch samples from the 2017 Bering Sea trawl fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-391, 36 p.

HELSER, T. E., I. M. BENSON, and B. K. BARNETT (editors). 2019. Proceedings of the research workshop on the rapid estimation of fish age using Fourier Transform Near Infrared Spectroscopy (FT-NIRS). AFSC Processed Rep. 2019-06, 195 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

HERMANN, A. J., G. A. GIBSON, W. CHENG, I. ORTIZ, K. AYDIN, M. WANG, A. B. HOLLOWED and K. K. HOLSMAN. 2019. Projected biophysical conditions of the Bering Sea to 2100 under multiple emission scenarios. ICES J. Mar. Sci. 76:1280-1304. https://doi.org/10.1093/icesjms/fsz043

HOLLOWED, A. B., M. BARANGE, V. GARÇON, S.-I. ITO, J. S. LINK, S. ARICÒ, H. BATCHELDER, R. BROWN, R. GRIFFIS and W. WAWRZYNSKI. 2019. Recent advances in understanding the effects of climate change on the world's oceans. ICES J. Mar. Sci. 76: 1215-1220. https://doi.org/10.1093/icesjms/fsz084

HOLSMAN, K. K., E. L. HAZEN, A. HAYNIE, S. GOURGUET, A. HOLLOWED, S. J. BOGRAD, J. F. SAMHOURI and K. AYDIN. 2019. Towards climate resiliency in fisheries management. ICES J. Mar. Sci. 76:1368-1378. https://doi.org/10.1093/icesjms/fsz031

JONES, D. T., N. E. LAUFFENBURGER, K. WILLIAMS, and A. DE ROBERTIS. 2019. Results of the acoustic trawl survey of walleye pollock (Gadus chalcogrammus) in the Gulf of Alaska, June August 2017 (DY2017-06), AFSC Processed Rep. 2019- 08, 110 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE Seattle, WA 98115.

KEARNEY, K. A. 2019. Freshwater input to the Bering Sea, 1950–2017, 107 p. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-388, 46 p.

KIM, S. R., J. J. KIM, W. T. STOCKHAUSEN, C.-S. KIM, S. KANG, H. K. CHA, H.-S. JI, S.-H. JANG, and H. J. BAEK. 2019. Characteristics of the eggs and larval distribution and transport process in the early life stage of the chub mackerel Scomber japonicus near Korean waters. Korean J. Fish. Aquat. Sci. 52:666-684. https://doi.org/10.5657/KFAS.2019.0666

KRIEGER, J. R., A. SREENIVASAN, and R. HEINTZ. 2019. Temperature-dependent growth and consumption of young-of-the-year sablefish Anoplopoma fimbria: Too hot, too cold or just right? Fish. Res. 209:32-39. https://doi.org/10.1016/j.fishres.2018.09.005

Kroetz, K., D. K. Lew, J. N. Sanchirico, and P. Donovan 2019. Recreational leasing of Alaska commercial halibut quota: the early years of the GAF program in Alaska. Coast. Manage. 47:207-226. https://doi.org/10.1080/08920753.2019.1564954

Kroetz, K., M. N. Reimer, J. N. Sanchirico, D. K. Lew, and J. Huetteman. 2019. Defining the economic scope for ecosystem-based fishery management. Proc. Nat. Acad. Sci. 116:4188-4193. https://doi.org/10.1073/pnas.1816545116

LANG, C. A., J. I. RICHAR, and R. J. FOY. 2019. The 2018 eastern Bering Sea continental shelf and northern Bering Sea trawl surveys: Results for commercial crab species. U.S. Dep. Commer., NOAA Tech.Memo. NMFS-AFSC-386, 220 p.

LAUTH, R. R., E. J. DAWSON, and J. CONNER. 2019. Results of the 2017 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-396, 260 p.

LEHNERT, H., and R. P. STONE. 2019. Two new species of Geodiidae (Porifera, Demospongiae, Astrophorina) from the Emperor Seamounts, North Pacific Ocean. Zootaxa 4671:381–395. http://dx.doi.org/10.11646/zootaxa.4671.3.4

LEVINE, M., and A. De ROBERTIS. 2019. Don't work too hard: Subsampling leads to efficient analysis of large acoustic datasets. Fish. Res. 219: 105323. https://doi.org/10.1016/j.fishres.2019.105323

LEW, D. K. 2019. Place of residence and cost attribute non-attendance in a stated preference choice experiment involving a marine endangered species. Mar. Resour. Econ. 34:225-245. https://doi.org/10.1086/705114

Lewis, D. J., S. Dundas, D. Kling, D. K. Lew, and S. Hacker. 2019. The non-market benefits of early and partial gains in managing threatened salmon. PLOS One 14(8): e0220260. https://doi.org/10.1371/journal.pone.0220260

LINDEBERG, M. R., and S. C. LINDSTROM. 2019. Assessment and catalog of benthic marine algae from the Alaska Peninsula, May 2016. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-389, 22 p + Appendices.

LONG, W. C., P. PRUISNER, K. M. SWINEY and R. J. FOY. 2019. Effects of ocean acidification on the respiration and feeding of juvenile red and blue king crabs (Paralithodes camtschaticus and P. platypus). ICES J. Mar. Sci. 76:1335-1343. https://doi.org/10.1093/icesjms/fsz090

LOREDO, S. A., R. A. ORBEN, R. M. SURYAN, D. E. LYONS, J. ADAMS and S. W. STEPHENSEN. 2019. Spatial and temporal diving behavior of non-breeding common murres during two summers of contrasting ocean conditions. J. Exper. Mar. Biol. Ecol. 517:13-24. https://doi.org/10.1016/j.jembe.2019.05.009

MALECHA, P., C. RODGVELLER, C. LUNSFORD, and K. SIWICKE. 2019. The 2018 longline survey of the Gulf of Alaska and eastern Aleutian Islands on the FV Alaskan Leader: Cruise Report AL-18-01. AFSC Processed Rep. 2019-02, 30 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.

MASUDA, M. M., and A. G. CELEWYCZ. 2019. Coded-wire tag sampling: the case for electronic-field detection. Northwest Sci. 93:102-111. https://doi.org/10.3955/046.093.0202

McCONNAUGHEY, R. A., J. G. HIDDINK, S. JENNINGS, C. R. PITCHER, M. J. KAISER, P. SUURONEN, M. SCIBERRAS, A. D. RIJNSDORP, J. S. COLLIE, T. MAZOR, R. O. AMOROSO, A. M. PARMA and R. HILBORN. 2019. Choosing best practices for managing impacts of trawl fishing on seabed habitats and biota. Fish Fish. Early Online. https://doi.org/10.1111/faf.12431

McGOWAN D. W., HORNE J. K., ROGERS L. A. 2019. Effects of temperature on the distribution and density of capelin in the Gulf of Alaska. Mar. Ecol. Prog. Ser. 620:119-138. https://doi.org/10.3354/meps12966

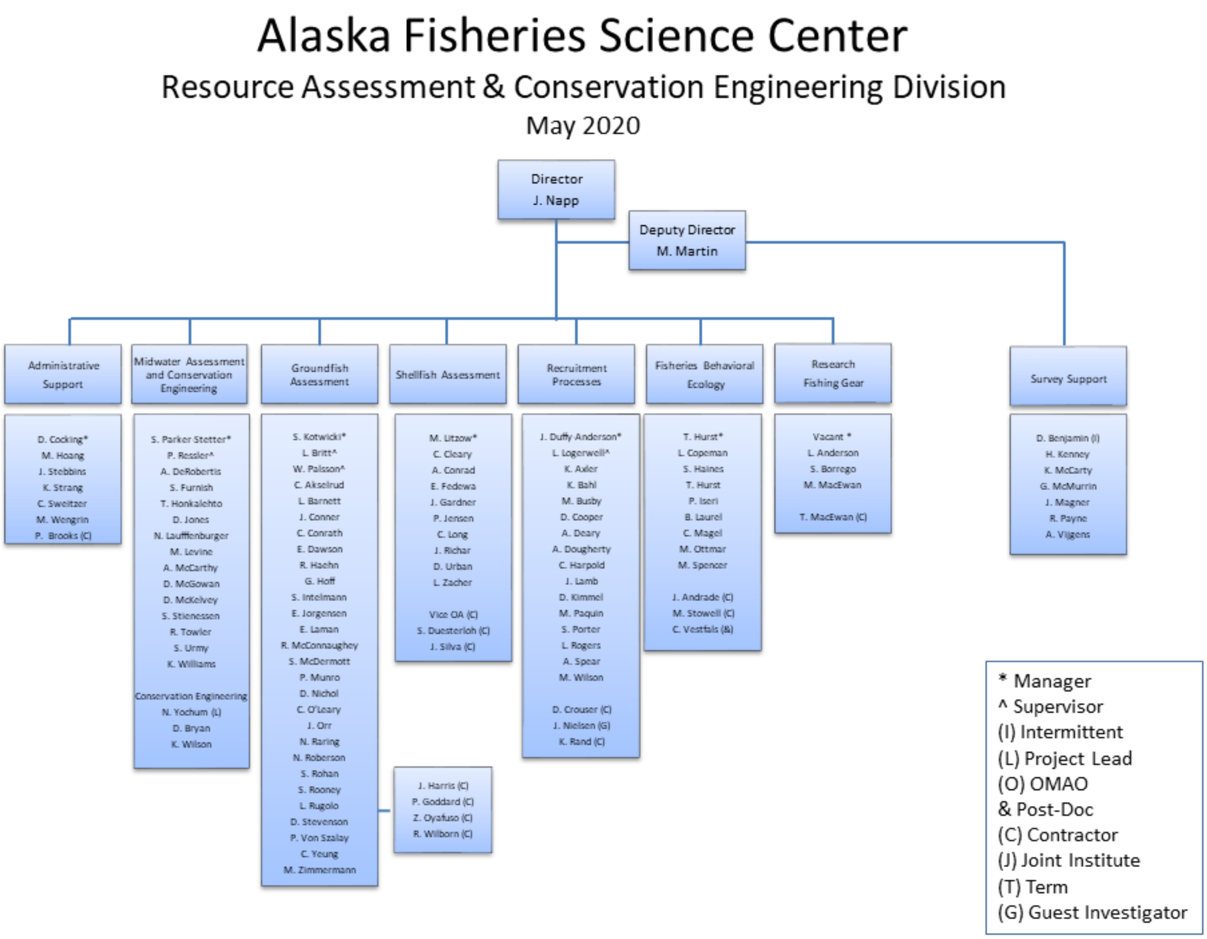
McGOWAN, D. W., J. K. HORNE, J. T. THORSON and M. ZIMMERMANN. 2019. Influence of environmental factors on capelin distributions in the Gulf of Alaska. Deep Sea Res. II. 165:

238-254. https://doi.org/10.1016/j.dsr2.2017.11.018
McKUIN, B. L., J. T. WATSON, A. C. HAYNIE, and J. E. CAMPBELL. 2019. Climate forcing by battered-and-breaded fillets and crab-flavored sticks from Alaska pollock. Elem. Sci. Anth., 7:48. http://doi.org/10.1525/elementa.386
MELVIN, E.F., K.S. DIETRICH, R.M. SURYAN, S.M. FITZGERALD. 2019. Lessons from seabird conservation in Alaskan longline fisheries. Cons. Biol. 33:842-852. https://doi.org/10.1111/cobi.13288
MORDY, C. W., P. J. STABENO, N. B. KACHEL, D. KACHEL, C. LADD, M. ZIMMERMANN, A. J. HERMANN, K. O. COYLE and M. J. DOYLE. 2019. Patterns of flow in the canyons of the northern Gulf of Alaska. Deep Sea Res. II. 165:203-220. https://authors.elsevier.com/c/1ZbS-3Ruf19TVN
NICHOL, D. G., S. KOTWICKI, T. K. WILDERBUER, R. R. LAUTH, and J. N. IANELLI. 2019. Availability of yellowfin sole Limanda aspera to the eastern Bering Sea trawl survey and its effect on estimates of survey biomass. Fish. Res. 211: 319-330.
O'FARRELL, S., J. N. SANCHIRICO, O. SPIEGEL, M. DEPALLE, A. C. HAYNIE, S. A. MURAWSKI, L. PERRUSO and A. STRELCHECK. 2019. Disturbance modifies payoffs in the explore-exploit trade-off. Nat. Commun. 10: 3363. https://doi.org/10.1038/s41467-019-11106-y
ORBEN, R.A., A.B. FLEISHMAN, A.L. BORKER, W. BRIDGELAND, A.J. GLADICS, J. PORQUEZ, P. SANZENBACHER, R. SWIFT, S. W. STEPHENSEN, M.W. MCKOWN, and R.M. SURYAN. 2019. Comparing imaging, acoustics, and radar to monitor Leach's storm-petrel colonies. PeerJ. 7:e6721 https://doi.org/10.7717/peerj.6721
ORR, J. W., D. E. STEVENSON, G. HANKE, I. B. SPIES, JAMES A. BOUTILLIER, and G. R HOFF. 2019. Range extensions and new records from Alaska and British Columbia for two skates, Bathyraja spinosissima and B. microtrachys. Northwest. Nat. 100:37–47. https://doi.org/10.1898/NWN18-21
PIETSCH, T. W., and J. W. ORR. 2019. Fishes of the Salish Sea: Puget Sound and the Strait of Georgia and Juan de Fuca. U. Wash. Press, Seattle, 1048 p. + 350 figs.
PIETSCH, T. W., and J. W. ORR. 2019. Obituary. Jean Richard Dunn (1934–2017). Copeia 107:379–381. https://doi.org/10.1643/OT-19-203
PIRTLE, J. L., S. K. SHOTWELL, M. ZIMMERMANN, J. A. REID and N. GOLDEN. 2019. Habitat suitability models for groundfish in the Gulf of Alaska. Deep Sea Res. II. 165:303-321. https://doi.org/10.1016/j.dsr2.2017.12.005
RODGVELLER, C. J. 2019. The utility of length, age, liver condition, and body condition for predicting maturity and fecundity of female sablefish. Fish. Res. 216:18-28. https://doi.org/10.1016/j.fishres.2019.03.013
ROGERS, M., R. BARE, A. GRAY, T. SCOTT-MOELDER and R. HEINTZ. 2019. Assessment of two feeds on survival, proximate composition, and amino acid carbon isotope discrimination in hatchery-reared Chinook salmon. Fish. Res. 219: 105303. https://doi.org/10.1016/j.fishres.2019.06.001
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. Mar. Ecol. Prog. Ser. 609:163–178. https://doi.org/10.3354/meps12809
RUDD, M. B., J. T. THORSON, and S. R. SAGARESE. 2019. Ensemble models for data-poor assessment: accounting for uncertainty in life-history information. ICES J. Mar. Sci. 76:870-883. https://doi.org/10.1093/icesjms/fsz012
SEUNG, C. K., and J. N. IANELLI. 2019. Evaluating alternative policies for managing an Alaska pollock fishery with climate change. Ocean Coast. Manage. 178: 104837.

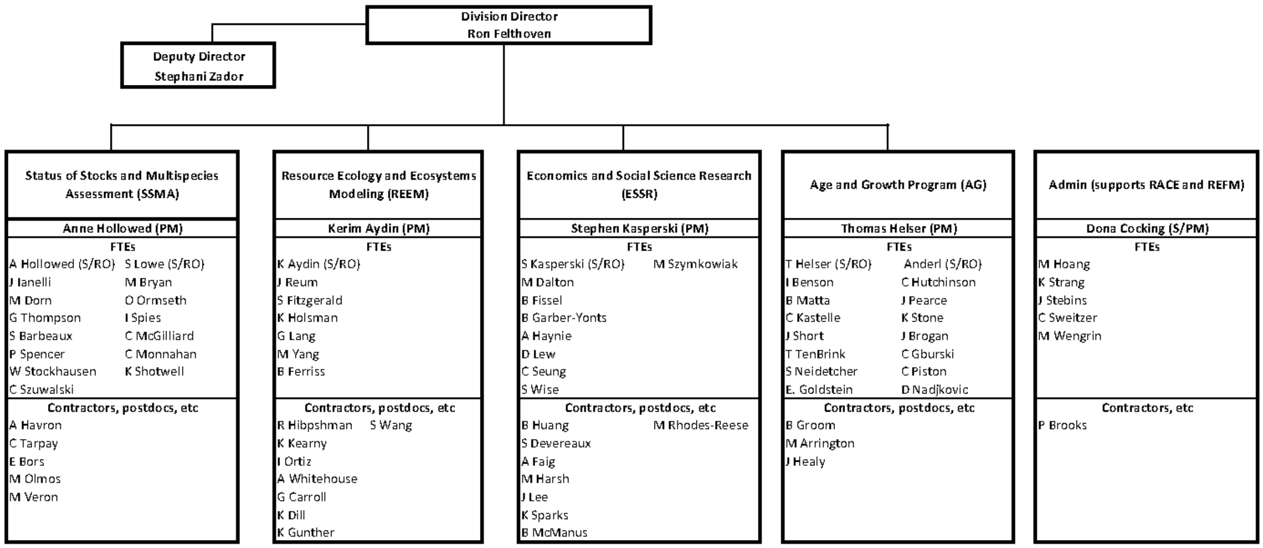
https://doi.org/10.1016/j.ocecoaman.2019.104837
SEWALL, F., B. NORCROSS, J. VOLLENWEIDER, and R. HEINTZ. 2019. Growth, energy storage, and feeding patterns reveal winter mortality risks for juvenile Pacific herring in Prince William Sound, Alaska, USA. Mar. Ecol. Prog. Ser. 623: 195-208. https://doi.org/10.3354/meps13013
SIGLER, M. F., K. B. ECHAVE. 2019. Diel vertical migration of sablefish (Anoplopoma fimbria). Fish. Oceanogr. Early online. https://doi.org/10.1111/fog.12428
STEVENSON, D. E., and R. R. LAUTH. 2019. Bottom trawl surveys in the northern Bering Sea indicate recent shifts in the distribution of marine species. Polar Biol. 42:407-421. https://doi.org/10.1007/s00300-018-2431-1
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. Fish. Bull. 117:8–14. https://spo.nmfs.noaa.gov/fishery-bulletin-journal/1171
STIENESSEN, S. C., T. HONKALEHTO, N. E. LAUFFENBURGER, P. H. RESSLER, and R. R. LAUTH. 2019. Acoustic Vessel-of-Opportunity (AVO) index for midwater Bering Sea walleye pollock, 2016-2017. AFSC Processed Rep. 2019-01, 24 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.
STIENESSEN, S., N. LAUFFENBURGER, and A. DE ROBERTIS. 2019. Results of the acoustic-trawl surveys of walleye pollock (Gadus chalcogrammus) in the Gulf of Alaska, February-March 2018 (DY2018-01 and DY2018-03). AFSC Processed Rep. 2019-05, 101 p. Alaska Fish. Sci. Cent., NOAA, Natl. Mar. Fish. Serv., 7600 Sand Point Way NE, Seattle WA 98115.
STOCKHAUSEN, W. T., K. O. COYLE, A. J. HERMANN, M. DOYLE, G. A. GIBSON, S. HINCKLEY, C. LADD, and C. PARADA. 2019. Running the gauntlet: Connectivity between natal and nursery areas for Pacific ocean perch (Sebastes alutus) in the Gulf of Alaska, as inferred from a biophysical individual-based model. Deep Sea Res. II 165: 74-88. https://doi.org/10.1016/j.dsr2.2018.05.016
STONE, R. P., H. LEHNERT, and G. R. HOFF 2019. Inventory of the eastern Bering Sea sponge fauna, geographic range extensions and description of Antho ridgwayi sp. nov. 4567:15. http://dx.doi.org/10.11646/zootaxa.4567.2.2
VESTFALS, C. D., F. MUETER, J. T. DUFFY-ANDERSON, M. S. BUSBY, and A. De ROBERTIS, 2019. Spatiotemporal distribution of polar cod (Boreogadus saida) and saffron cod (Eleginus gracilis) early life stages in the Pacific Arctic. Polar Biol. 42:969-990 https://doi.org/10.1007/s00300-019-02494-4
Watson J. T., A. C. Haynie, P. J. Sullivan, L. Perruso, S. O'Farrell, J. N. Sanchirico, F. J. Mueter. 2018. Vessel monitoring systems (VMS) reveal an increase in fishing efficiency following regulatory changes in a demersal longline fishery. Fish. Res. 207: 85-94. https://doi.org/10.1016/j.fishres.2018.06.006
WATSON, J.T. 2019. Spatial and temporal visualizations of satellite-derived sea surface temperatures for Alaska fishery management areas. Pac. States E-Journal Sci. Visual. https://doi.org/10.28966/PSESV.2019.003
YANG, Q, E. COKELET, P. J. STABENO, L. LI, A. B. HOLLOWED, W. A. PALSSON, N. A. BOND, and S. J. BARBEAUX 2019. How "The Blob" affected groundfish distributions in the Gulf of Alaska. Fish Oceanogr. 00: 1– 20. https://doi.org/10.1111/fog.12422
YEUNG, C., and D. W. COOPER. Contrasting the variability in spatial distribution of two juvenile flatfishes in relation to thermal stanzas in the eastern Bering Sea. ICES J. Mar. Sci. Early Online. https://doi.org/10.1093/icesjms/fsz180
ZIMMERMANN, M. 2019. Comparison of the physical attributes of the central and eastern Gulf of

Alaska integrated ecosystem research program inshore study sites. Deep Sea Res. II 165:280-291. https://authors.elsevier.com/a/1ZbS-3Ruf15fNK
ZIMMERMANN, M., A. DE ROBERTIS and O. ORMSETH 2019. Verification of historical smooth sheet bathymetry for the Gulf of Alaska – Integrated Ecosystem Research Program. Deep Sea Res. II 165:292-302. https://authors.elsevier.com/a/1ZbS-3Ruf11rJq
ZIMMERMANN, M., M. M. PRESCOTT, and P. J. HAEUSSLER. 2019. Bathymetry and geomorphology of Shelikof Strait and the Western Gulf of Alaska. Geosciences. 9:409. https://doi.org/10.3390/geosciences9100409

APPENDIX I. RACE ORGANIZATION CHART

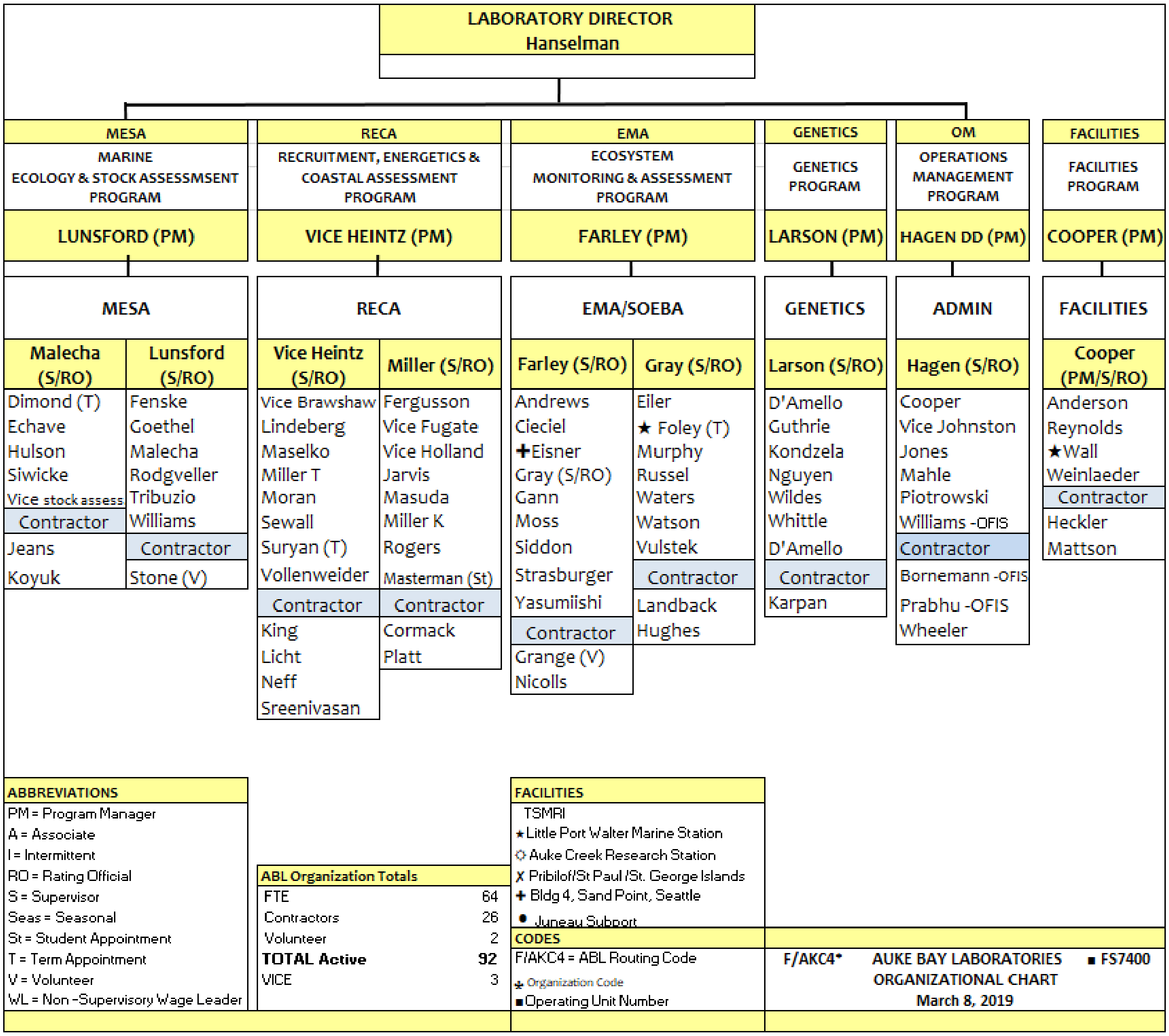


APPENDIX II. REFM ORGANIZATION CHART



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