Alaska Fisheries Science Center of the National Marine Fisheries Service
2018 Agency Report to the Technical Subcommittee of the Canada-US Groundfish Committee
April 2019

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TABLE OF CONTENTS

VIII. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT IN 2018

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 2018 our activities were guided by our Strategic Science Plan (www.afsc.noaa.gov/GeneralInfo/FY17StrategicSciencePlan.pdf) with annual priorities specified in the FY18 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. Annual 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.

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 comprised 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 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 2018, RACE Groundfish Assessment Program (GAP) and Shellfish Assessment Program (SAP) scientists conducted bottom trawl survey of Alaskan groundfish and invertebrate resources during the annual eastern Bering Sea Shelf Bottom Trawl Survey, including a rapid response extension into the northern Bering Sea shelf to investigate how a record low in sea ice and cold water temperatures affected fish and crab distributions and biomass. GAP also carried out the biennial Aleutian Island Bottom Trawl Survey.

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 eastern Bering Sea (summer). Track lines for the summer survey were extended northward to examine climate-mediated effects of loss of sea ice and the cold pool on fish distribution. A collaborative cruise to test the efficacy of different types of trawl excluders 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 Bering Sea 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, Arrowthooth and Kamchatka Flounder and Northern & Southern Rock Sole, Alaska Plaice, Greenland Turbot. Summer surveys concentrate on the age-0 and age-1 juvenile stages of the winter/spring spawners as well as summer spawners (e.g. Yellow-Fin Sole). This survey also estimates whether or not age-0 fish have sufficient energy reserves to survive their first winter. In 2018 the summer RPA surveys were cut short due to NOAA ship electrical issues.

Research on environmental effects on groundfish species such as the impacts of ocean acidification on early life history growth and survival continue at our Newport, Oregon facility. Similarly the 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 2018 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. 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 currently 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 will host an ICES workshop on the impacts of unavoidable survey effort reduction (ICES WKUSER) in the winter 2019/2020. 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. <u>REFM DIVISION</u>

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) is the primary group at ABL involved with groundfish activities. Major focus of the MESA Program is on research and assessment of sablefish, rockfish, and sharks in Alaska. Presently, the program is staffed by 10 scientists. ABL's Ecosystem Monitoring and Assessment Program (EMA), Recruitment Energetics and Coastal Assessment Program (RECA), and Genetics Program also conduct groundfish-related research and surveys and all programs have contributed to this report.

In 2018 the ABL Division conducted the following surveys that sample groundfish: 1) the AFSC's annual longline survey in Alaska, 2) surface trawl surveys in the northern and southeastern Bering Sea, and 3) nearshore juvenile sablefish tagging surveys in southeast and central Alaska.

Projects at ABL included: 1) tagging and analyses of sablefish, sharks, and Greenland turbot movement, 2) ageing and genetics studies of sharks, 3) maturity of sablefish, 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 nation-wide Ecosystem and Socioeconomic reports for use in stock assessment, and 8) the formation of a sablefish coast-wide assessment and research group (CA, OR, WA, BC, AK).

In 2018 ABL continued to preparation 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 Acting Laboratory Director Pete Hagen at (907) 789-6001 or Pete.Hagen@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.

II. Surveys

2018 Eastern Bering Sea Continental Shelf and “Rapid-Response” Northern Bering Sea Bottom Trawl Surveys – RACE GAP

The thirty-seventh in a series of standardized annual bottom trawl surveys of the eastern Bering Sea (EBS) continental shelf was completed on 31 July 2018 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.

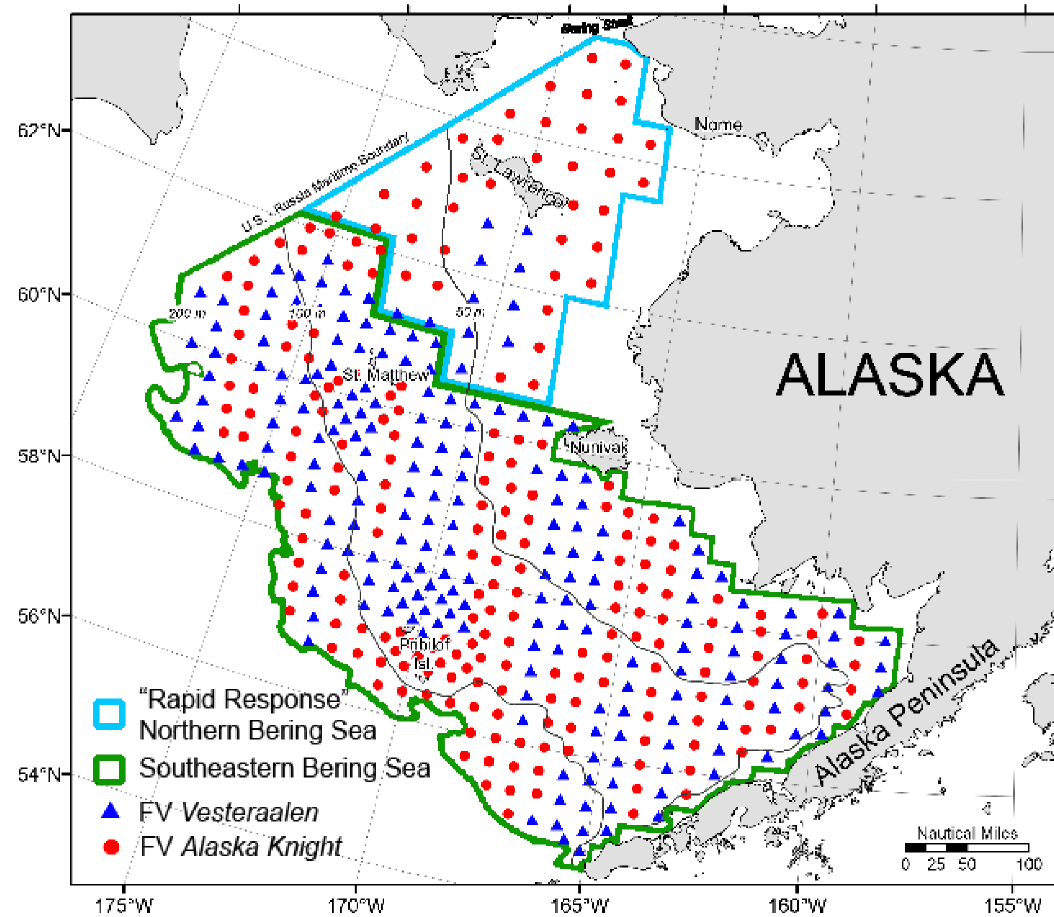

Fig. 1. Map showing survey stations sampled during the 2018 eastern and northern Bering Sea shelf bottom trawl survey.

Survey estimates of total biomass on the eastern Bering Sea shelf for 2018 were 3.1 million metric tons (t) for walleye pollock, 506.1thousand t for Pacific cod, 1.89 million t for yellowfin sole, 1.05 million t for northern rock sole, 18.0 thousand t for Greenland turbot, and 125.7 thousand t for Pacific halibut. There were decreases in estimated survey biomass for most major fish taxa compared to 2017 levels. Walleye pollock biomass decreased 35%, Pacific cod 21%, yellowfin sole 32%, northern rock sole 21%, for Alaska plaice 15%, Greenland turbot 16%, and Pacific halibut 0.78 %. Arrowtooth flounder biomass increased 21%.

The summer 2018 survey period was warmer than the long-term average for the fifth consecutive year. The overall mean bottom temperature was 4.16°C in 2018, which was warmer than 2017 (2.83 °C); however, the mean surface temperature was 7.58C in 2018, which was slightly lower than 2017 (7.83°C).

After the completion of the EBS shelf survey, which started for both vessels in Dutch Harbor on 3 June 2018, both vessels transitioned into sampling survey stations in the southwest corner of the

NBS survey region. The F/V *Vesteraalen* conducted sampling in the NBS from 31 July to 3 August, and the F/V *Alaska Knight* from 01 August to 14 August. A total of 49 30 x 30 nautical mile sampling grid stations in the combined EBS and NBS were successfully sampled in 2018.

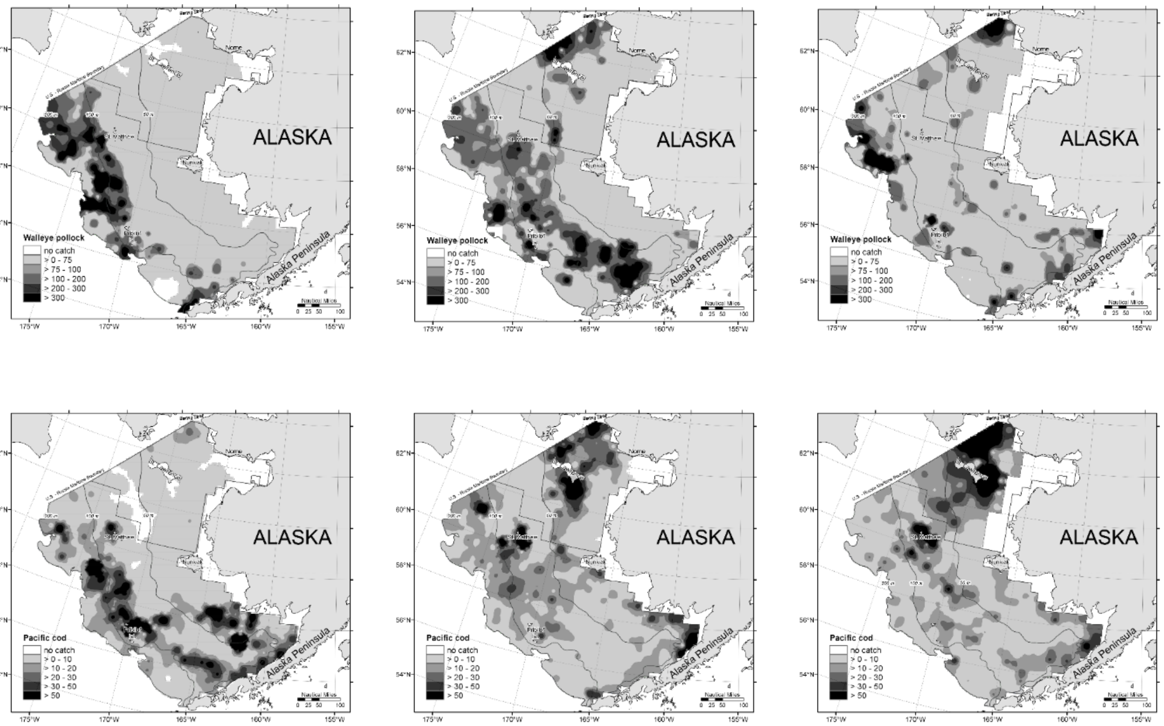

Fig. 2. Spatial distribution of large gadids, in terms of mean CPUE (kg/ha), observed during the 2010, 2017, and 2018 bottom trawl surveys of the EBS and NBS: Top left is walleye pollock in 2010, top middle is walleye Pollock in 2017, and top right is walleye pollock in 2018; bottom left is Pacific cod in 2010, bottom middle is Pacific cod in 2017, and bottom right is Pacific cod in 2017.

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. The total pollock biomass from the EBS was 3.74 million mt, while pollock biomass from the NBS was only 0.02 million mt. In 2017, pollock biomass in the EBS was concentrated mostly on the middle shelf (Fig. 2, top middle). In the NBS, there was a high concentration of pollock biomass to the north of St. Lawrence Island, and the total pollock biomass from EBS was 4.82 million mt, while pollock biomass from the NBS was 1.3 million mt. In 2018, again pollock distributions were quite different than in 2010 or 2017. In the EBS, pollock were densest in the south east corner of Bristol Bay and in small clusters along the Aleutian chain, and near the shelf break between 59°N and 60°N. In the NBS, pollock were most concentrated in the most northwestern corner of the NBS survey grid, along the U.S. – Russia Maritime Boundary (Figure. 2, top right). The total pollock biomass from EBS was 3.1 million mt, while pollock biomass from the NBS was 1.1 million mt in 2018.

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 860,000 mt, while biomass from the NBS was only 29,000 mt. In 2017, Pacific cod biomass was distributed differently (Fig. 2, bottom. middle). Pacific cod were highly concentrated in only a few areas of the EBS and cod densities on the shelf were generally low, particularly on the middle and outer shelf in the southern parts of the survey area. In contrast, cod densities in the NBS were high both to the north and south of St. Lawrence Island. Total estimated cod biomass from the EBS was 644,000 mt, while biomass from the NBS was 283,000 mt. In 2018, 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 507 thousand mt, while biomass from the NBS was 565 thousand mt in 2018. In all survey years, Pacific cod were concentrated in areas with bottom temperatures >0°C.

Survey estimates of total biomass in the EBS shelf (not including the NBS) for other major species in 2018 were 1.89 million mt for yellowfin sole, 1.05 million mt for northern rock sole, 511 thousand mt for arrowtooth flounder, and 125.7 thousand mt for Pacific halibut. Compared to 2017 levels, there was an overall general decrease in survey biomass for the major species: walleye pollock biomass decreased 35%, Pacific cod 21%, yellowfin sole 32%, northern rock sole 21%, and Pacific halibut 0.78%. Arrowtooth flounder biomass increased 21%.

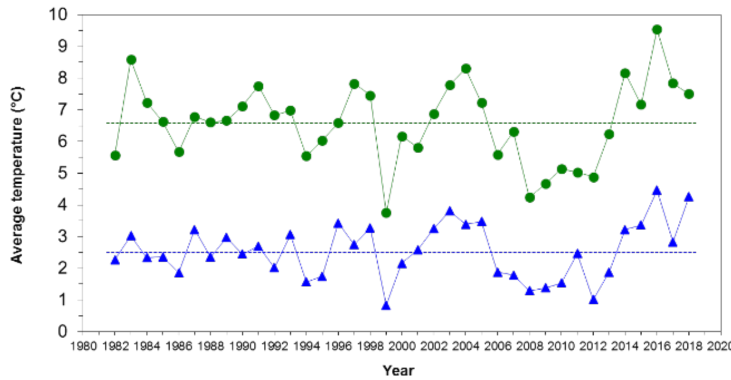

Fig. 3. Graph of mean annual surface and bottom temperatures for the eastern Bering Sea shelf bottom trawl survey.

The surface temperature mean for 2018 eastern Bering Sea shelf decreased from 2017 estimates, while the bottom temperature mean increased from 2017 estimates, but both were still warmer than the long-term time-series mean (Fig. 3). The 2018 mean surface temperature was 7.6°C, which was 0.2°C lower than 2017 and 1°C above the time-series mean (6.6°C). The mean bottom temperature was 4.2°C, which was 1.4°C above the mean bottom temperature in than 2017, but 1.7°C above the time-series mean (2.5°C). The 'cold pool', defined as the area where temperatures <2°C, only appeared in a few stations just to the west of St. Lawrence Island at a latitudes between 62° N and 64° N and between 50 and 100 m bottom depth. This extent was significantly less developed than in 2017, when the cold pool extended south-east to latitude 54° N.

2018 Aleutian Islands Biennial Bottom Trawl Survey of Groundfish and Invertebrate Resources – RACE GAP

The ninth biennial groundfish assessment survey of the Aleutian Islands region was conducted during the summer of 2018 by the Alaska Fisheries Science Center's (AFSC) Resource Assessment and Conservation Engineering Division's Groundfish Assessment Program (RACE-GAP). This effort constitutes the fifteenth in the full series dating from 1980. The survey area covered the continental shelf and upper continental slope to 500 m in the Aleutian Archipelago from Islands of Four Mountains (170° W long.) to Stalemate Bank (170° E long.), including Petrel Bank and Petrel

Spur (180° long.), and the northern side of the Aleutian Islands between Unimak Pass (165° W long.) and the Islands of Four Mountains. The survey was conducted aboard two chartered trawlers, the *FV Ocean Explorer* and *FV Sea Storm*. Samples were collected successfully at 420 survey stations using standard RACE Division Poly Nor'Eastern high-opening bottom trawl nets with rubber bobbin roller gear.

The primary survey objectives were to define the distribution and estimate the relative abundance commercially or ecologically important principal groundfish and invertebrate species that inhabit the Aleutian marine habitat and to collect additional data to define biological parameters useful to fisheries researchers and managers such as growth rates; length-weight relationships; feeding habits; and size, sex, and age compositions. During these surveys, we also measure a variety of physical, oceanographic, and environmental parameters. We also conducted a number of special studies and collections for investigators both from within the AFSC and from elsewhere.

The survey design is a stratified-random sampling scheme of successfully trawls stations stratified into 45 combinations of depth and regions and applied to a grid of 5x5 km2 cells. 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.

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. Pacific ocean perch or POP (*Sebastes alutus*) was the most abundant species with an estimated biomass of 1,016,309 metric tons (t). Atka mackerel (*Pleurogrammus monopterygius*), northern rockfish (*Sebastes polyspinis*), and walleye pollock (*Gadus chalcogrammus*) were also abundant with estimated biomasses of 354,871, 212,536 t, and 197,079 t, respectively. Catches of POP were large throughout the survey area at intermediate depths. Arrowtooth flounder (*Atheresthes stomias*) and northern rock sole (*Lepidopsetta polyxystra*) were the most abundant flatfish species. The skate assemblage was primarily comprised of three skate species, whiteblotched (*Bathyraja maculata*), Aleutian (*B. aleutica*), and leopard (*B. panthera*) skates, with a wide diversity of species captured in the eastern portion of the survey area. Survey results are presented as estimates of catch per unit of effort and biomass, species distribution and relative abundance, population size composition, and length-weight relationships for commercially important species and for others of biological interest. The survey data are available at https://www.afsc.noaa.gov/RACE/groundfish/survey_data/data.htm and can also be obtained through the AKFIN system (www.psmfc.org). The Plan Team incorporated these survey results directly into Aleutian Island stock assessment and ecosystem forecast models that form the basis for groundfish harvest advice for ABCs and TAC for 2019.

The data report for the 2017 Gulf of Alaska Bottom Trawl Survey can be found at https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-374.pdf

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

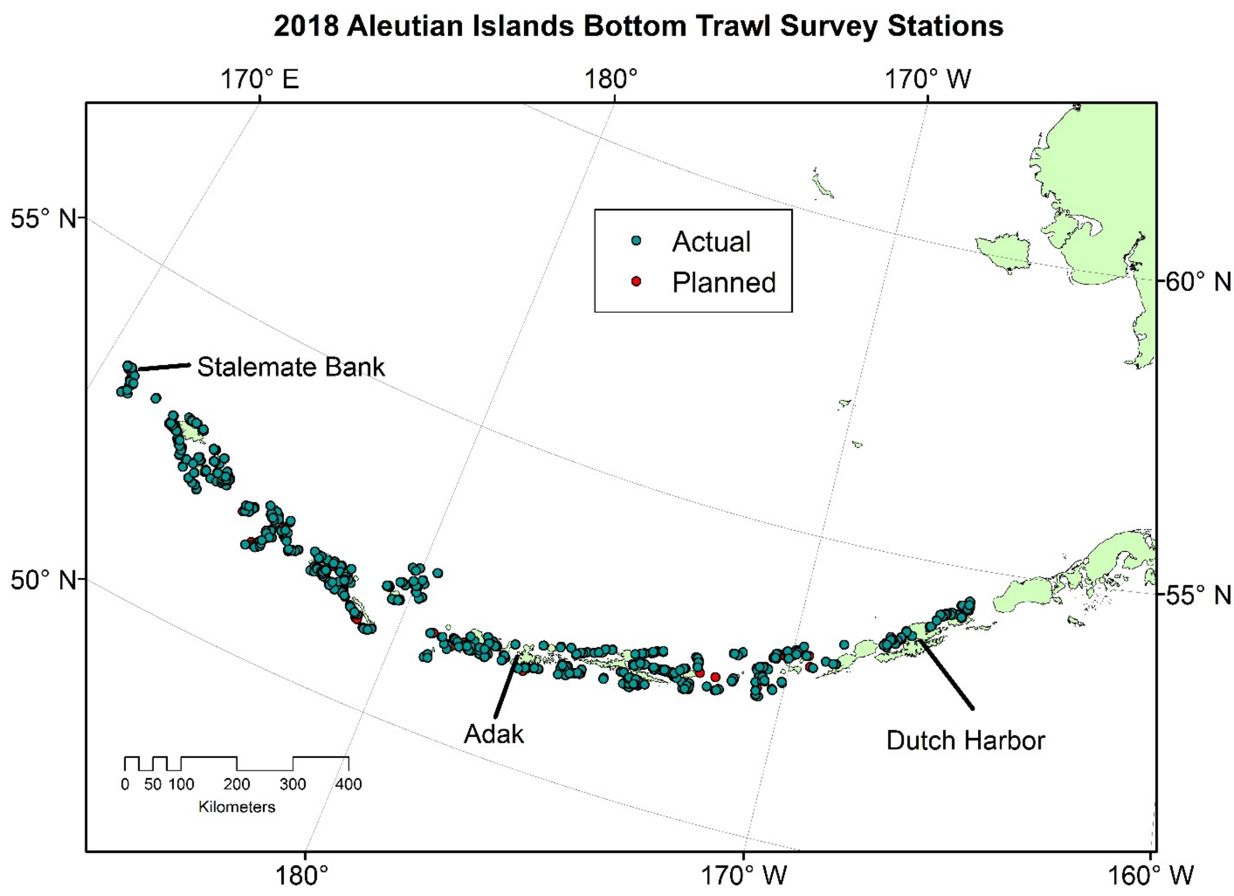

Figure 1. Planned and occupied stations during the 2017 Gulf of Alaska Biennial Bottom Trawl Survey.

Winter Acoustic-Trawl Surveys in the Gulf of Alaska -- MACE Program

Two cruises were conducted to survey several GOA walleye pollock (Gadus chalcogrammus) spawning areas in the winter of 2018. The first cruise (DY2018-01) surveyed the Shumagin Islands area (i.e., Shumagin Trough, Stepovak Bay, Renshaw Point, Unga Strait, and West Nagai Strait; 7-10 February), Sanak Trough (11 February), Morzhovoi Bay (11 February), and Pavlof Bay (12 February). The second cruise (DY2018-03) covered Shelikof Strait (15-21 March) and Marmot Bay (21-22 March).

All surveys were conducted aboard the NOAA ship Oscar Dyson, 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. The trawl hauls conducted in the GOA winter surveys included a

CamTrawl stereo camera attached to the net forward of the codend. The CamTrawl was used to capture stereo images for species identification and fish length measurements as fishes passed through the net toward the codend, primarily as a comparison with lengths measured from fish caught in the net in support of research on automated image analysis.

In the Shumagin Islands, acoustic backscatter was measured along 872 km (471 nmi) of transects. The survey transects were spaced 1.9 km (1.0 nmi) apart southeast of Renshaw Point and in the eastern half of Unga Strait, 3.7 km (2.0 nmi) apart in the western half of Unga Strait, 4.6 km (2.5 nmi) apart in Stepovak Bay and West Nagai Strait, and 9.3 km (5.0 nmi) apart in Shumagin Trough. The majority of walleye pollock in the Shumagin Islands in 2018 were between 9-14 cm fork length (FL). This size range is characteristic of age-1 pollock. This size range accounted for 99.1% of the numbers and 55.7% of the biomass. Larger pollock between 40-60 cm FL accounted for 43.8% of the biomass of all pollock observed in this area. This larger size range is likely dominated by age-6 walleye pollock, and suggests the continued success of the 2012 year class. Walleye pollock between 9 and 14 cm FL were present mainly in Shumagin Trough. Pollock between 40 and 60 cm FL were present mainly off Renshaw Point, where they have historically been detected (but were absent in 2017), and near the mouth of Stepovak Bay. The majority of the pollock were scattered throughout the water column between 50-200 m depth, within approximately 50 m of the bottom, and occasionally formed small, very dense (i.e., "cherry ball") schools. The maturity composition of males > 40 cm FL (n = 100) was 0% immature, 4% developing, 93% pre-spawning, 3% spawning, and 0% spent. The maturity composition of females > 40 cm FL (n = 128) was 3% immature, 9% developing, 88% pre-spawning, 0% spawning, and 0% spent, based on data from specimens collected from seven AWT hauls. The estimated amounts of pollock for the Shumagin area were 1,247 million pollock weighing 17,390 t (with a relative estimation error of 8.3%), which is 42% lower than last year's estimate (29,621 t) and 24% of the historical mean of 73,330 t for this survey.

In Sanak Trough, acoustic backscatter was measured along 165km (89 nmi) of transects spaced 3.7 km (2 nmi) apart. A few walleye pollock with FL between 11 and 12 cm FL were present (2% by numbers), but the vast majority of the pollock were between 37 and 56 cm FL. This mode accounted for 99.9% of the biomass of all pollock observed in Sanak Trough and likely represents age-6 fish. The majority of walleye pollock biomass was located in the middle of the surveyed trough and distributed throughout the water column below 50 m, concentrated around 140 m. The maturity composition for males > 40 cm FL (n = 18) was 0% immature, 0% developing, 89% pre-spawning, 11% spawning, and 0% spent. The maturity composition for females > 40 cm FL (n = 31) was 0% immature, 10% developing, 90% pre-spawning, 0% spawning, and 0% spent, based on data from specimens collected from one AWT haul. The biomass estimate of 1,317 t (with a relative estimation error of 12.2%) is 38% higher than last year's estimate of 957 t, but represents only 3.5% of the historic mean of 36,823 t for this survey.

In Morzhovoi Bay, acoustic backscatter was measured along 68.5 km (37 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 10 and 59 cm FL in Morzhovoi Bay. Walleye pollock between 10-14 cm FL, indicative of age-1 pollock, accounted for 24% of the numbers but only 0.4% of the biomass of all pollock observed in this area. Larger pollock between 39-59 cm FL accounted for 75% and 99.6% of the numbers and biomass, respectively. Walleye pollock were located throughout the surveyed area and were concentrated between 50-100 m depth from the surface. The maturity composition for males > 40 cm FL (n = 9) was 0% immature, 0% developing, 56% pre-spawning, 44% spawning, and 0% spent. The maturity composition for females longer than 40 cm FL (n = 21) was 0% immature, 19% developing, 67% pre-spawning, 14% spawning, and 0% spent, based on data from specimens collected from one AWT haul. The biomass estimate of 3,722 t (with a relative estimation error of 23.0%), is comparable to the biomass estimates generated between 2007 and 2013 and in 2017 (mean = 2,667 t; standard deviation = 897 t), and approximately a third of the estimate from either 2006 (11,700 t) or 2016 (11,412 t).

In Pavlof Bay, acoustic backscatter was measured along 75 km (40.5 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 10 and 60 cm FL. Walleye pollock between 10-14 cm fork length (FL), indicative of age-1 pollock, accounted for 77% of the numbers but only 4.7% of the biomass of all pollock observed in this area. Larger pollock between 25-60 cm FL accounted for 23% and 95.3% of the numbers and biomass, respectively. The majority of walleye pollock biomass in Pavlof Bay was located in the NW portion of the surveyed area and was scattered throughout the water column between 25-150 m from the surface. The maturity composition for males > 40 cm FL (n = 29) was 0% immature, 24% developing, 41% pre-spawning, 34% spawning, and 0% spent. The maturity composition for females > 40 cm FL (n = 38) was 0% immature, 11% developing, 87% pre-spawning, 3% spawning, and 0% spent, based on data from specimens collected from two AWT hauls. The biomass estimate of 4,619 t (with a relative estimation error of 19.9%) is roughly double either the 2016 or 2017 estimates of 2,130 t and 2,228 t, respectively. Surveys of Pavlof Bay were also conducted in 2002 and 2010, but an equipment malfunction and inclement weather, respectively, prevented trawling.

In the Shelikof Strait sea valley, acoustic backscatter was measured along 1613 km (871 nmi) of transects spaced 13.9 km (7.5 nmi) apart. The majority of walleye pollock in Shelikof Strait were between 9 and 62 cm FL with two length modes centered around 12 and 44 cm FL (Fig. 41). Age-1 walleye Pollock, between 10-14 cm FL, accounted for 53% of the numbers but only 1.6% of the biomass of all pollock observed in this area. Larger pollock between 39-62 cm FL accounted for 44% and 97.5% of the numbers and biomass, respectively. Walleye pollock were observed throughout the surveyed area and were most abundant in the central part of the surveyed area. They were detected as a thick, uniform layer between 150m to 300 m from the surface. Dense midwater pollock aggregations of pollock ≥ 39 cm FL were encountered higher in the water column, generally above 100 m. Spawning aggregations historically observed in the northwestern part of the Strait were not observed in 2018 (or in 2016-2017), which contrasts with previous years. The maturity composition in the Shelikof Strait area for males > 40 cm FL (n = 324) was 0% immature, 2% developing, 5% pre-spawning, 69% spawning, and 24% spent. The maturity composition of females > 40 cm FL (n = 383) was 0% immature, 2% developing, 30% pre-spawning, 24% spawning, and 44% spent, based on data from specimens collected from 14 AWT hauls and 3 PNE hauls. The biomass estimate of 1,320,867 t (with a relative estimation error of 3.9%) is 88% of that observed in 2017 (1,489,723 t) and almost twice the historic mean of 690,451 t. Survey biomass estimates in 2017 and 2018 are the largest since the mid-1980s.

In Marmot Bay, acoustic backscatter was measured along137.5 km (74 nmi) of transects spaced 1.75 km (1.0 nmi) apart in inner Marmot Bay, and 43.5 km (23.5 nmi) of a zig-zag transect in outer Marmot Bay. Walleye pollock ranged between 8 and 56 cm FL with two clear modes at 10 and 45 cm FL. Age-1 walleye pollock between 10-14 cm FL accounted for 74% of the numbers but only 4% of the biomass of all pollock observed in this area. Walleye pollock that ranged from 39 to 56 cm FL accounted for 94.6% of the biomass. The majority of walleye pollock biomass occurred in aggregations in Spruce Gully, just NE of Spruce Island. These aggregations were typically within 100 m of the seafloor. A diffuse acoustic scattering layer present near the seafloor in the inner Bay was composed of age-1 pollock. The maturity composition in Marmot Bay for males > 40 cm FL (n = 60) was 0% immature, 2% developing, 8% pre-spawning, 58% spawning, and 32% spent. The maturity composition of females > 40 cm FL (n = 40) was 0% immature, 10% developing, 25% pre-spawning, 3% spawning, and 63% spent, based on data from specimens collected from three

AWT hauls. The biomass estimate of 13,531 t was slightly less than both last year's estimate of 14,259 and the historic mean of 15,576 t.

Summer 2018 acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye pollock--MACE

An acoustic-trawl survey of walleye pollock (*Gadus chalcogrammus*) in the southeastern Aleutian Basin near Bogoslof Island was conducted 3-7 March, 2018 aboard the NOAA Ship *Oscar Dyson*. The survey covered 1,500 nmi^2 of the Central Bering Sea Convention Specific Area.

Acoustic backscatter was measured at 38 kHz along 35 north-south parallel transects, which were spaced 3-nmi apart. Backscatter in the eastern, Umnak region was sampled with five trawl hauls to identify the species composition of the acoustic scattering layers and to provide biological samples. Mechanical problems with the trawl-winch system unfortunately prevented any trawling in the western Samalga region, where the densest backscatter was distributed.

For the five trawl samples in the Umnak region, pollock was the dominant species by weight, and represented 98.5% of the total catch. Northern smoothtongue dominated the catch by number (48.6%), with pollock second most numerous at 37.5% of the total catch. Pollock lengths ranged from 37 to 63 cm fork length (FL), with a primary mode at 49 cm.

Pollock specimens from the Umnak region were examined for maturity stages. Of the 183 males, 7% were in the pre-spawning stage, 56% were spawning, and 37% were in the post-spawning stage. Of the 223 females, 18% were in the pre-spawning stage, 3% were spawning, and 79% were in the post-spawning stage. The average gonado-somatic-index for pre-spawning mature (i.e., FL≥ 39.9) female pollock in the Umnak region was 0.17.

Pollock biomass was distributed on all transects with minor concentrations in the Umnak region and the bulk of the biomass located in a relatively small area of the Samalga region. The densest concentration was located on transect 26, in the Samalga region, which represented 66% of the total estimated pollock biomass. This layer extended horizontally for about 9 nmi with a vertical extent from 150 m down to 650 m below the surface.

The pollock abundance estimate in 2018 was 964 million fish weighing 663 thousand metric tons for the entire surveyed area. The overall size-composition for the pollock was unimodal at 49 cm FL, with an average length at 48.2 cm. The estimates represent an increase of 11% in abundance and 31% in biomass from the 2016 survey estimates of 866 million fish weighing 507 thousand metric tons. Based on the 1D geostatistical analysis, the relative estimation error for the biomass estimate was 42.5%. This error rate was the largest estimated to date and likely reflects the high-density biomass estimate on transect 26, in the Samalga region.

The estimated age-composition for pollock ranged from 5 to 12 years of age. Sixty-eight percent of the estimated biomass were 8-9-year old fish (2010-2009 year classes), and another 14% were 6-year-old fish (2012 year class).

A major assumption underlying the survey results for 2018 was that the backscatter observed in the Samalga region was primarily from pollock. Backscatter observed on transect 26 in this region was particularly important because it contributed 66% of the estimated pollock biomass in 2018. Because no trawl samples occurred in the Samalga region, we relied on prior pollock surveys to support this assumption. Similar backscatter confirmed by trawling was observed in this region during the 2014 and 2016 surveys.

Summer acoustic-trawl surveys of walleye pollock in the eastern Bering Sea

The MACE Program conducted an acoustic-trawl survey of Eastern Bering Sea shelf walleye pollock (Gadus chalcogrammus) between 6 June and 26 August 2018. Midwater abundance and distribution were assessed from Bristol Bay to the U.S.-Russia Convention Line using acoustic-trawl survey methods aboard the NOAA ship Oscar Dyson. This survey has been conducted since 1979; triennially through 1994, and biennially or annually since then. The survey design covered the EBS shelf between roughly the 50 m and 200 m isobaths, from 162° W to the U.S.–Russian Convention line. The adjoining Russian portion of the EBS shelf was not surveyed as permission to survey that region was not granted in 2018. A northern extension beyond the traditional (core) survey area was added in 2018 based on observations of pollock extending north of the core survey area in 2016 (Honkalehto et al. 2018), saildrone observations (Mordy et al. 2017), and analysis of fish backscatter data collected in this northern region from the NOAA summer EBS bottom trawl survey in 2017. The survey design initially consisted of 28 north-south oriented parallel transects spaced 20 nmi apart over the Bering Sea shelf from 162° W (west of Port Moller, Alaska) to about 178° 20 E, excluding Russian waters and a northern extension, with similar spacing. The initial plan was amended with the following three changes: 1) Due to Oscar Dyson engine malfunction during leg 2, the remaining northern extension transect spacing was increased, and 2) an additional leg (3b) was added to the survey. Finally, 3) A second Oscar Dyson engine malfunction during leg 3b forced us to drop the final three transects, and the survey ultimately consisted of 25 transects.

The primary survey objective was to collect daytime 38 kHz acoustic backscatter and trawl data to estimate the abundance of walleye pollock. Additional survey sampling included conductivity-temperature-depth (CTD) measurements to characterize the Bering Sea shelf temperature conditions, and supplemental nighttime trawls to improve acoustic species classification and to obtain an index of euphausiid abundance using multiple frequency techniques. In addition to these nighttime trawls, AFSC scientists from the Recruitment Processes Alliance (RPA) participated on leg 3b to collect data on groundfish recruitment, including Methot and Bongo tows. Two drifters were also deployed for Pacific Marine Environmental Laboratory (PMEL) researchers during the survey. Sampling devices used during the survey include an Aleutian Wing Trawl (AWT) rigged with pocket nets to estimate fish escapement and a trawl-mounted stereo camera (CamTrawl) designed to identify species and determine size and density of animals as they pass by the camera during a haul; an 83-112 Eastern bottom trawl without roller gear; a Methot trawl, and Bongo nets.

Biological data and specimens were collected from 119 AT trawl hauls. The majority of these hauls (100) targeted backscatter during daytime for species classification: 97 with an AWT, 3 with a bottom trawl, and 7 with a Methot trawl. The remaining 12 hauls were either nighttime bongo net tows (6) targeting larval fish or nighttime Methot tows (6) targeting euphausiids. Catch data for some of these hauls assisted with backscatter classification. CamTrawl image data were successfully collected for 83 AWT hauls. Among midwater hauls used to classify backscatter for the survey, walleye pollock was the most abundant species by weight (83.6%) and by number (90.2%), followed by northern sea nettle jellyfish (Chrysaora melanaster; 12.4% by weight and 4.5% by number). Among bottom trawls, pollock was the most abundant species by weight (31.3%)

and snow crab (Chionoecetes opilio) the most abundant by number, followed by Pacific cod (Gadus macrocephalus; 16.5% by weight and 1.4% by number). Methot hauls were dominated by weight by northern sea nettles (57.4%) and euphausiids (37.8%), and numerically by euphausiids (98%).

Temperature measurements during the 2018 survey produced an estimated mean SST of 8.48 °C (range 5.2°-10.6°C; Fig. 3, upper panel). The estimate was cooler than 2016 (mean SST 11.4°C , range 7.4°-14.0°C), and 2014 (mean SST 9.6°C, range 6.4°- 12.4°C), but still much warmer than relatively cold survey years 2006-2012 (means between 4.9° - 6.8°C). About 35% of the summed acoustic backscatter observed in the core survey area between 16 m below the surface and 3 m off bottom (the midwater layer) during the 2018 survey was attributed to age 1+ walleye pollock. This was lower than the percentage of pollock observed in 2016 (52%), 2014 (45%) and 2012 (56%), and much less than that observed in 2010 (82%). In the northern extension area, about 38% of the backscatter was attributed to pollock. Pollock were observed in a variety of aggregations including near-bottom layers, small dense schools (cherry balls) in midwater, and diffuse aggregations of individual fish. The remaining non-pollock midwater backscatter was attributed to an undifferentiated plankton-fishes mixture (60%), or in a few isolated areas, to rockfishes (Sebastes spp.) or other fishes (2%). The near-bottom analysis (Lauffenburger et al. 2017) attributed ~ 60.5% of the backscatter in the near-bottom zone in the core survey area to pollock, and 93.7% of the backscatter in the near-bottom of the northern extension area to pollock. The northern extension area contributed about 8.7% additional pollock backscatter to the survey over the amount in the core survey area.

Estimated numbers and biomass of walleye pollock in midwater to within 0.5 m of the bottom along the U.S. Bering Sea shelf in the core survey area were 5.57 billion fish weighing 2.5 million t. This 2018 biomass estimate represents ~40% decrease compared to 2016 (4.06 million t), and a 30% decrease from the 2014 biomass estimate (3.44 million t). It is on par with the biomass estimates in 2010 and 2012 (2.64 million t and 2.30 million t, respectively. The relative estimation error for the U.S. EEZ walleye pollock biomass estimate for the entire water column was 0.039, indicating a patchier distribution of pollock than observed in 2016 (0.019). Pollock were observed throughout the EEZ area between the 100- and 200-m isobaths. East of 170° W, pollock abundance was 1.28 billion fish, weighing 0.74 million t (27% of total midwater biomass, Fig. 8). This was less than half of the pollock biomass observed east of the Pribilof Islands in the AT survey in 2016 (1.80 million t). In the U.S. EEZ core survey area west of 170° W, pollock numbered 4.29 billion and weighed 1.75 million t, which was 64% of total midwater biomass. The majority of the pollock biomass in the survey was found in the region to the south and west of St. Matthew Island (e.g., transects 20-25). Pollock biomass decreased inside the SCA from 0.54 million t in 2016 to 0.23 million t in 2018. Estimates for the entire survey and the SCA correlate well ($r2 = 0.79$ $p < 0.001$) throughout the 1994-2018 time series. The pollock estimate in the northern extension area was 492 million fish weighing 0.24 million metric tons, contributing an additional 9% by number and weight compared with the amount of pollock estimated within the core survey area. In the northern extension, fish were sparsely but evenly distributed between the 50- and 100-m isobaths.

Pollock length compositions differed between midwater and near bottom layers, and modal lengths tended to decline to the west. East of 170° W, pollock ranged between 8 and 72 cm FL with a mode of 43 cm. Very few fish smaller than 30 cm were observed east of 170° W. In the U.S. EEZ core survey area west of 170° W, pollock ranged from 8 to 75 cm FL with multiple modes observed at 17, 26 and 42 cm FL. Within the northern extension of the survey area fish were slightly longer than in the core survey area (mode of 42 cm with a long right tail), and a few much smaller fish were also seen (mode of 14 cm). Near-bottom pollock were both smaller (mode of 15 cm) and larger (mode of 45 cm) in comparison to midwater fish throughout the survey area in 2018. Age data are not yet available for this survey.

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Summer 2018 acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye pollock

Acoustic backscatter data (Simrad ES60, 38 kHz) were collected aboard two fishing vessels chartered for the AFSC summer 2018 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 2018. The 2018 AVO index of midwater pollock abundance on the eastern Bering Sea shelf decreased 13.5% from 2016 and decreased 8.0% from 2017. However, the AFSC biennial acoustic-trawl (AT) survey conducted using NOAA Ship *Oscar Dyson* in summer 2018 decreased 48.2% from 2016. Even so, the correlation between the AVO index and the AT survey biomass only decreased minimally (r^2= 0.74, n= 9 surveys, Figure 2, vs. r^2= 0.76, n=8 surveys for the period 2006-2016). The percentage of pollock backscatter east of the Pribilof Islands was 14% (Figures 3, 4). Although this is larger than the percentages in summers 2010-2012 (range 4-9%), it is the lowest percentage observed east of the Pribilof Islands since 2013.

For more information, contact MACE Program Manager, Chris Wilson, (206) 526-6435.

Longline Survey – ABL

The AFSC has conducted an annual longline survey of sablefish and other groundfish in Alaska from 1987 to 2018. 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 2018, the 41st annual longline survey sampled the upper continental slope of the Gulf of Alaska and the eastern and central Aleutian Islands region. One hundred and forty-eight longline hauls (sets) were completed during June 1 – August 28 by the chartered fishing vessel *Alaskan Leader*. Total groundline set each day was 16 km (8.6 nmi) long and contained 160 skates and 7,200 hooks.

Sablefish (*Anoplopoma fimbria*) was the most frequently caught species, followed by giant grenadier (*Albatrossia pectoralis*), shortspine thornyhead (*Sebastolobus alascanus*), Pacific cod (*Gadus macrocephalus*), and rougheye/blackspotted rockfish (*Sebastes aleutianus/S. melanostictus*). A total of 80,865 sablefish, with an estimated total round weight of 175,088 kg (386,003 lb), were caught during the survey. This represents a decrease of 3,552 sablefish over the 2017 survey catch. Sablefish, shortspine thornyhead, and Greenland turbot (*Reinhardtius hippoglossoides*) were tagged with external Floy tags and released during the survey. Length-weight data and otoliths were collected from 2,248 sablefish. Killer whales (*Orcinus orca*) depredating on the catch occurred at two stations in the western Gulf of Alaska and two stations in the Aleutian Islands. Sperm whales *(Physeter macrocephalus)* were observed during survey operations at 18 stations in 2017. Sperm whales were observed depredating on the gear at four stations in the central Gulf of Alaska, seven stations in the West Yakutat region, and ten stations in the East Yakutat/Southeast region.

Several special projects were conducted during the 2018 longline survey. Satellite pop-up tags were deployed on spiny dogfish (*Squalus acanthias*) and blood samples were obtained in the Gulf of Alaska. Information from these tags and from the blood samples will be used to investigate discard mortality rates and stress response from capture events. Throughout the survey, stereo cameras were installed outboard of the hauling station to collect imagery that will be used for the refinement of electronic monitoring. The imagery will be used as a training dataset to develop machine learning for length measurements and species identification. Additionally, a multispectral camera was used on the 2-day experimental leg to take detailed images of rougheye and blackspotted rockfish. These images will be used, along with DNA samples taken from the fish, to develop and verify algorithm-based species identifications for potential use during electronic monitoring. Yelloweye rockfish (*Sebastes ruberrimus*) samples were collected for a study examining reproductive life history. Hormone concentrations, extracted from growth increments within their opercula, will be used to reconstruct individual reproductive life histories (e.g., age at maturity and spawning frequency). This information may be used to refine the parameters and results of the Southeast Alaska yelloweye rockfish stock assessment. Additionally, samples were collected for a genetics study aimed at examining yelloweye population structure from California up to Alaska.

Longline survey catch and effort data summaries are available through the Alaska Fisheries Science Center’s website: http://www.afsc.noaa.gov/ABL/MESA/mesa_sfs_ls.php. Full access to the longline survey database is available through the Alaska Fisheries Information Network (AKFIN).

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Northern Bering Sea Integrated Ecosystem Survey – ABL

The 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 ABL Ecosystem Monitoring and Assessment program in partnership with the Alaska Department of Fish and Game, United States Fish and Wildlife Service, and the AFSC Recruitment Processes Program conducted a survey August 27 to September 20, 2018 aboard a chartered fishing vessel, which included the collection of data on pelagic fish species and oceanographic conditions in the Northern Bering Sea shelf from 60°N to 65.5°N (Fig. 1). Overall objectives of the survey are to provide an integrated ecosystem assessment of the northeastern Bering Sea to support: 1) the Alaska Fisheries Science Center's Loss of Sea Ice

Program and Arctic Offshore Assessment Activity Plan, 2) the Alaska Department of Fish and Game Chinook Salmon Research Initiative program, and 3) sample collections within Region 2 of the Distributed Biological Observatory.

Physical and biological data are typically collected from 50 stations and oceanographic and fish data are collected at 5 Distributed Biological Observatory stations annually. Headrope and footrope depth and temperature are monitored with temperature and depth loggers (SBE39) at each station.

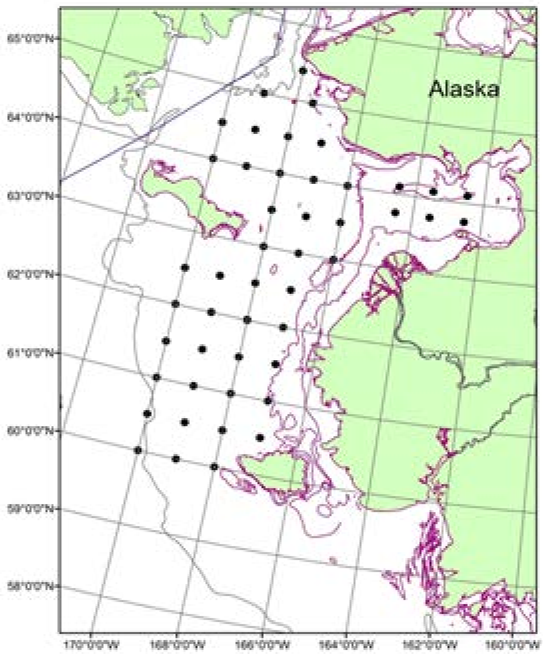

Figure 1. Stations sampled during the August 27 to September 20, 2018 surface trawl survey in the northern Bering Sea.

For more information, contact Jim Murphy 907-789-6651, Jim.Murphy@noaa.gov or Kristin Cieciel at (907) 789-6089, Kristin.Cieciel@noaa.gov.

Late-Summer Pelagic Trawl Survey (BASIS) in the Southeastern Bering Sea, August-September 2018 – ABL

BASIS fisheries-oceanographic surveys in the SEBS have been conducted annually since 2002 (with the exception of 2013) and biennially since 2016. Scientists from the Alaska Fisheries Science Center (AFSC), Recruitment Processes Alliance (RPA) conducted a fisheries-oceanographic survey in the southeastern Bering Sea (SEBS) aboard the chartered FV *Northwest Explorer* from September 20 to 3 October, 2018. Note: This survey was originally scheduled to be conducted aboard the NOAA Vessel *Oscar Dyson* with more days at sea from August to September, but due to mechanical issues the vessel was not available. In 2018, the reduced survey covered the SEBS shelf between roughly the 50 m and 100 m isobaths, from 161º W to 171º W (Figure 1). A surface trawl (top 20 m), CTD cast, and zooplankton bongo net tow were performed at each core trawl station (18 stations total); a CTD cast and bongo net tow were performed at each oceanography station (8 stations total). In addition, six targeted midwater tows were performed to collect data on the vertical distribution of age-0 Walleye pollock.

During this survey, trawl catch and ecosystem data were collected with a priority to provide information on commercially important species (e.g., pollock, Pacific cod), ecologically important forage species (e.g., Capelin, Pacific herring), and all salmon species. In 2018, we observed warmer surface and bottom temperatures, lower large copepod abundances (an important prey item for age-0 pollock), and average age-0 pollock abundances. Findings from additional research associated with this survey have been included separately in this report.

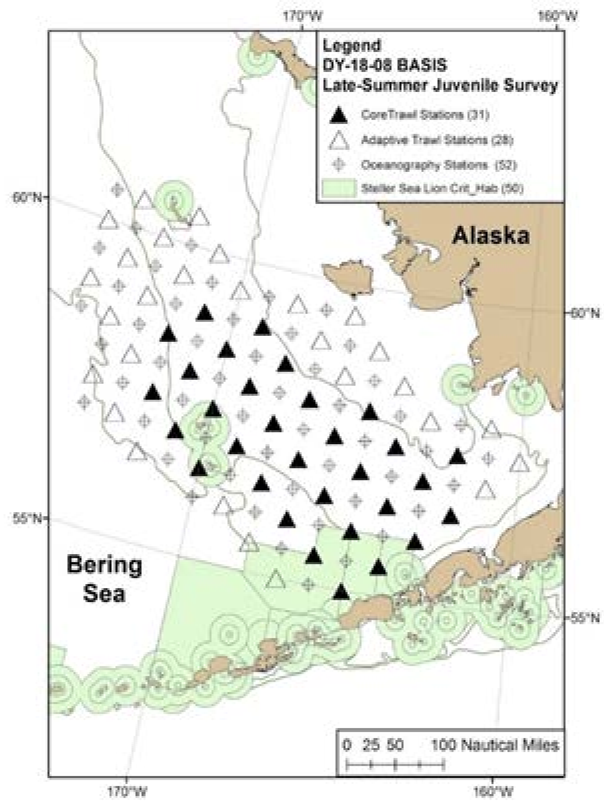

Figure 1. Station locations for the 2018 BASIS cruise in the southeastern Bering Sea (not all locations were sampled due to fewer sea days).

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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.

In 2018, FMA continued the development and testing of new and innovative EM technologies by deploying stereo and chute camera systems on fixed gear and trawl catcher-processor vessels, as well as on surveys conducted by NOAA Fisheries and the International Pacific Halibut Commission. Electronic monitoring systems were also tested for the first time at shoreside processors to investigate alternative methods to account for incidentally caught Salmon. Considerable headway was made testing hardware and developing the necessary applications to automate species identification and length estimation. This year, FMA also made remarkable progress identifying fish within the Rockfish complex. Using a multi-spectrum chute system, the Blackspotted, Shortraker, and Rougheye Rockfish were able to be distinguish from one another with a 91.7% accuracy. Within the Salmon complex, Chinook, Chum, Pink, and Coho salmon were able to be distinguished from one another to an accuracy level 97.7%.

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

Spiny Dogfish Ecology and Migration - ABL

A tagging program for spiny dogfish was begun in 2009, with 186 pop-off satellite archival tags

(PSATs) deployed between 2009 - 2018. Data were recovered from 157 of those tags (nine tags are still at liberty), with eight tags physically recovered. The PSATs record depth, temperature, light levels and sunrise/sunset for geolocation. A subset of the data is transmitted to ARGOS satellites and any if any tags are physically recovered, the high resolution data can be downloaded. Preliminary results suggest that spiny dogfish can undertake large scale migrations rapidly and that they do not always stay near the coast (e.g. a tagged fish swam from nearby Dutch Harbor to Southern California in nine months, in a mostly straight line, not following the coast). Also, the spiny dogfish that do spend time far offshore have a different diving behavior than those staying nearshore, with the nearshore animals spending much of the winter at depth and those offshore having a significant diel diving pattern from the surface to depths up to 450 m. Staff at ABL are working with a contractor (Julie Nielsen, Kingfisher Marine Research) to develop a Hidden Markov Movement (HMM) model based on these tag data and incorporating environmental variables (e.g. temperature/depth profiles and sea-surface temperature). The HMM model will provide daily locations in the form of probability surfaces as well as total residence probabilities for the duration of deployment for each tag. The results will be used to define habitat utilization distributions, and eventually inform Essential Fish Habitat.

In 2012 six spiny dogfish were tagged in Puget Sound, WA, with both PSATs and acoustic transmitters. The purpose of the double tagging was to use the acoustic locations as known locations and evaluate the accuracy and precision of the light-based geolocation data from the PSATs. A manuscript examining those tags is in preparation, and those data are being used in a simulation environment to test the Hidden Markov Movement model.

In 2016 staff at ABL began a collaboration with the University of Florida to examine stress physiology in spiny dogfish. In 2017 and 2018 a total of 13 PSATs were deployed on fish and blood samples were collected to correlate longer-term survival (i.e., > 3 months) with stress physiology and injuries.

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

Population Genetics of Pacific Sleeper Sharks - ABL

The purpose of this study is to investigate the population structure of Pacific sleeper sharks in the eastern North Pacific Ocean. Tissue samples have been opportunistically collected from ~200 sharks from the West Coast, British Columbia, the Gulf of Alaska, and the Bering Sea. Sequences from three regions of the mitochondrial DNA, cytochrome oxidase c- subunit 1 (CO1), control region (CR), and cytochrome b (cytb), were evaluated as part of a pilot study. A minimum spanning haplotype network separated the Pacific sleeper sharks into two divergent groups, at all three mtDNA regions. Percent divergence between the two North Pacific sleeper shark groups at CO1, cytb, and CR respectively were all approximately 0.5%. We obtained samples from Greenland sharks, *S microcephalus*, which are found in the Arctic and North Atlantic, to compare to the two observed groups in the North Pacific samples. The Greenland shark samples were found to diverge from the other two groups by 0.6% and 0.8% at CO1, and 1.5% and 1.8% at cytb. No Greenland shark data was available for CR. Results suggest that Greenland shark do not comprise one of the groups observed in the North Pacific sleeper shark samples. The consistent divergence from multiple sites within the mtDNA between the two groups of Pacific sleeper sharks indicate a historical physical separation. There appears to be no modern phylogeographic pattern, as both types were found throughout the North Pacific and Bering Sea.

Staff have been developing microsatellite markers, however, they are finding extremely low variability, and only three have been identified so far. The genetics lab at ABL has a new miSeq analyzer and plan to use the Pacific sleeper shark samples as the first project on it. They are exploring sibling and parentage relationships as well as continuing to search for any microsatellites with variability.

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

Ageing of Pacific Sleeper Sharks – ABL

A pilot study is underway by staff at ABL, REFM, and the PIFSC 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. The pilot study, consisting of four animals, is first determining if 14C is detectable in the eye lens and staff are working with experts in the field of eye lens forensics and ageing via 14C to determine if the method is informative for this species. Previous studies in a closely related species have suggested extreme longevity, but a number of concerns exist for directly using 14C and reference curves to come up with an age because the source of the 14C is unclear. The eye lens forms during gestation, which is likely at least 2 years and all of the nourishment is likely supplied by a yolk sac, derived from ovum that took an unknown number of years to develop. Further, the 14C is a reflection of the diet of the female, which could be an accumulation of 14C from variously aged prey. Results of the pilot study are expected by spring 2019 and will guide how the study is planned for the remainder of the samples.

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

2. Stock Assessment

Sharks - ABL

The shark assessments in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA) are on biennial cycles in even years. There are currently no directed commercial fisheries for shark species in federally or state managed waters of the BSAI or GOA, and most incidentally captured sharks are not retained.

In the 2018 assessments, catch estimates from 2003-2018 were updated from the NMFS Alaska Regional Office's Catch Accounting System. In the GOA, total shark catch in 2018 was 2,141 t, which was up from the 2017 catch of 1,632 t. The GOA assessment also reports catch of sharks occurring in federally managed fisheries in NMFS areas 649 (Prince William Sound) and 659 (Southeast Alaska inside waters), 719 t in 2017 and 95 t in 2018, however these do not accrue against the TAC. The assessment authors have been tasked with working with Council staff to explore options for incorporating these catches into the assessment.

The most recent trawl survey was in 2017, with the next planned for 2019. The trawl survey biomass estimates are used for ABC and OFL calculations for spiny dogfish and are not used for other shark species. The 2017 survey biomass estimate for spiny dogfish (53,979 t, CV = 19%) is about the same as the 2015 biomass estimate of 51,916 t (CV = 25%). Prior to 2015, the biomass was nearly three times greater; such variability in annual estimates is expected due to the patchy distribution of this species. The random effects model for survey averaging was used to estimate the 2017 (and thus 2018 because there was no survey that year) GOA biomass for spiny dogfish (54,301 t), which was used for Tier 5 calculations of spiny dogfish ABC and OFL.

The GOA shark assessment is s complex of both Tier 5 and 6 species. In the 2018 assessment, spiny dogfish were recommended to move to Tier 5 and the method for spiny dogfish changed over previous assessments where a trawl survey catchability value was estimated based on tag data and the survey biomass adjusted accordingly (258,577 t) and the $F_{OFL} = F_{max}$ from a demographic analysis. The Tier 6 species in the complex remained consistent, using the historical mean catch to calculate ABC and OFLs. The recommended GOA-wide ABC and OFL for the entire complex is based on the sum of the ABC/OFLs for the individual species, which resulted in an author recommended ABC = 8,184 t and OFL = 10,913 t for 2019 and 2020.Because the survey biomass estimates on the BSAI are highly uncertain and not informative, all shark species are considered Tier 6. The Tier 6 calculations in the BSAI are based on the maximum catch of all sharks from the years 2003-2015. The resultant recommended values for 2019 and 2020 were ABC = 517 t and OFL = 689 t. In the BSAI, estimates of total shark catch from the Catch Accounting System from 2018 were 94 t, which is not close to the ABC or OFL. Pacific sleeper shark are usually the primary species caught, however catches of salmon shark have been greater for the last two years (71 and 51t salmon shark in 2017 and 2018, respectively and 59 and 38 t of Pacific sleeper sharks).

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

C. <u>Skates</u>

1. Research

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.

No changes were made to the model but a new method was used to estimate catches of Alaska skate and the other species in the skate complex was created (official catch estimates at the species level are unavailable due to problems with species identification in the fisheries) . Estimates from this method were used in the Alaska skate model and to produce exploitation rates for the skates in the "other skates" group.

The Alaska skate model produced similar results to the 2016 model run, and harvest recommendations are changed only slightly from last year. Spawning biomass of Alaska skate increased continuously from 2006 (194,515 t) through 2018 (268,836 t), and is currently at an all-time high. Recruitment of Alaska skate was above average for all cohorts spawned between 2003 and 2010, but has been below average for all cohorts spawned since 2011. The remaining species of skates have relatively flat or increasing biomass, except for whiteblotched and leopard skates in the Aleutian Islands. Both of these species have been declining (since 2006 [whiteblotched] and 2010 [leopard]). For the skate complex as a whole, ABCs for 2019 and 2020 total 42,714 t and 40,813 t, respectively, and OFLs for 2019 and 2020 total 51,152 t and 48,944 t, respectively.

Big skate biomass has increased substantially in the southeastern Bering Sea and it is likely these skates are part of the Gulf of Alaska population. Exploitation rates of Bering and big skates exceed 0.1. While this is a concern, there are several reasons why these rates are likely acceptable. Alaska skate is common in the northern Bering Sea survey area, and increased abundance there matches the overall increase in the Alaska skate population

Gulf of Alaska (REFM)

The skate complex in the GOA is assessed biennially and there was no assessment in 2018, so harvest recommendations are the same as last year. Big skate and longnose skate are the primary skate species in the GOA, and they have separate harvest recommendations from the remaining species ("other skates"). Big skate OFL and ABC in 2019 are 3,797 t and 2,848 t, respectively; longnose skate OFL and ABC in 2019 are 4,763 t and 3, 572 t. The ABCs for these two stocks are apportioned among GOA regulatory areas. The other skates group has a gulfwide OFL and ABC: in 2019 these are 1,845 and 1,384.

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

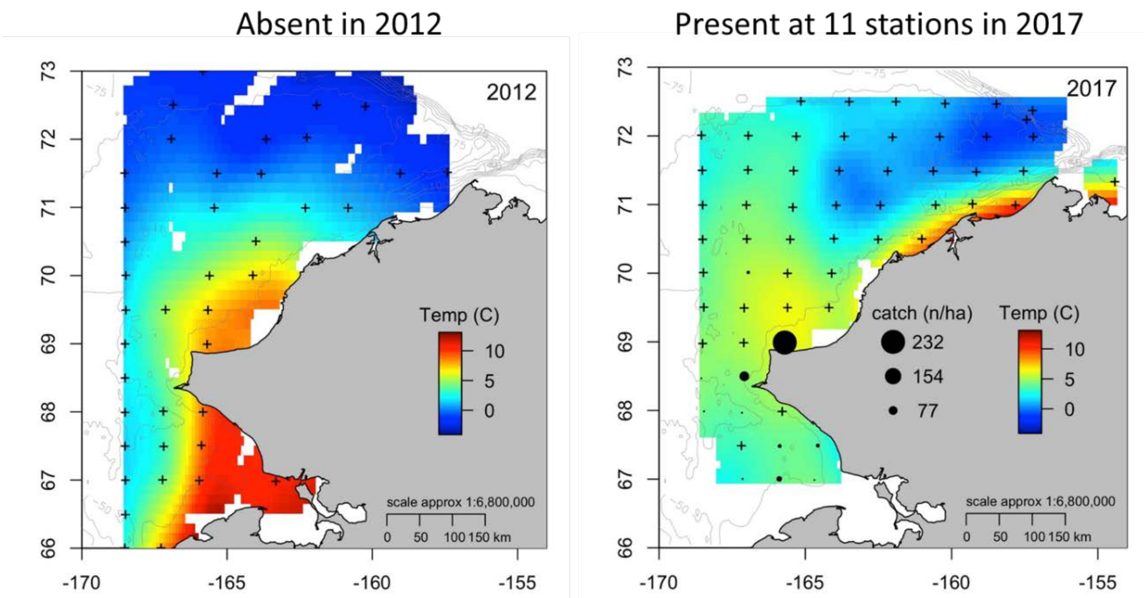
D. Pacific Cod

1. Research

Pacific cod juveniles in the Chukchi Sea-RPP

Dan Cooper, Libby Logerwell, Nissa Ferm, Robert Lauth, Lyle Britt, 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 two years: 2012 (Arctic EIS) and 2017 (Arctic IERP; Figure 1). Pacific cod juveniles (59-83mm TL) were present at 11 of 59 stations in 2017 (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 than in in 2012, the southern and shallow sites with Pacific cod presence in 2017 were not uniformly warmer in 2017, and in fact some were cooler 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, and catch rates were lower than in nursery areas of the southeastern Bering Sea. Juvenile Pacific cod were also caught in surface and midwater trawls during the 2018 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.



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

Cod samples collected during the 2012-2013 Bering Arctic Subarctic Integrated Survey (BASIS) (adults) and the 2017 Arctic Integrated Ecosystem Research Program (Arctic IERP) survey (juveniles) were genetically analyzed with 15 microsatellite markers and mtDNA sequences. Little population structure was evident for Arctic cod in the Chukchi Sea. Some of those morphologically identified as age-0 Arctic cod were genetically identified as pollock, and were found further north than previously observed (to latitude 70°), or a different stock of Arctic cod, which were all found north of latitude 72°. Due to the difficulty of visual identification of cod species at this early life history stage, all age-0 cod samples collected in the upcoming 2019 Arctic IERP survey will be genetically identified to species prior to other research project analyses.

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

Warm Blob Effects on Juvenile Pacific Cod – ABL

To understand how environmental conditions during the "Warm Blob" may have influenced age-0 Pacific Cod survival, 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 July and August of their first year of life, we fed fish high fat and low fat diets at three temperatures: 9, 12, and 15 C. Chemical analysis of fish condition indices is underway, including total fat, protein, and caloric content, as well as RNA/DNA, which is an index of instantaneous growth rate. A replicate study will be conducted in 2019 using smaller fish collected two months earlier.

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 fall of 2020 and 2021, 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.

Climate change and location choice in the Pacific cod longline fishery

Pacific cod is an economically important groundfish that is targeted by trawl, pot, and longline gear in waters off Alaska. An important sector of the fishery is the "freezer longliner" segment of the Bering Sea which in 2008 accounted for $220 million of the Pacific cod first wholesale value of $435 million. These vessels are catcher/processors, meaning that fish caught are processed and frozen in a factory onboard the ship.

A dramatic shift in the timing and location of winter-season fishing has occurred in the fishery since 2000. This shift is related to the extent of seasonal sea ice, as well as the timing of its descent and retreat. The presence of winter ice cover restricts access to a portion of the fishing grounds. Sea ice also affects relative spatial catch per unit effort by causing a cold pool (water less than 2°C that persists into the summer) that Pacific cod avoid. The cold pool is larger in years characterized by a large and persistent sea ice extent. Finally, climate conditions and sea ice may have lagged effects on harvesters' revenue through their effect on recruitment, survival, total biomass, and the distribution of size and age classes. Different sizes of cod are processed into products destined for district markets. The availability and location of different size classes of cod, as well as the demand for these products, affects expected revenue and harvesters' decisions about where to fish.

Understanding the relationship between fishing location and climate variables is essential in predicting the effects of future warming on the Pacific cod fishery. Seasonal sea ice is projected to decrease by 40% by 2050, which will have implications for the location and timing of fishing in the Bering Sea Pacific cod longline fishery. Our research indicates that warmer years have resulted in lower catch rates and greater travel costs, a pattern which we anticipate will continue in future warmer years. For further information, contact Alan.Haynie@noaa.gov.

2. Stock Assessment

Eastern Bering Sea (REFM)
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, 2017, and 2018 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 to the stock assessment model have been considered since the 2017 assessment. Sixteen models were considered in the preliminary assessment, which included last year's model, models with updated treatment of the NBS survey data, and complex models that included time-varying parameters and/or multiple areas with movement between them. Eight models were presented in the final assessment. None of the final assessment models considered multiple areas, but some did treat the EBS and NBS surveyed areas as separate time-series. Updated data for the 2018 assessment included abundance and size composition from the EBS bottom trawl survey through 2018, total catch through 2018, and fishery and survey age compositions through 2017.

Four different survey abundance time-series were calculated using three different areas: the standard EBS shelf survey area, the expanded EBS shelf survey area which includes strata 82 and 90, and the NBS area with the truncated survey stations used in 2018. The expanded EBS survey area was preferred over the standard area and showed a 32% decline in abundance (numbers of fish) from 2017 to 2018. The NBS survey showed a 78% increase in abundance from 2017 to 2018, and summing the expanded EBS survey and the NBS survey results in a 1.8% decrease in abundance from 2017. Estimated spawning biomass (from the preferred model) increased from 2009 through 2017 to 303,676 t, and is predicted to decrease to 290,205 t in 2019, which is still above B40%. Recruitment is estimated to have been below average since the 2014 year class.

The maximum permissible ABC for 2019 as calculated using the present model fit is 181,000 t. However, risk matrix analysis for this stock resulted in "concern" levels of 3 for all categories (assessment, population dynamics, and environmental/ecosystem). This conclusion was based on the uncertainty in the distribution of Pacific cod, dramatic declines in the EBS shelf survey index, recent poor environmental conditions, lack of incoming recruitment, and structural uncertainty across presented assessment models. As a result, the recommended 2019 ABC was reduced to 144,800 t. The 2019 OFL from the new model is 216,000 t, which is greater than the projected OFL from the previous assessment. The 2019 projected OFL, given a 2019 ABC of 144,800 t is 183,000 t, and would be164,000 t with a 2019 ABC of 181,000 t. The stock would drop well into Tier 3b in 2020 if the full ABC of 181,000 t were taken in 2019, but would almost remain in Tier 3a in 2020 with the recommended 2019 ABC of 144,800 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. The recommended ABC is 20,600 t, and OFL is 27,400 t.

Gulf of Alaska (REFM)
In 2017, survey biomass estimates for GOA Pacific cod plummeted. This was attributed to an increase in natural mortality resulting from increased metabolic costs (due to anomalously high water temperatures) and reduced prey availability. In 2017 this event was modeled by allowing natural mortality (M) during 2015-2016 to vary from the rest of the time series. For 2018, a similar model was used with the following changes: the M “block” was widened to include 2014-2016, age composition data before 2007 were omitted, and length-based rather than age-based maturity was applied due to a bias discovered in age readings prior to 2007. Data updated from the 2017 assessment included catch for 2017 and 2018 (preliminary catch projected through the end of 2018), fishery size composition for 2017 and 2018, 2018 AFSC longline survey abundance index (Relative Population Numbers, RPN) and size composition, and age data from the 2017 AFSC bottom trawl survey and 2012-2017 fisheries. The longline survey RPN for 2018 dropped 40% from 2017 to 2018 and was 73% lower than the 2015 RPN estimate.

The B40% estimate was 68,896 t, with projected 2019 spawning biomass of 34,701 t. The 2012 year-class remains the strongest in the recent period, followed closely by the 2013 year-class. Recruitment since 2013 is below the 1977-2015 average. Spawning biomass was projected to decline through 2020. The 2018 spawning biomass is estimated to be at 20.4% of B100%. The F35% and F40% values are 0.76 and 0.62, respectively. The maximum permissible ABC is 19,665 t but the authors recommended that it be reduced so that the projected biomass is above 20% of B100% in 2019 (if the stock is below B20%, directed fishing is prohibited due to Steller sea lion regulations). The recommended ABC is 17,000 t for 2019 which is a 6% decrease from the 2018 ABC of 18,000 t. Since the 2014 assessment, the random effects model has been used for Pacific cod apportionment.

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

E. Walleye Pollock

1. Research

Fall Energetic Condition of Age-0 Walleye Pollock Predicts Survival and Recruitment Success - ABL

Age-0 Walleye pollock were collected during the late summer BASIS survey in the southeastern Bering Sea (SEBS) from 2003-2017, except for 2015. The Average Energy Content (AEC; kJ/fish) was calculated as the product of the average individual mass, for all age-0 pollock in the tow, and the average energy density. The product of the two averages represents the average energy content for an individual age-0 pollock in a given year.

The AEC of age-0 pollock integrates information about size and energy density into a single index, therefore reflecting the effects of size-dependent mortality over winter as well as prey conditions during the age-0 period. Late summer represents a critical period for energy allocation in age-0 pollock and their ability to store energy depends on water temperatures, prey quality, and foraging costs. Prey availability for age-0 pollock differs between warm and cold years with cold years having greater densities of large copepods (e.g., *Calanus marshallae*) over the SEBS shelf. Zooplankton taxa available in cold years are generally higher in lipid content and the ability of age-0 pollock to store limit is maximized in cold water.

Energy density was at a minimum in 2003 (3.63 kJ/g), a warm year, and at a maximum in 2010 (5.26 kJ/g), a cold year (Figure 1). In contrast, the size (mass or length) of the fish has been less influenced by thermal regime. We relate AEC of the age-0 pollock to the number of age-1 recruits per spawner (R/S) using estimates of adult female spawning biomass as the number of spawners. Relating the AEC of age-0 pollock to recruitment from the age-structured stock assessment indicates the energetic condition of pollock prior to their first winter predicts their survival to age-1. The AEC of age-0 pollock in warm years between 2003-2017 accounts for 74% of the variation in age-1 recruits per spawner, but only 9% in cold years between 2003-2017.

The model fit under cold years suggests survival and recruitment success are more variable and likely the result of a suite of processes, including bottom-up and top-down pathways. 2017 was a moderate year in the southeastern Bering Sea in terms of thermal conditions, with an extensive, yet narrow cold pool. As such, it is difficult to predict the success of the 2017 year-class.

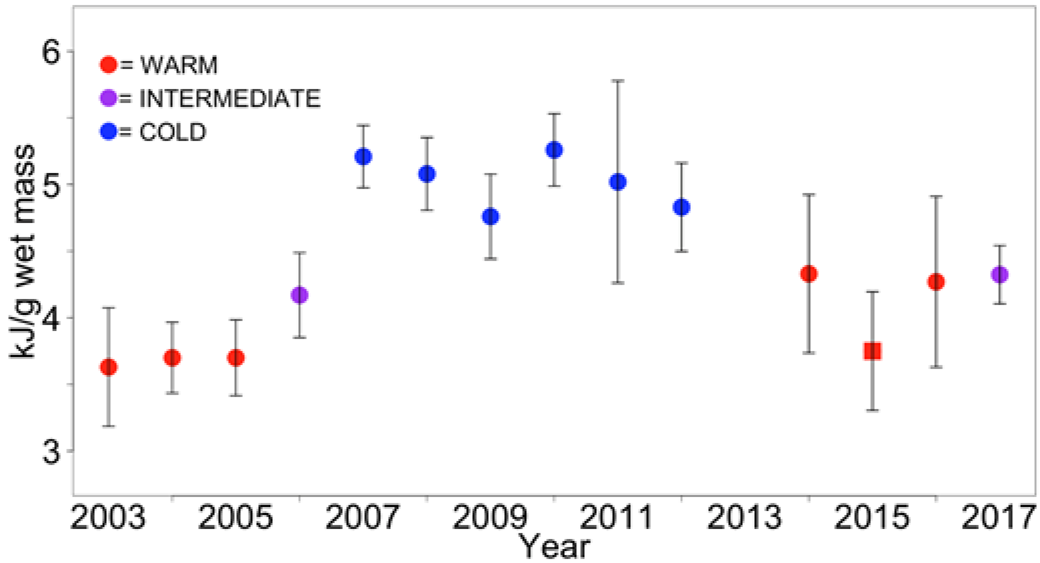


Figure 1: Average energy density (kJ/g) of age-0 Walleye pollock (*Gadus chalcogrammus*) collected during the late-summer BASIS survey in the eastern Bering Sea 2003-2017. Fish were collected with a surface trawl in all years except in 2015, when an oblique trawl was used.

For more information contact Elizabeth Siddon (Elizabeth.Siddon@noaa.gov).

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

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. 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. The TC index was positively correlated with subsequent recruitment of pollock to age-1 through age-4 from 1964 to 2018, but not significantly correlated for the shorter period (1997-2018) (Table 1).

The 2018 TC index value of -4.06 was slightly above the long-term average of -4.61. Therefore, we expect average recruitment of pollock to age-3 in 2020 from the 2017 year class (Figure 2). However, both the late summer sea surface temperature (10.67 °C) in 2017 and spring sea temperatures (6.61 °C) in 2018 were warmer than the long-term average of 9.8 °C in late summer and 5.2 °C in spring since 1949. The 2017 TC index value of -6.16 was below the long-term average of -4.61, therefore, we expect lower than average recruitment of pollock to age-3 in 2019 from the 2016 year class (Figure 2). The 2016 TC index value of -3.19 was above the long-term average of -4.60. Therefore, we expect slightly above average recruitment of pollock to age-3 in 2018 from the 2015 year class.

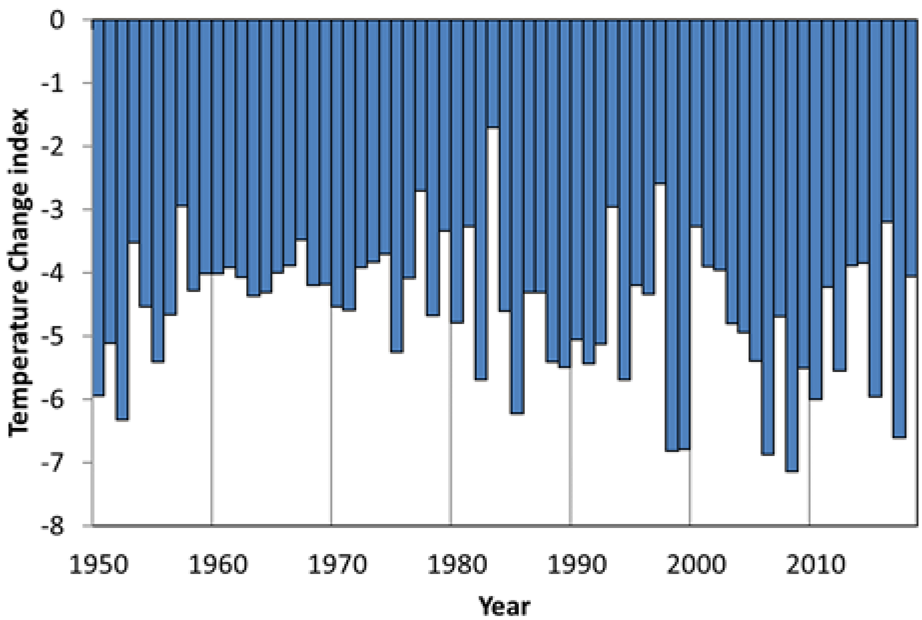


Figure 1: The Temperature Change index values from 1949 to 2018. Values represent the differences in sea temperatures on the south eastern Bering Sea shelf experienced by the 1948-2017 year classes of pollock. Less favorable conditions (more negative values) represent a warm summer during the age-0 life 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.

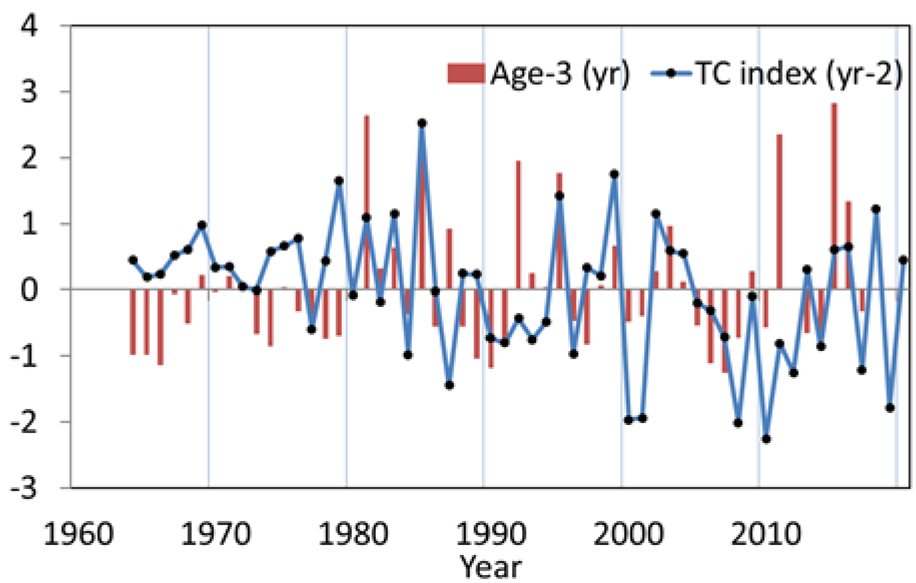


Figure 2: Normalized time series values of the temperature change index (t-2) from 1964-2020, showing conditions experienced by the 1961-2017 year classes of pollock during the summer age-0 and spring age-1 life stages. Normalized values of the estimated abundance of age-3 walleye pollock in the eastern Bering Sea from 1964-2017 (t) for the 1961-2014 year classes. Age-3

walleye pollock estimates are from Table 28 in Ianelli et al. 2017. The TC index indicate above average conditions for the 2015 and 2017 year class and below average conditions for the 2016 year class.

Table 1: Pearson's correlation coefficient relating the Temperature Change index to subsequent estimated year class strength of pollock. Bold values are statistically significant ($p < 0.05$).

Correlations						
	Age-1	Age-2	Age-3	Age-4	Age-5	Age-6
1964-2017	**0.35**	**0.35**	**0.33**	0.27	0.23	0.21
1996-2017	0.38	0.40	**0.44**	0.39	0.36	0.41

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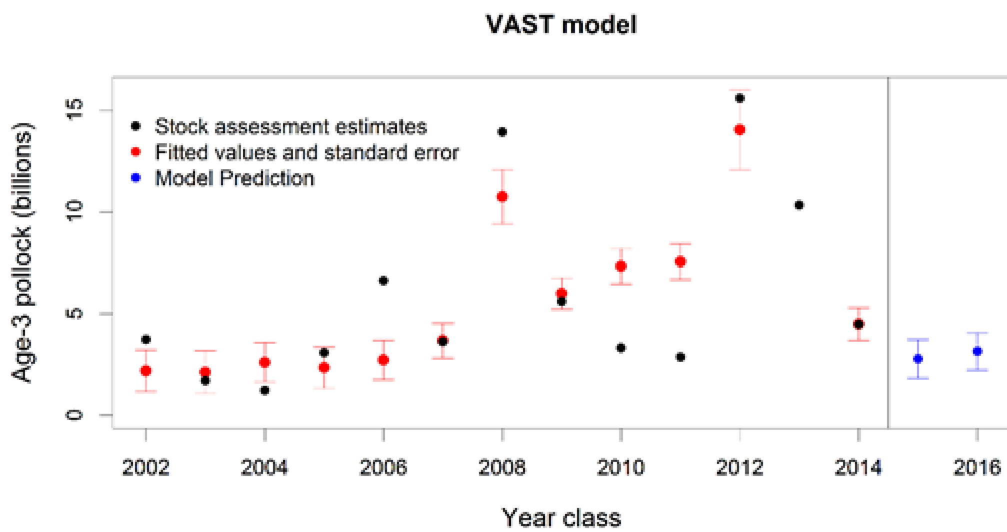
For more information contact Ellen Yasumiishi (907) 789-6604, ellenyasumiishi@noaa.gov

Large copepod abundance (observed and modeled) as an indicator of pollock recruitment to age-3 in the southeastern Bering Sea - 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 2002-2014 year classes (Ianelli et al., 2017). Two estimates of a time series of large copepod abundances were calculated: the first used observed survey 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 4_2_0 (Thorson et al. 2015). We specified 50 knots, a log normal distribution, and the delta link function between probability or encounter and positive catch rate in VAST.

Positive, significant, linear relationships were found between observed and VAST modeled mean abundances of large copepods collected during the age-0 stage of pollock and stock assessment estimates of age-3 pollock for the 2002-2014 year classes (Figure 1). Our regression models predict an abundance of 2.83 and 3.39 billion age-3 pollock with a standard error of 1.35 and 1.24 billion for the 2015 and 2016 year classes, respectively. Likewise, estimates using VAST predict an abundance of 2.77 and 3.15 billion age-3 pollock with a standard error of 0.96 and 0.91 billion for the 2015 and 2016 year classes, respectively. Our results suggest that decreases in the availability of large copepod prey, which are high in lipid content, in 2015 and 2016 were not favorable 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.



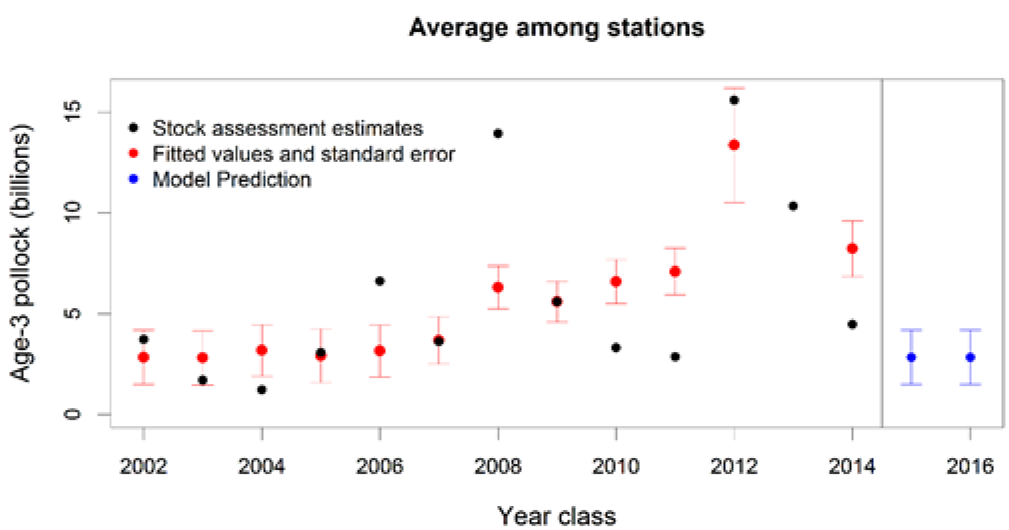


Figure 1. Fitted means and standard errors (red) of the age 3 pollock abundance estimated from the linear regression models using means of large copepods from observed data (top) and VAST model (bottom), and pollock stock assessment estimates (black) from Ianelli et al. (2017). Predicted estimates of age 3 pollock for 2015 and 2016 year classes (recruited into fishery as age 3's in 2018 and 2019, respectively) are shown in blue.

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Ianelli, J. N., S. Kotwicki, T. Honkalehto, K. Holsman, and B. Fissel. 2017. Assessment of walleye pollock stock in the Eastern Bering Sea. *In*: *Stock Assessment and Fishery Evaluation*

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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

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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

Taxonomy, Body Size, and the Predator-Prey Mass Ratio: Three Fish Species in the Gulf of Alaska - RPP

Matthew T. Wilson, David G. Kimmel, Kathryn L. Mier

The predator-prey mass ratio (PPMR), a parameter of size-structured food web models, has received much scrutiny about whether it varies with predator body size. PPMR relates theoretically to trophic efficiency and determines feeding kernel dynamics. We demonstrate that taxonomy and ontogeny affect the outcome of PPMR size-independence hypothesis tests by governing predator diet. We focused on the trophic link between zooplankton and 3 species of small neritic forage fishes: capelin *Mallotus catervarius*, eulachon *Thaleichthys pacificus*, and walleye pollock *Gadus chalcogrammus*, which were subdivided into age-0 and older (age-1) groups. These fishes support the piscivore-dominated, fishery-rich coastal ecosystem of the Gulf of Alaska (GOA). Body weight data were from 3615 individual predators that contained 163845 prey. The size-independence hypothesis was most commonly rejected because predators outgrew specific prey taxa, as indicated by a positive slope (Fig. 1). Predators that transitioned from small- to larger-sized taxa were able to maintain (slope = 0) or decrease (negative slope) PPMR. We hypothesized that maximum trophic efficiency from zooplankton to nektonic forage fishes occurs when the community is dominated by predators able to fully exploit euphausiids. We concluded that taxonomic and ontogenetic variation in predator diets were fundamental to whether the realized PPMR was independent of predator body size and this related to trophic transfer efficiency. Development of detailed, realistic size-structured food web models should consider taxonomic and inter-annual effects on the size-independence of realized PPMR to more realistically estimate fish production.

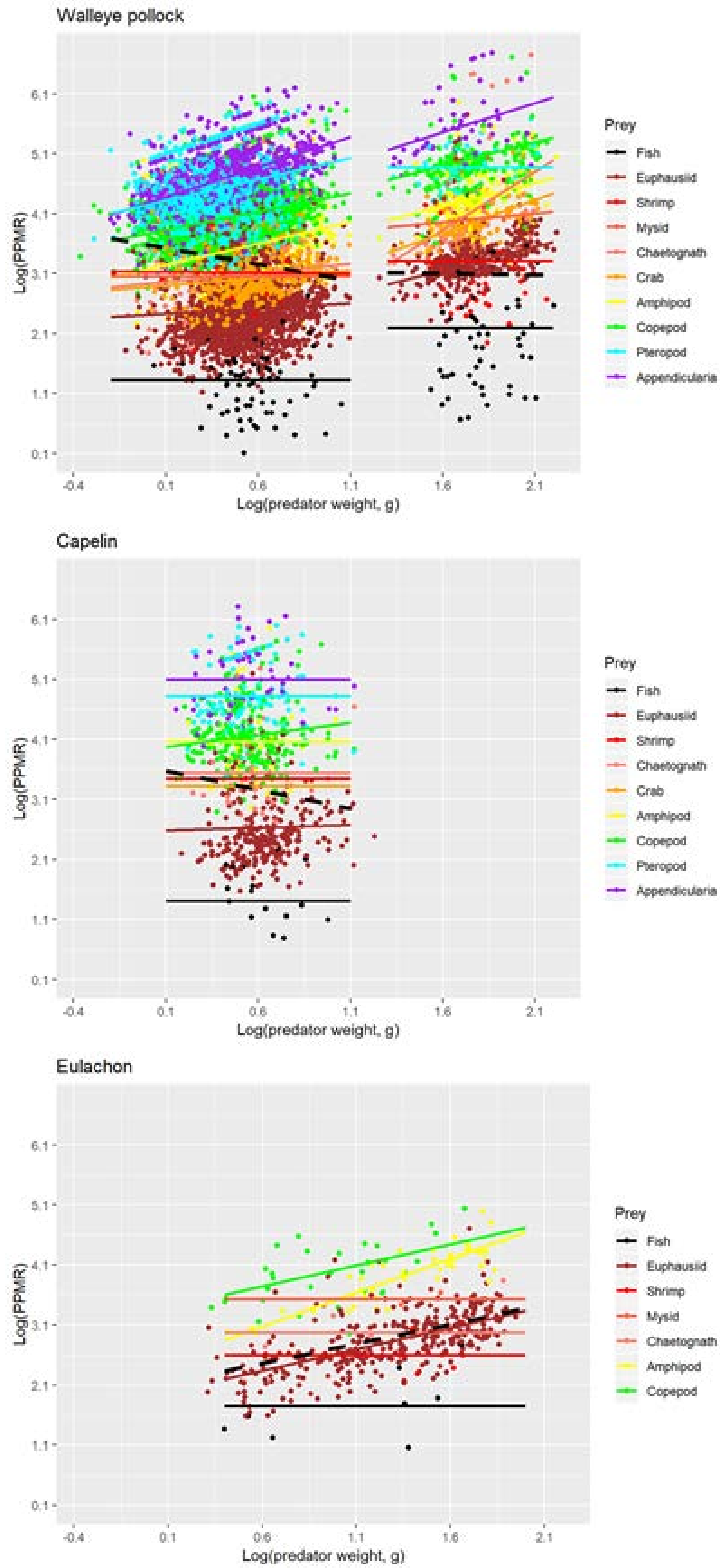

Figure 1. Log_{10} predator-prey body mass ratios (PPMR) by log_{10} body weight for individual

predators and prey group. Mean functional relationships based on modified individual-predator prey weights (i.e., by prey group) are represented by thin solid lines; prey groups are sorted by mean individual weight. For comparison, mean functional relationships based on prey weights pooled across taxa are represented by thick dashed black lines.

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How regional differences in size, condition, and prey selectivity may have contributed to density-dependent regulation of 2013 year class of Walleye Pollock in the Western Gulf of Alaska - RPP
Jesse F. Lamb and David G. Kimmel

During the fall 2013 western Gulf of Alaska (WGOA) survey, age-0 walleye pollock (*Gadus chalcogrammus*) were found in high abundance compared to other years: an average of 0.42m^2, compared to 0.06m^2(2011) and 0.00087m^2(2015). To assess the potential for density-dependent resource competition we are examining diet and condition of age-0 fish from the 2013 year class. We hypothesized that fish from different areas along the WGOA shelf may have had dietary differences that related to fish size and condition. We are testing this hypothesis by comparing fish size and condition in different regions of the WGOA to diets and prey distributions. Similar to previous studies, smaller, more numerous walleye pollock (n=503) were found southwest of Kodiak Island (Region A) and larger, less numerous walleye pollock (n=288) were found in the northeast WGOA, near Kodiak Island (Region B). We found pollock diet composition was similar in larger fish (60-80mm); however, differences in diet were found among the smaller fish (Fig 1, left). Using a measure of prey diet preference, the Prey-Specific Index of Relative Importance (PSIRI), we found significant overlap in the top five prey selected by pollock for both regions (Fig 1, right). Despite Region A having smaller fish than Region B, both regions shared the top two preferred prey items: large calanoid copepods and juvenile/adult euphausiids (Fig 1, right). Regional differences were found in the remaining selected prey items: pteropods and euphausiid calyptopis/furcilia stages in Region A compared to tunicates and anomuran crabs in Region B (Fig 1, right). These results may suggest density-dependent food limitation in Region A as higher quality prey may be been depleted by more numerous walleye pollock and this contributed to density-dependent mortality of the 2013 year class in the WGOA. We plan on examining pollock condition as well as finer scale spatial patterns in pollock diet composition moving forward.

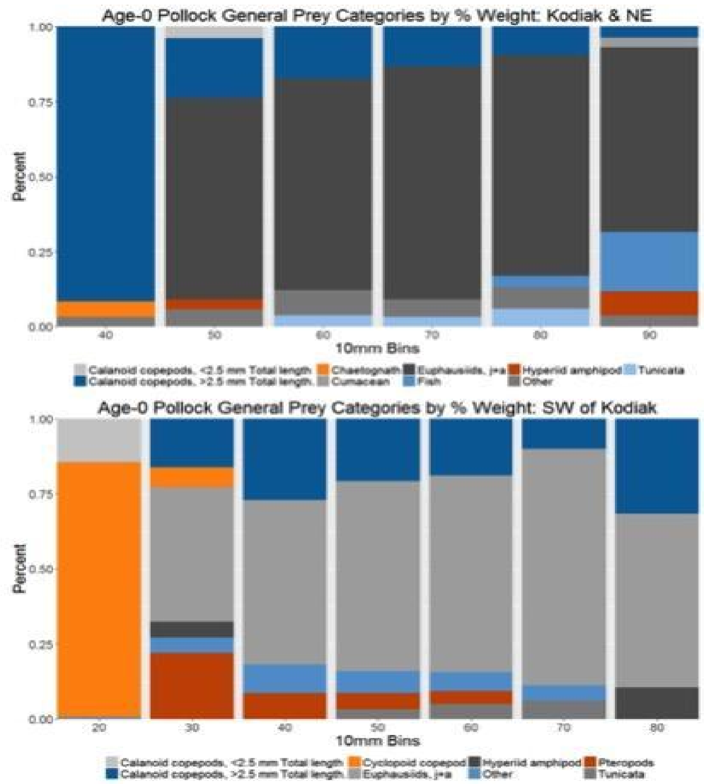

Figure 1. Age-0 pollock diet composition (percent weight) by 10mm length bins. The "Other" prey category was the sum total of prey categories that comprised less than 3% of the total prey weight in both regions.

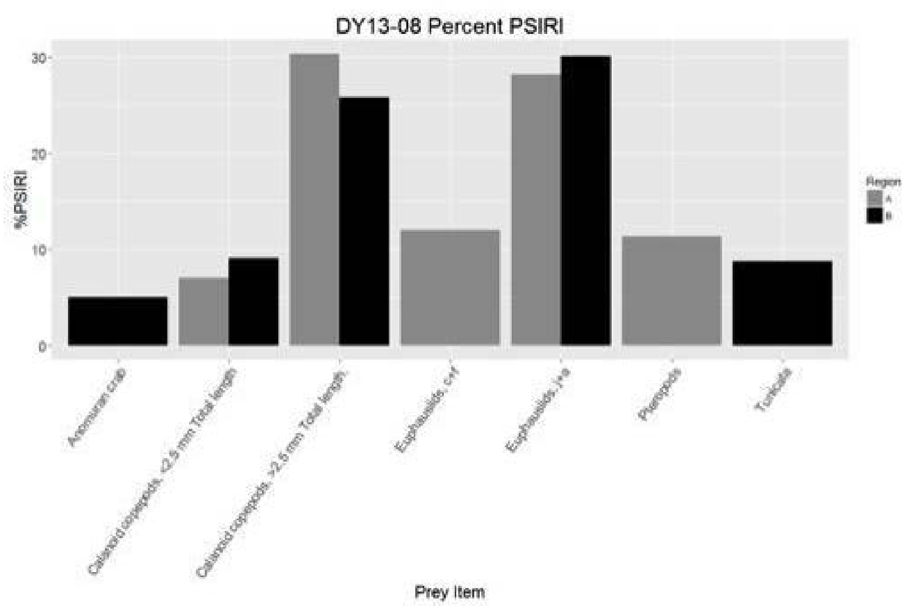

Figure 2. The top five selected prey taxa as determined by the PSIRI for stations southwest of Kodiak Isl. (Region A) and stations surrounding and to the northeast of Kodiak Isl. (Region B).

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Bering Sea

Vertical Distribution of age-0 walleye pollock in the eastern Bering Sea - RPP
Adam Spear and Alex Andrews

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. Although not observed, 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. Further studies will include depth specific changes in condition of fish to determine whether age-0 pollock in deeper waters during warm years have higher energy density.

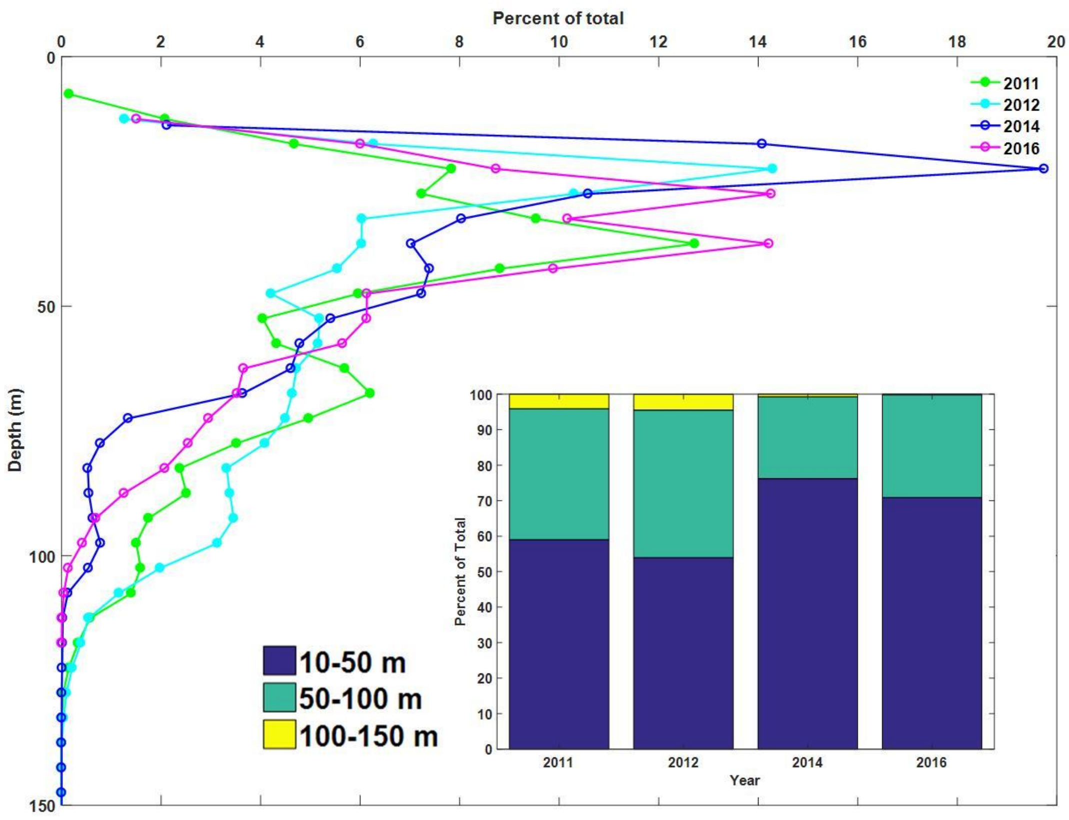

Figure 1. Depth distribution as percent of total abundance (fish nmi^{-2}) of age-0 pollock estimated by acoustic-trawl methods in 2011,2012, 2014,2016. Both plots show a shift in distribution towards the surface during warm years (2014, 2016). Colder years show a shift towards deeper waters.

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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

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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)
This is a mature assessment done annually with new catch, survey, and composition information. For the 2018 assessment this included data from the 2018 NMFS bottom-trawl (BTS) and acoustic-trawl (ATS) surveys as well as total catch through 2018. In addition, opportunistic acoustic data from vessels (AVO) conducting the 2018 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 2016 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 (above average by factors of 2.19, 2.43, and 1.80 for the post-1976 time series, respectively), along with spawning exploitation rates below 20% since 2008. Spawning biomass is projected to be above BMSY in 2019 by a factor of 1.36.

The updated estimate of BMSY from the present assessment is 2.280 million t, 12% above last year's estimate of 2.043 million t. Projected spawning biomass for 2019 is 3.107 million t. As has been the approach for many years, the maximum permissible ABC harvest rate was based on the ratio between MSY and the equilibrium biomass corresponding to MSY. The harmonic mean of this ratio from the present assessment is 0.510, 9% above last year's value of 0.466. The harvest ratio of .510 is multiplied by the geometric mean of the projected fishable biomass for 2019 (6.073 million t) to obtain the maximum permissible ABC for 2019, which is 3.096 million t, down 10% from the maximum permissible ABCs for 2019 projected in last year's assessment. However, as with other recent EBS pollock assessments, the authors recommend setting ABCs well below the maximum permissible levels. Their reasons for doing so are listed in the "risk matrix" contained in the SAFE chapter, where assessment concerns are categorized as Level 1 ("normal"), and population dynamic and environmental/ecosystem concerns are both categorized as Level 2 ("substantially increased concern"). The authors conclude that these levels of concern warrant setting the 2019 and 2020 ABCs at 2,163,000 t and 1,792,000 t (reductions of 30% and 26% from the corresponding maxABCs).

The OFL harvest ratio under Tier 1a is 0.645, the arithmetic mean of the ratio between MSY and the equilibrium fishable biomass corresponding to MSY. The product of this ratio and the geometric mean of the projected fishable biomass for 2019 determines the OFL for 2019, which is 3.914 million t. The current projection for OFL in 2020 given a projected 2019 catch of 1.350 million t is 3.082 million 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. Nevertheless, when CEATTLE is run in single-species mode, the 2019 "target" ABC value is within 5% of the authors' and Team's recommended 2019 ABC value. When CEATTLE is run in multi-species mode, the 2019 "target" ABC is 37% higher than the author's and Team's 2019 ABC value. The CEATTLE estimates of age 1 natural mortality are trending towards average after a peak in 2016. The climate-enhanced recruitment projections from CEATTLE model indicates the increase in 2018 age 1 recruitment may have been due to favorable environmental conditions in 2017. The model projects a decrease in 2019 age 1 recruitment to levels below 2017 age 1 recruitment due to poor environmental conditions in the spring-fall of 2018.

Aleutian Islands (REFM)
In 2018 there was a full assessment for AI pollock. The model accepted in 2015 was used again for this year's assessment. New data included catches through 2018, biomass data from the 2018 AI bottom trawl survey, and 2016 AI bottom trawl survey age composition data. In 2018, for the first time in eight years, there was a directed pollock fishery although it was small at 188 t. As of October 2018 there had been only 1,590 t of incidental catch, primarily in the Atka mackerel and rockfish fisheries.

This year's assessment estimates that spawning biomass reached a minimum level of about B35% in 2003 and then generally increased during the period with no directed fishery (1999-2017), with a projected value of B47% for 2019. The increase in spawning biomass since 1999 has resulted more from a dramatic decrease in harvest than from good recruitment, as the 2015 year class is the first since 1989 to exceed the 1977-2015 average (the 2015 year class is about 2% above average). The model estimates 2019 spawning biomass at 95,253 t which is above the B40% value of 81,312 t, and estimates the values of F40% as 0.331 and F35% as 0.415. The 2019 maximum permissible ABC and OFL are 52,887 t and 66,981 t, respectively.

Bogoslof Island (REFM)
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 2019 is 183,080 t and the maximum permissible ABC for 2019 is 137,310 t. The OFL and ABC for 2020 is the same.

Gulf of Alaska (REFM)
The 2018 GOA pollock assessment used a new model similar to the one used in 2017. The main difference in the 2018 suite of models is that the winter acoustic survey time series includes a net-selectivity correction, which results in increased estimates of abundance of age-1 and to a lesser degree age-2 fish, while the estimates for adult (3+) fish are slightly reduced. The effects on overall survey biomass are small. The abundance estimates for age-1 and age-2 pollock from the Shelikof Strait survey were used as separate indices in the model. The 2018 model also removed a power term on the age-1 pollock index, which was thought to no longer be structurally appropriate given the net- selectivity corrected data which greatly increased age-1 abundance estimates. Data were updated to include 2017 total catch and catch-at-age from, 2018 biomass and age composition from the Shelikof Strait acoustic survey, 2017 age composition from the NMFS bottom trawl survey, 2018 biomass from the ADFG trawl survey, and 2017 age composition from the summer GOA-wide acoustic survey.

In 1998, the stock dropped below B40% for the first time since the early 1980s and reached a minimum in 2003 at 25% of unfished stock size. Over the years 2009-2013, the stock increased from 32% to 60% of unfished stock size but declined to 39% by 2016. The spawning stock is projected to decline in 2019 as the 2012 year class starts to decline in size. Survey data in 2018 are contradictory, similar to 2017, with acoustic surveys indicating the 2nd largest biomass in 30 years and the ADF&G bottom trawl survey showing a slight increase but still remaining near historic lows. These divergent trends are likely due to changes in the availability of pollock to different surveying methods. The model estimate of female spawning biomass in 2019 is 345,352 t, which is 62% of unfished spawning biomass (based on average post-1977 recruitment) and above the B40% estimate of 221,000 t.

This year's pollock assessment also incorporated a risk assessment matrix for evaluating whether a reduction from the maximum permissible ABC is warranted. This represents a trial approach in assessing additional risks to the stock that may be missed within the stock assessment model. The author scored the current risk conditions as Level 2 across all categories indicating a substantially increased level of concern, with the details of the scoring rationale provided in the document. Reduction from maximum ABC was calculated by averaging the projection of the current maxABC from last year's assessment with the maxABC for 2019. This alternative produced a 14.3% reduction over the maxABC for 2019 which the Team noted was quite similar to the author's recommended reduction.

Harvest specifications for GOA pollock are set on an area basis. For pollock in the Gulf of Alaska west of 140° W longitude , the model estimated 2019 age-3+ biomass is 1,126,750 t, the 2019 OFL is 194,230 t, and the 2019 ABC is 135,850 t (a decrease of 16% from the 2018 ABC). The 2019 Prince William Sound guideline harvest level (managed by the Alaska Department of Fish & Game) is 3,396 t (2.5% of the ABC). For pollock in southeast Alaska the ABC is 8,773 t for 2019 and 2020. These recommendations are based on placing southeast Alaska pollock in Tier 5 of the NPFMC tier system and basing the ABC and OFL on natural mortality (0.3) and the biomass estimate from a random effects model fit to the 1990-2017 bottom trawl survey biomass estimates in Southeast Alaska.

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).

F. Pacific Whiting (hake)

There are no hake fisheries in Alaska waters.

G. Rockfish

1. Research

Habitat use and productivity of commercially important rockfish species in the Gulf of Alaska - RACE GAP

The seasonal use of habitat by rockfishes within the Gulf of Alaska is not well understood and more research is needed to determine the relative importance of high relief habitats containing biotic structures to these species within this region. We examined the density and community structure of commercially important rockfishes in the Gulf of Alaska in three habitat types during three seasons. Low relief, high relief, and habitat containing structure forming invertebrates (biotic habitat) were sampled during spring, summer, and winter seasons at three sites (Portlock Bank, the 49 Fathom

Pinnacle, and the Snakehead Bank) in the central Gulf of Alaska near Kodiak Island using stereo drop cameras (SDC) and bottom trawls. Stereo drop cameras were also used in several locations throughout the central and eastern Gulf of Alaska to determine if localized rockfish/habitat relationships were consistent over a broader region within this large marine ecosystem. The community structure within all three sites was dominated by dusky rockfish (*Sebastes variabilis*), northern rockfish (*S. polyspinis*), Pacific ocean perch (*S. alutus*), and harlequin rockfish (*S. variegatus*). Community structure and density between seasons were not significantly different but there were differences between sites and habitats within these sites. Stereo drop camera images showed that high relief and biotic habitats had higher rockfish densities and that rockfish densities were highest at the 49 Fathom Pinnacle site. Community structure differed between sites with the 49 Fathom Pinnacle site dominated by adult dusky, northern, and harlequin rockfish while the Snakehead Bank site was dominated by juvenile Pacific ocean perch, harlequin rockfish, and other small or juvenile rockfish. Within the Snakehead Bank site, the low relief habitat had a completely different community structure dominated by flatfish while the high relief and biotic habitats were dominated by rockfishes. The pattern of higher densities in high relief areas was also found in the camera transects throughout the broader central Gulf of Alaska for northern, dusky, and harlequin rockfish, but not for Pacific ocean perch. This research highlighted the role of complex habitat as Essential Fish Habitat for juvenile Pacific ocean perch and adult northern and dusky rockfish throughout the entire year.

Conrath, C. C. Rooper, R. Wilborn, D. Jones, and B. Knoth (in review) Seasonal habitat use and community structure of rockfishes in the Gulf of Alaska.

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

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. There is a need for more detailed assessment of the reproductive biology of deep water rockfish species including: the rougheye rockfish complex (rougheye and blackspotted rockfish, *S. aleutianus* and *S. melanostictus*), and shortraker rockfish, *S. borealis*. The analysis of maturity for these deeper water rockfish species has been complicated by the presence of a significant number of mature females that skip spawning. Results for rougheye rockfish, blackspotted, and shortraker rockfish are presented below. To complete these studies samples are needed from additional areas and time periods.

In addition, there is a need to examine the variability of rockfish reproductive parameters over varying temporal and spatial scales. It remains unknown if there is variability in rockfish reproductive parameters at either annual or longer time scales however, recent studies suggest variation may occur for the three most commercially important species, Pacific ocean perch, *Sebastes 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 2019 reproductive season. A proposal to examine latitudinal and spatial differences in the reproductive parameters of Pacific ocean perch and black rockfish has been submitted to obtain funds for sampling until 2022.

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.

Conrath, C. (in press) Reproductive Potential of Dusky and Northern Rockfish within the Gulf of Alaska. Fishery Bulletin.

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 accents 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, as it is unknown if they have different life history parameters. This study re-examines 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.

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.

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

2. Assessment

Pacific Ocean Perch (POP) – Bering Sea and Aleutian Islands - REFM
In the BSAI, POP are assessed using an age-structured population dynamics model implemented in the software program AD Model Builder. For 2018, new data included updated catch data through 2017, projected 2018-2020 catch estimates, fishery age data from 2015 and 2017, fishery length data from 2016, biomass estimate and length data from the 2018 Aleutian Islands (AI) bottom trawl survey, age data from the 2016 AI and eastern Bering Sea (EBS) bottom trawl surveys, updated length-at-age, weight-at-age, and age-to-length conversion matrices, and reweighted age and length data using the iterative reweighting procedure. The only change to the assessment methodology was an increase in the number of year nodes for the fishery selectivity spline (from 4 nodes to 5).

The 2018 survey biomass estimates in the Aleutian Islands increased by 3% from 2016, continuing the high survey biomass trend over the last three surveys. The 2018 estimates in the AI regions were within 6% of the 2016 estimates; however, there was a large increase (30%) in the EBS area between 2016 and 2018. These continued high survey biomass estimates have contributed to a substantial increase in estimated stock size in recent years; however, there remains a poor residual pattern in the fit to this survey index.

Spawning biomass is projected to be 399,024 t in 2019 and decline to 386,835 t in 2020. The 2000, 2005, and 2008 year classes are estimated to be 198%, 99%, and 104% above average, respectively. The maximum permissible value of FABC (F40%) under Tier 3a is 0.079, which results in a recommended 2019 ABC of 50,594 t and 2020 ABC of 49,211 t. The OFL fishing mortality rate (F35%) is 0.095. which results in a 2019 OFL of 61,067 t and 2020 OFL of 59,396 t.

The ABC was apportioned regionally based on the proportions in combined survey biomass as follows (values are for 2019): EBS = 14,675 t, Eastern Aleutians (Area 541) = 11,459 t, Central

Aleutians (Area 542) = 8,435 t, and Western Aleutians (Area 543) = 16,025 t. The recommended OFLs for 2019 and 2020 are not regionally apportioned.

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

Pacific Ocean Perch -- Gulf of Alaska - ABL
In 2018 the Pacific ocean perch assessment was presented in an executive summary format as a scheduled "off-year" assessment. Full assessments are scheduled to coincide with years when a Gulf of Alaska trawl survey is conducted. Therefore, only the projection model was run, with updated catches. New data in the 2018 assessment included updated 2017 catch and estimated 2018 catch. No changes were made to the assessment model.

Spawning biomass was above the $B_{40\%}$ reference point and projected to be 176,934 t in 2019 and to decrease to 172,345 t in 2020. 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 117,448 t, 0.094, and 0.113, respectively. Spawning biomass for 2019 is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier "a" of Tier 3. The 2019 and 2020 catches associated with the $F_{40\%}$ level of 0.094 are 28,555 t and 27,652 t, respectively, and were the authors' and Plan Team's recommended ABCs. The 2019 and 2020 OFLs are 33,951 t and 32,876 t.

A random effects model was used to set regional ABCs based on the proportions of model-based estimates for 2019: Western GOA = 3,227 t, Central GOA = 19,646 t, and Eastern GOA = 5,682 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 2019 is 3,296 t and for E. Yakutat/Southeast the ABC in 2019 is 2,386 t. The recommended OFL for 2019 is apportioned between the Western/Central/W. Yakutat area (31,113 t) and the E. Yakutat/Southeast area (2,838 t). Pacific ocean perch is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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Dusky Rockfish-- Gulf of Alaska -- ABL
In 2018, an age-structured stock assessment was conducted for Gulf of Alaska dusky rockfish. Model data were updated to include survey age compositions for 2015 and 2017, final catch for 2015, 2016, and 2017 and preliminary catch for 2018, fishery age compositions from 2014 and 2016, and fishery size compositions for 2015 and 2017. Additionally, geostatistical model-based trawl survey biomass estimates for 2017 were updated and included. There were no changes in the assessment methods. The stock assessment is posted here https://www.afsc.noaa.gov/REFM/Docs/2017/GOAdusky.pdf.

Estimates of female spawning biomass for 2019 and 2020 from the current year (2018) assessment model are 20,342 t and 20,106 t, respectively. Both estimates are above the $B_{40\%}$ estimate of 18,535 t. The dusky rockfish stock is in Tier 3a and the recommended maximum permissible 2019 ABC of

3,700 t was from the updated projection model. This ABC is 6.5% lower than the 2018 ABC of 3,957 t.

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 2018 and 2019.

	Western	Central	Eastern	[Eastern sub-areas]		Total
Area Apportionment	21.1%	74.7%	4.2%	W.Yak	EY/SE	100%
2019 ABC (t)	781	2,764	155	95	60	3,700
2020 ABC (t)	774	2,742	154	94	60	3,670

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Northern Rockfish – Bering Sea and Aleutian Islands - REFM
This chapter was presented in a partial assessment format because it was a scheduled “off-year” assessment under the stock assessment prioritization guidelines. Therefore, only the projection model was run, with updated catches. New data in the 2018 assessment included updated 2017 catch and estimated 2018-2020 catches.

Exploitation rates (i.e., catch/biomass) have averaged 0.015 from 2004-2018, which is below the exploitation rate associated with fishing at F40%. New projections were very similar to last year’s projections because observed catches were very similar to the estimated catches used last year. Spawning biomass is projected to be 104,201 t in 2019 and to decline to 102,480 t in 2020. Exploitation rates by area since 2004 appeared to be low in all areas in most years with some increase in all areas except the eastern AI in 2018.

The current estimates of B40%, F40%, and F35% are 65,870 t, 0.065, and 0.080, respectively. The maximum permissible value of FABC under Tier 3a is 0.065, which results a recommended 2019 ABC of 12,664 t and 2020 ABC of 12,396 t. The OFL fishing mortality rate is 0.080 which results in a 2019 OFL of 15,507 t and 2020 OFL of 15,180 t.

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

Northern Rockfish – Gulf of Alaska-ABL
In 2018, an assessment was conducted for Gulf of Alaska northern rockfish. Model data were updated to include survey biomass estimates for 2017, survey age compositions for 2015 and 2017, final catch for 2015, 2016, and 2017, preliminary catch for 2018, fishery age compositions from 2014 and 2016, and fishery size compositions for 2015 and 2017. The assessment model was

changed for this year to include use of the Vector Autoregressive Spatio-Temporal (VAST) model for the biomass estimate of survey biomass and the survey index likelihood weights were rescaled.

Estimates of female spawning biomass for 2019 and 2020 from the 2018 model are 36,365 t and 34,046 t, respectively. Both estimates are above the $B_{40\%}$ estimate of 30,480 t.The northern rockfish stock is in Tier 3a and the recommended maximum permissible 2019 ABC of 4,529 t was from the updated projection model. This stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. The following table shows the recommended ABC apportionment (t) for 2018 and 2019.

Area	Western 26.28%	Central 73.70%	Eastern 0.02%	Total 100%
2019 Area ABC (t)	1,190	3,338	1	4,529
2019 OFL (t)				5,402
2020 Area ABC (t)	1,122	3,147	1	4,270
2020 OFL (t)				5,093

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

Shortraker Rockfish - - Bering Sea and Aleutian Islands - REFM

Harvest recommendations for shortraker rockfish in the BSAI are made using Tier 5 methods (OFL = F * biomass, where F=M; ABC = 0.75 * OFL). New data included updated catch data through 2018, and biomass estimates from the 2018 AI bottom trawl survey.

Estimated shortraker rockfish biomass in the BSAI has been relatively stable since 2002. Increases in the 2018 AI survey biomass estimates occurred in the western and eastern AI with a decrease in the central AI. According to the random effects model, total biomass (AI and EBS slope combined) from 2002-2018 has been very stable, with a slight increase in the estimate of 2019 biomass since the 2016 assessment, from 22,191 t in the 2016 assessment to 24,055 t in the current assessment. The time series from the random effects model is much smoother than the time series for the raw data due to large standard errors associated with the survey biomass estimates. Exploitation rates have generally been well below the ABC levels in all areas, except for the western area, where exploitation rates exceeded the ABC levels rom 2011-2013. The accepted value of M for this stock is 0.03 for shortraker rockfish, resulting in a maxFABC value of 0.0225. The resulting OFL and ABC for 2019 are 722 t and 541 t, respectively.

Shortraker Rockfish – 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) Tiers 4, 5, and 6 rockfish remain on a biennial stock assessment schedule with a full stock assessment produced in even years and no stock assessment produced in odd years. Because 2018 was an "off year," the values for the 2018 fishery were rolled over for the 2019 fishery.

Estimated shortraker rockfish biomass is 38,361 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 863 t for the 2019 fishery. Gulfwide catch of shortraker rockfish was 751 t in 2018. This is up from 553 t in 2017.

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

Other Rockfish – Gulf of Alaska – ABL

Like for shortraker rockfish (see above), 2018 was an "off year," and the 2018 values are rolled over for the 2019 fishery. The Other rockfish (OR) stock complex consists of up to 25 species in Tiers 4, 5, and 6 (depending on the management area). Biomass estimates and ABC/OFL values for the OR complex are the sum of the recommendations for each species. The total estimated OR complex biomass is 96,107 t. The recommended ABC for the 2019 fishery is 5,590 t. Gulfwide catch of OR was 1,225 t in 2018. This is up from 1,078 t in 2017.

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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.

The 2016 assessment used an age-structured model applied to the entire BSAI area, using data from both the EBS slope survey and AI survey. In the 2018 assessment, this approach was altered so that an age-structured model was applied only to the AI portion of the population, while the EBS portion of the population was assessed with Tier 5 methods (OFL = F * biomass, where F=M; ABC = 0.75 * OFL). Updated data included 2018 AI survey biomass estimate and length composition, total catch through 2018 (2018 total catch projected), 2016 AI survey age composition, survey and fishery age date through 2017, and revised growth parameters. New methods were used for weighting (Francis) and for estimating selectivity (two-parameter logistic curve). The Plan Team recommended combining the results of two alternative models by model averaging.

Spawning biomass for AI blackspotted/rougheye rockfish in 2019 is projected to be 6,858 t and is projected to continue increasing (based on averaging Models 18.1 and 18.2). There is some evidence of several large recruitments in the 2000s, but there is also evidence of relatively high mortality and declining abundance of larger/order fish. The most recent survey in the AI (2018) was nearly identical to the previous survey in 2016. The BSAI was separated into AI and BS components for this assessment year, returning to the practice that had been used prior to the 2016 assessment. For the AI, the projected female spawning biomass for 2019 of 6,858 t is less than B40%, (8,611 t). The adjusted FABC =F40% values for 2019 and 2020 are 0.027 and 0.0295, respectively. For the BS, recommended 2019 ABC is 451 t and 2019 OFL is 547 t. The apportionment of the 2019 ABC to subareas is 163 t for the Western and Central Aleutian Islands and 288 t for the Eastern Aleutian Islands and Eastern Bering Sea.

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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, a partial assessment was conducted for RE/BS in 2018. This consists of an executive summary with recent fishery catch and survey trends as well as recommend harvest levels for the next two years. There were no changes made to the assessment model inputs since this was an off-cycle year. However, new data added to the projection model included an updated 2017 catch estimate and new catch estimates for 2018-2020. Please refer to last year's full stock assessment and fishery evaluation (SAFE) report for further information regarding the stock assessment (Shotwell et al., 2017, available online at https://www.fisheries.noaa.gov/resource/data/2018-assessment-rougheye-and-blackspotted-rockfish-stock-complex-gulf-alaska).

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. For an off-cycle year, we do not re-run the assessment model, but do update the projection model with new catch information. This incorporates the most current catch information without re-estimating model parameters and biological reference points. As with last year, we use the full assessment base model from 2015.

The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished. The tests for evaluating these three statements on status determination require examining the official total catch from the most recent complete year and the current model projections of spawning biomass relative to $B_{35\%}$ for 2018 and 2020. The official total catch for 2017 is 523 t, which is less than the 2017 OFL of 1,594 t; therefore, the stock is not being subjected to overfishing. The estimates of spawning biomass for 2018 and 2020 from the current year (2018) projection model are 15,057 t and 14,926 t, respectively. Both estimates are well above the estimate of $B_{35\%}$ at 7,873 t and, therefore, the stock is not currently overfished nor approaching an overfished condition.

Catch of rougheye and blackspotted rockfish increased in all areas in 2018 compared to 2017, but remains within the range of the time series. The increase is consistent across gear types with one-third taken in longline fisheries and two-thirds taken in trawl fisheries. The majority of the RE/BS rockfish catch remains in the rockfish and sablefish fisheries, with some increase in the flatfish fisheries. The 2018 longline survey abundance estimate (relative population number or RPN) decreased about 31% from the 2017 estimate and is slightly below the long-term mean. The decrease was consistent across areas with the exception of the West Yakutat region, which had a 20% decrease. This information was not used for updating the 2018 projection model for RE/BS rockfish as this was an off-cycle year.

For the 2019 fishery, the Plan Team accepted the authors' recommended maximum permissible ABC of 1,428 t ($F_{ABC} = F_{40\%} = 0.04$) and OFL of 1,715 t ($F_{OFL}=F_{35\%} = 0.048$).

The apportionment percentages are the same as in the 2017 full assessment using the three-survey weighted average method and providing the random effects method as reference. Please refer to the last full stock assessment for information regarding the apportionment rationale for RE/BS rockfish. Area apportionments based on the three-survey weighted average method are as follows for 2019: Western GOA = 174 t, Central GOA = 550 t, and Eastern GOA = 704 t.

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H. Thornyheads

1. Research
None at present.

2. Stock Assessment

Gulf of Alaska - ABL

The Gulf of Alaska (GOA) thornyhead complex are assessed on a biennial stock assessment schedule with a full stock assessment produced in even years and no stock assessment produced in odd years. For this on-cycle year, we incorporated Relative Population Weights (RPWs) from the 1992-2018 AFSC longline surveys and updated catch. Estimated thornyhead rockfish biomass is 89,609 t, which is a decrease of 1% from the previous estimate in the 2017 assessment.

Gulf of Alaska thornyheads (*Sebastolobus*) are assessed as a stock complex under Tier 5 criteria 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. In 2018 a new method of combining the AFSC longline survey Relative Population Weight (RPW) index (1992 - 2018) with the AFSC bottom trawl survey biomass index (1984 – 2017) within the RE model was used to estimate the exploitable biomass that is used to calculate the ABC and OFL values for the 2019 fishery. Estimated thornyhead biomass is 89,609 t, which is a decrease of 1% from the 2017 estimate. This is the first decline in thornyhead biomass in the GOA after seeing an increasing pattern since 2011. 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 the recommended ABC is 2,016 t for the 2019 fishery. Gulfwide catch of thornyhead rockfish was 1,021 t in 2017 and 1,109 t in 2018. Thornyhead rockfish in the GOA are not being subjected to overfishing. It is not possible to determine whether this complex is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

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I. Sablefish

1. Research

Groundfish Tag Program - ABL

The ABL MESA Program continued the processing of sablefish tag recoveries and administration of the tag reward program and Sablefish Tag Database during 2018. Total sablefish tag recoveries for the year were around 700. Twenty four percent of the recovered tags in 2018 were at liberty for over 10 years. About 37 percent of the total 2018 recoveries were recovered within 100 nautical miles (nm; great circle distance) from their release location, 33 percent within 100 – 500 nm, 20 percent within 500 – 1,000 nm, and 10 percent over 1,000 nm from their release location. The tag at liberty the longest was for approximately 40 years, and the greatest distance traveled of a tag recovered in 2018 was 2,013 nm. Six adult sablefish and 3 juvenile sablefish tagged with archival tags were recovered in 2018. First reports describing the vertical movement (using collected depth data) of adult sablefish from these electronic tags has recently been published (Sigler and Echave 2019).

Tags from shortspine thornyheads, Greenland turbot, Pacific sleeper sharks, lingcod, spiny dogfish, and rougheye rockfish are also maintained in the Groundfish Tag Database. Twenty nine thornyhead and 1 spiny dogfish were recovered in 2018. Releases in 2018 on the AFSC groundfish longline survey totaled 3,604 adult sablefish, 740 shortspine thornyheads, 5 Greenland turbot, and 32 spiny dogfish. Pop-up satellite tags (PSAT) were implanted on 10 spiny dogfish and 14 sablefish. An additional 287 juvenile sablefish were tagged during two juvenile sablefish cruises in 2018.

Sigler MF, Echave KB. 2019. Diel vertical migration of sablefish (*Anoplopoma fimbria)*. Fish Oceanogr. 2019:00:1-15. https://doi.org/10.1111/fog.12428

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 2018. ABL staff coordinated with a University of Alaska Fairbanks (UAF) graduate project to collect stomach contents and tag juvenile sablefish in St. John Baptist Bay near Sitka, AK over 4 days (July 17 – July 20). A total of 36 juvenile sablefish were caught and tagged and released. Average length of fish during July sampling was 35 cm. Calculating CPUE was not possible due to the inconsistent sampling, but total catch was down from the 164 individuals tagged in 2017. UAF returned in October for further sampling and experienced much higher catch rates, tagging an additional 251 juvenile fish over 4 days (October 20 – 23). Of note, the October sampling appears to have only captured young of the year (YOY) sablefish, whereas the July sampling caught age-1 fish. The average length of tagged fish was 25 cm, with total length range of 21 – 28 cm.

While juvenile sablefish have consistently been tagged in St. John Baptist Bay, a shallow bay with soft bottom nearby Sitka in Southeast Alaska, no other locations have been found to consistently hold juvenile sablefish. Therefore, movement of juvenile fish from areas other than the eastern GOA is relatively unknown. In2018 ten days (9/22 – 9/31) were spent sampling various bays in the

Central Gulf of Alaska (CGOA) from Whittier, the Kenai Peninsula, the Alaska Peninsula (Katmai), and around the southern half of Kodiak Island (Figure 1). This sampling cruise in the CGOA was conducted using NOAA National Cooperative Research Funds as a follow-up to compare with the highly successful 2015 CGOA juvenile tagging and unsuccessful 2016 CGOA sampling. A broad spatial distribution, including various habitat types and depths, were fished (Figure 1), but all were nearshore at between depths of 30 and 175 ft. Locations fished were chosen based on historical NMFS bottom trawl survey data, NMFS/ADFG mesh survey data, and anecdotal information provided by sport fishermen via an online outdoor forum. Methods included rod and reel jigging with squid (*Illex*) as bait. No sablefish were caught during the research cruise, and bycatch was minimal.

Several reasons for not catching sablefish in the CGOA are possible. Juvenile sablefish have historically been very difficult to find. In addition, the late season may have played a role in their absence. Juvenile sablefish generally spend their first one to two years of life in nearshore habitats before emigrating to offshore habitats, however, tag recovery and NMFS longline survey data from the Central and Western GOA have shown age-1 and age-2 sablefish to be in deeper shelf and slope waters at an earlier age than sablefish in the Eastern GOA. Near the end of the trip we spoke with a vessel returning from a halibut longlining trip in southern Shelikof Strait at an average depth of 275 ft. They reported that every other hook on the set had a 35-38 cm sablefish (age-1). Therefore, the fish may already be in deeper water and not available to our sampling in nearshore waters.

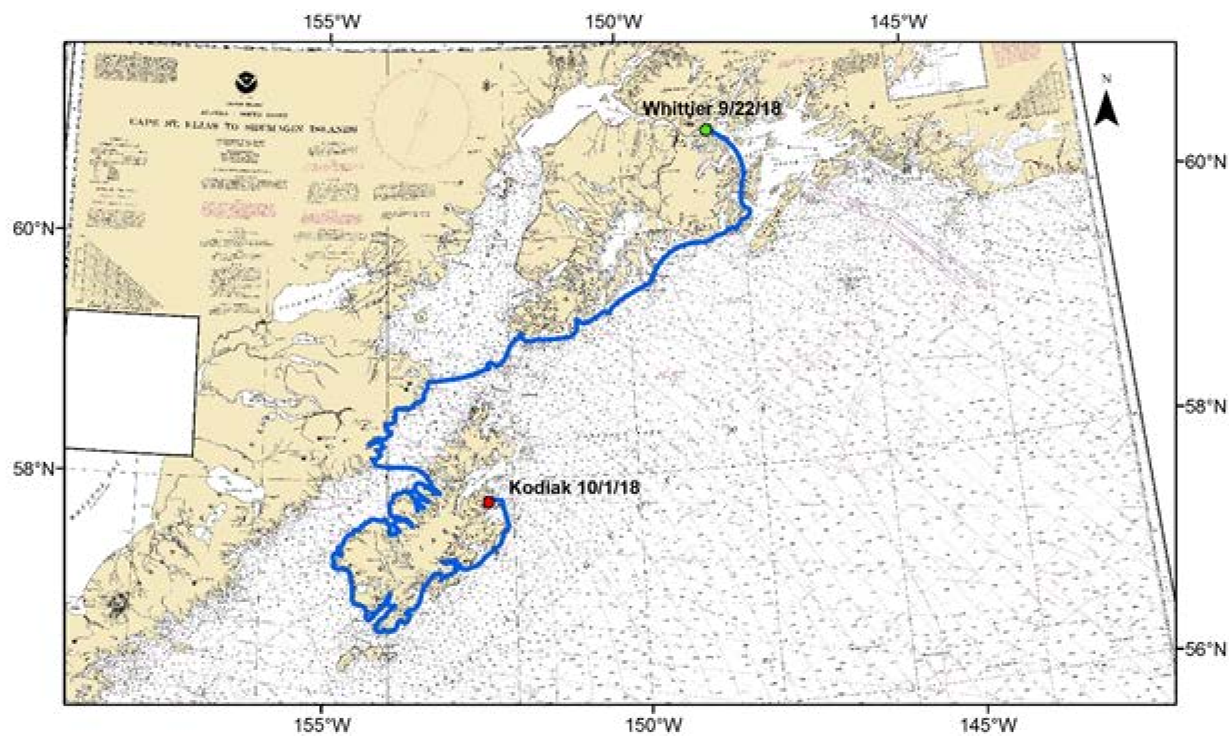


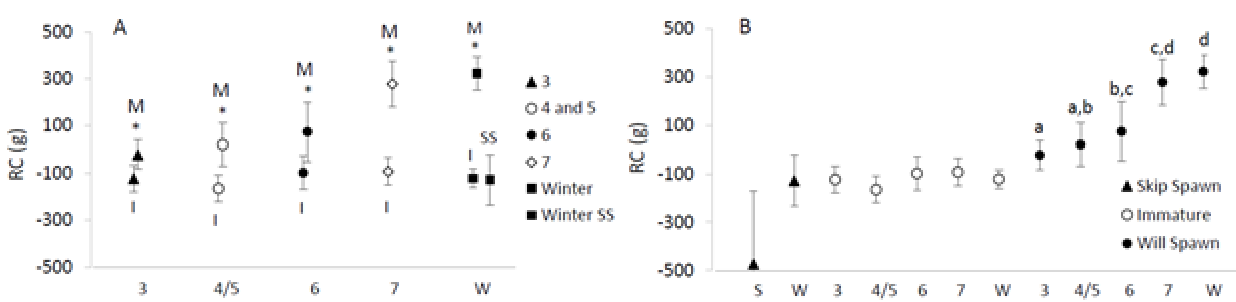
Figure 1. Rough track line of a tagging cruise beginning in Whittier on September 22, 2018 and ending in Kodiak on October 1, 2018.

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

Relative liver size and body condition topredicting maturity and fecundity of sablefish – ABL
The objectives of this study were to determine if relative body condition and relative liver size (hepatosomatic index, HSI) could be utilized to predict maturity 6–8 months prior to spawning, when samples are readily available, and if these condition measures were related to fecundity. Female sablefish were sampled onthe annual AFSC summer longline survey in July and August 2015 and during a winter survey in December 2015, which is 1 to 3 months prior to the spawning season in the Gulf of Alaska. The relative body condition and relative liver weight (hepatosomatic index, HSI) of fish increased throughout the summer survey, reaching measurements similar to those observed during the winter (relative condition; Figure 1). There were significant differences between immature and mature fish HSI and relative body condition and these differences increased throughout the summer, making these factors useful for predicting maturity on the last legs of the survey. On these later legs, models that utilized relative body condition and HSI, as well as length and age, to predict whether a fish was immature or would spawn produced maturity curves that best matched models based on histological maturity classifications. However, models without HSI may be the best choice for future work because liver weight is not regularly collected on annual surveys.

Utilizing the winter data set when fecundity could be enumerated, fecundity was significantly related to relative condition and HSI. Increasing or decreasing these measures of condition by one standard deviation in a model of fecundity, which also included length, resulted in an estimated decrease in fecundity of 32% or an increase of 47% for an average size fish (78 cm). These results show the importance of incorporating fish condition into measures of population productivity.

Figure 1. Relative condition (RC) for sablefish collected on Legs 3 through 7 of the summer longline survey (S) or in the winter (W). Immature (I), mature (M), and skip spawning (SS) fish are labeled for the winter so that skip spawning fish can be differentiated from the other two groups. In Panel A, an * represents a significant difference between maturity categories during that sampling period. Panel B includes much of the same data in panel A, except that each maturity category is presented together and significant differences within each maturity category between sampling periods are denoted by a different letter. In Panel B, SS samples are pooled for all of summer (N = 11) and compared to those collected in the winter (N = 16). The 95% confidence intervals (CI) are marked with whiskers and the lower portion of the CI for summer skip spawning fish is truncated to maintain the same scale as Panel A.



For more information contact Cara Rodgveller (cara.rodgveller@noaa.gov).

2. Stock Assessment

Bering Sea, Aleutian Islands, and Gulf of Alaska - ABL
A full sablefish stock assessment was produced for the 2019 fishery. New data included in the assessment model were relative abundance and length data from the 2018 longline survey, relative abundance and length data from the 2017 fixed gear fishery, length data from the 2017 trawl fisheries, age data from the 2017 longline survey and 2017 fixed gear fishery, updated catch for 2017, and projected 2018 - 2020 catches. Estimates of killer and sperm whale depredation in the fishery were updated and projected for 2018 - 2020.

The longline survey abundance index increased 9% from 2017 to 2018 following a 14% increase in 2017 from 2016. The lowest point of the time series was 2015. The fishery catch-rate/abundance index stayed level from 2016 to 2017 and is at the time series low (the 2018 data are not available yet). The maximum permissible ABC for 2019 is 10% higher than the 2018 maximum permissible ABC of 25,583 t. The 2017 assessment projected a 41% increase in ABC for 2019 from 2018. Instead of maximum permissible ABC, we recommended that the 2019 ABC to be equal to the 2018 ABC, which translates to a 45% downward adjustment from max ABC. The final 2019 ABC of 15,068 t is 1% higher than the 2018 ABC because of updated whale depredation adjustments that are slightly smaller. The author recommended ABCs for 2019 and 2020 are lower than maximum permissible ABC for several important reasons.

First, the 2014 year class is estimated to be 2 times higher than any other year class observed in the current recruitment regime (1977 – 2014). 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 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. It is unlikely that the 2014 year class will be average or below average, but projecting catches under the assumption that it is 7.5x average introduces risk given the uncertainty associated with this estimate. Only one large year class since 1999 has been observed, and there are only two observations of age compositions to support the magnitude of the 2014 year class. Our caution seems justified as the estimate of the 2014 year class has decreased 30% since last year's estimate. The cause of this decrease could be simply imprecision in the age compositions for the first year it was seen, or something real like an increase in natural mortality. 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.

Recommending an ABC lower than the maximum should result in more of the 2014 year class entering into the spawning biomass. This more precautionary ABC recommendation buffers for uncertainty until more observations of this potentially large year class are made. Because sablefish is an annual assessment, we will be able to consider another year of age composition in 2019 and allow this extremely young population to further mature so they can fully contribute to future spawning biomass.

The following additional bullets summarize the evidence for a lower ABC than maximum permissible:

- The estimate of the 2014 year class strength declined 30% from 2017 to 2018.
- Despite projected increases in spawning biomass in 2017, the 2018 spawning biomass and stock status is lower than in 2017.
- Despite conservative fishing mortality rates, the stock has been in Tier 3b for many years.
- Fits to survey abundance indices are poor for recent years.
- The AFSC longline survey Relative Population Weight index, though no longer used in the model, has strongly diverged from the Relative Population Number index, indicating few large fish in the population.
- The retrospective bias has increased in the last two years, and the bias is positive (i.e., historical estimates of spawning biomass increase as data is removed).
- The amount of older fish comprising the spawning biomass has been declining rapidly since 2011.
- The very large estimated year class for 2014 is expected to comprise about 10% of the 2019 spawning biomass, despite being less than 20% mature.
- 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.
- The body condition of maturing sablefish in the recent years of high recruitment is lower than average, and much lower than during the last period of strong recruitments.
- Another potential marine heat wave is forming in 2018, which may have been beneficial for sablefish recruitment in 2014, but it is unknown how it will affect current fish in the population or future recruitments.
- 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.

Finally, as is now standard practice, we also recommend a lower ABC than maximum permissible based on estimates of whale depredation occurring in the fishery in the same way as recommended and accepted starting in 2016. Because we are including inflated survey abundance indices as a result of correcting for sperm whale depredation, this decrement is needed to appropriately account for depredation on both the survey and in the fishery. The methods and calculations are described in the Accounting for whale depredation section.

Survey trends support keeping ABC level relative to last year. Although there was a modest increase in the domestic longline survey index time series in the last two years, and a large increase in the GOA bottom trawl survey in 2017, these increases are offset by the very low status of the fishery abundance index seen in 2016 and 2017. The fishery abundance index has been trending down since 2007. The IPHC GOA sablefish index was not used in the model, but was similar to the 2015 and 2016 estimates in 2017, about 50% below average abundance. The 2008 year class showed potential to be large in previous assessments based on patterns in the AFSC survey age and length compositions; this year class is now estimated to be about average. The 2014 year class appears to be very strong, but year classes have sometimes failed to materialize later and the estimate of this year class is still uncertain and has declined by 30% since the 2017 assessment. Because of the estimated size of the 2014 year class, spawning biomass is projected to climb rapidly through 2022, and then is expected to rapidly decrease assuming a return to average recruitment in the future. Maximum permissible ABCs are projected to rapidly increase while authors' recommended lower ABCs will still increase quickly to 20,144 t in 2020 and 40,000 t in 2021.

Projected 2019 spawning biomass is 33% of unfished spawning biomass. Spawning biomass had increased from a low of 28% of unfished biomass in 2002 to 34% in 2008 and has declined again to about 26% of unfished in 2018 but is projected to increase in 2019. The last two above-average year classes, 2000 and 2008, each comprise 8% and 11% of the projected 2019 spawning biomass, respectively. These two year classes are fully mature in 2019. The very large estimated year class for 2014 is expected to comprise about 10% of the 2019 spawning biomass, despite being less than 20% mature.

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Coastwide research discussions for sablefish – ABL
Sablefish stock assessments are conducted independently for the US 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. Since all areas show similar downward trends in estimated biomass, there is need for a more synthetic understanding of sablefish demography and dynamics. In late April 2018, scientists from DFO, NWFSC, Alaska Department of Fish and Wildlife and AFSC met to discuss ongoing sablefish research, sablefish assessment models, and opportunities for collaboration. This meeting's discussions are captured in a technical memorandum (https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-387.pdf), which details a work plan for the group. A PhD student at the University of Washington and a Post-Doc researcher affiliated with DFO are now on board and working on coastwide growth and movement analyses. Maturity data across management regions are also being synthesized and reviewed for utility. It is hoped that this collaborative project will help form a more complete picture of the population dynamics of sablefish at a coastwide scale. Further analyses on coastwide abundance trends via simulation studies or enhanced assessment methods are in the works. This is a collaborative project and all regions are welcome to contribute. We hope this project will help foster communication and collaboration across management areas.

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J. 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.

K. Atka Mackerel

1. Research

Small-scale abundance and movement of Atka mackerel and other Steller sea lion groundfish prey in the Western Aleutian Islands--NPRB project 1305. GAP
This project assessed the small-scale abundance, local exploitation rate, and essential habitat of Atka mackerel, the dominant prey of the endangered Western Steller sea lion stock. In addition, we describe species composition, relative abundance, and the environmental parameters influencing distribution patterns of other Steller sea lion prey species on a local scale relevant to Steller sea lions. Our study areas were at Seguam pass in the Eastern Aleutian Islands and all fished population centers in the Western Aleutian Islands, divided into two main regions: the 543

Nearshore region and the 543 Seamount region. Atka mackerel population sizes estimates from the tagging study were approximately 610,000 metric tons (mt) at Seguam Pass, 312,000 mt in the Western Aleutian 543 Nearshore region and 306,000 mt in the Western Aleutian 543 Seamount region. Exploitation rates in all three areas ranged from 9.8 % at Seguam Pass. 3% in the Nearshore region and 1% in the Seamount region, all below the projected fishing mortality in the Atka mackerel stock assessment. There did not seem to be evidence of localized depletion, however several study sites within the regions experienced higher fishing efforts such as Seguam Pass in the Eastern Aleutian Islands, Ingenstrem rock and Buldir West in the Western Aleutian Nearshore region, and Heck Canyon in the Western Aleutian 543 Seamount region.

In addition, we examined environmental, biological, and management factors and their influence on CPUE for five Steller sea lion prey species (Atka mackerel, northern rockfish, Pacific cod, walleye pollock) using a redundancy analysis. We examined CPUE of Atka mackerel, northern rockfish and invertebrates inside vs. outside the Trawl Exclusion zones (TEZs) and found no significant difference for Atka mackerel and northern rockfish; however, invertebrate densities were significantly higher inside the TEZs. Atka mackerel CPUE decreased from the eastern most study site (Seguam Island) to the west study sites, near Agattu and Ingenstrem, where SSL non-pup and pup counts are still in decline with tidal and bottom current being the most influential. Conversely, northern rockfish showed a steady increase from east to west with the highest CPUE occurring in the west study sites and no environmental variables were correlated with northern rockfish CPUE distributions.

We examined the spatial distribution of the ocean environment as well as Atka mackerel's biological properties on a local scale (10s of nm) such as length distribution, food habits, and reproductive maturity. Water column properties such as temperature and salinity were similar in all areas except the Agattu and Ingenstrem Rock in the Western Aleutian 543 Nearshore region, which exhibited markedly lower temperatures, salinity, and the largest seasonal temperature fluctuations, identifying them as distinct water masses. Atka mackerel decreased by size and weigh from east to west, with the largest fish at Seguam pass and the smallest fish in the Western Aleutian 543 Seamount area. Seguam Pass showed a large influx of young fish in October 2014, which was not observed in the Western Aleutian regions. Atka mackerel males in spawning color were mostly observed at Agattu in the Western Aleutians Island 543 Nearshore region. Length and age at maturity showed that fish matured at slightly larger size at Seguam (50% maturity 35.7cm) than in the Western Aleutian 543 Nearshore region and 543 Seamount region (50% maturity at 33.4 and 32.7cm, respectively). In the Western Aleutian region Atka mackerel exhibited greater stomach fullness during the spring, eating mostly euphausiids and copepods. At Seguam there was no seasonal difference in stomach fullness with euphausiids comprising the largest part of their diet. In all areas the diet in the fall was more diverse and included Atka mackerel eggs as a major component for larger fish.

Lastly, we described the habitat type and species composition in areas close to Steller sea lion rookeries, which are located in untrawlable grounds with towed stereo cameras. We conducted 63 transects and identified and quantified fish species and associated habitat. The preferred Steller sea lion prey species Atka mackerel, Irish lords and greenling were highly associated with rocky bottom, whereas rockfish and Pacific cod occurred on rocky bottom and gravel, whereas flatfish and sculpins were mostly associated with unconsolidated substrate.

In conclusion, we found the highest density and biomass of Atka mackerel, with the largest fish in best body condition at Seguam pass study site, with decreasing density, biomass estimates, and fish size in the Western area. In addition, Atka mackerel comprised a larger part of the total species composition at Seguam pass, with rockfish steadily increasing from east to West and comprising almost half of the species composition in the 543Seamount region. Steller sea lion rookeries at Seguam pass are located close the study sites, whereas in the Western Aleutian Islands only Buldir and Agattu are close to Steller sea lion rookeries with most of the Atka mackerel aggregations a greater distance apart. This might indicate the Seguam pass is an ideal area for Steller sea lion foraging success for Atka mackerel whereas the Western Aleutian Island areas are further away from the rookery, have smaller biomass and higher diversity of other less favorable prey for Steller sea lion. See the report and data at:

http://projects.nprb.org/#metadata/48a5836c-4c2d-442b-a5c0-68e2cb7e1f71/project
For more information, contact Susanne McDermott at (206) 526-4417 or Susanne.mcdermott@noaa.gov

Results of the 2016 and 2017 Central and Western Aleutian Islands Underwater Camera Survey of Steller Sea Lion Prey Fields-GAP

Recent satellite tagging efforts indicate that foraging areas of endangered adult female Steller sea lions (SSL) in the central and western Aleutian Islands include shallow, nearshore regions. However, prey availability in these regions remains poorly understood because traditional bottom trawl surveys either cannot sample or lack precision on the rocky, nearshore habitats where sea lions haul out. We attempted to overcome these sampling challenges by opportunistically deploying a towed underwater stereo camera system near SSL rookeries and haulouts during the NOAA AFSC Marine Mammal Laboratory ship-based population survey of SSL in 2016 and 2017. A total of 63 15-minute transects were conducted in depths ranging from 20-100 m. Fish and associated habitat were identified, quantified, and measured along transects. While stereo image quality did not always allow for identification of all fish to the species level, it did allow for identification of many prey species (i.e. Atka mackerel (Pleurogrammus monopterygius), Pacific cod (Gadus macrocephalus)) and species groups (i.e. rockfish, flatfish, and sculpins) that are consumed by SSL during the summer. Camera transects encompassed substrates ranging from sand to high-relief boulder fields, and greater fish abundance was associated with rockier terrain. Substrates and associated fish abundances varied widely over small (10-100 m) spatial scales, suggesting that nearshore survey activities should be structured to account for extreme spatial variability. The relatively low cost of our camera system, combined with its ability to be deployed quickly during available vessel time, make it a promising tool for future fish surveys of nearshore and untrawlable habitat.

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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 2018 included catch through 2018 (2018 projected), 2017 fishery age compositions, and 2018 AI survey biomass estimates.

Spawning biomass reached an all-time high in 2005, then decreased almost continuously through 2018 (the estimated spawning biomass in 2019 is projected to be roughly 37% of what it was in 2005). It is projected to decrease further, at least through 2020. Total biomass follows the same decreasing trend. The 1998-2001 year classes were all very strong, and the 2006 and 2007 year classes 56% and 33% above average. The projected female spawning biomass for 2019 (106,800 t) is projected to be below B40% (113,510 t), and the stock is projected to remain below B40% through 2023.

The projected 2019 maxABC at F40% = 0.44 is 68,500 t, down 26% from the 2018 ABC and down 19% from last year's projected ABC for 2019. The projected 2019 OFL at F35% = 0.53 is 79,200 t, down 27% from the 2018 OFL and down 19% from last year's projected OFL for 2019. A risk matrix was completed for this stock, with Level 1 ratings for all three categories, so no adjustment to maxABC was proposed. The four-survey weighted averaging method was used to apportion ABC among areas: 23,970 t for Area 541 and the Bering Sea region (a 35% decrease from 2018), 14,390 t for Area 542 (a 55% decrease from 2018), and 30,140 t for Area 543 (a 30% increase from 2018).

The ecosystem considerations section of the assessment chapter was updated with the 2018 survey information. Temperature anomaly profiles from the 2018 AI survey data show that the water temperature continues to be warm at depth. Temperature may affect recruitment of Atka mackerel and availability to the bottom trawl survey. It is possible that the reduced recruitment since 2007 is due to changing environmental factors such as water temperature, which is known to affect Atka mackerel eggs, larvae, and hatching times, and could possibly have an impact on productivity and food supply for larval Atka mackerel. However, this has not yet been evaluated fully. The large drop in the Central area survey biomass was inconsistent with Atka mackerel biomass changes in the other AI areas (Eastern and Western Aleutians), and reported fishing conditions in the region. The lack of any moderate to large catches of Atka mackerel by the survey in only one area may have been due to a combination of environmental factors that could have affected catchability, Atka mackerel availability, and fish movement and behavior.

Atka mackerel is the most common prey item of the endangered western Steller sea lion throughout the year in the AI. Steller sea lion (SSL) surveys indicate slight population increases, except in the western Aleutians (area 543). Regulations implemented in 2015 significantly adjusted SSL management measures that were in place from 2011-2014 and re-opened area 543 to directed fishing for Atka mackerel, removed the TAC reduction in area 542, and re-opened areas in 541 and 542 that had been closed to directed Atka mackerel fishing.

Gulf of Alaska (REFM)
No assessment was conducted for Atka mackerel this year, but a full stock assessment will be conducted in 2019. Until then, the values generated from the previous stock assessment will be rolled over for 2019 specifications. 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.

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L. Flatfish

1. Research

Spatial variation in juvenile flatfish growth and condition in relation to thermal phases in the Bering Sea shelf--GAP

Research continues in characterizing and assessing the productivity of the habitats of yellowfin sole (*Limanda aspera*; YFS) and northern rock sole (*Lepidopsetta polyxystra*; NRS) in the Bering Sea. Field sampling has been conducted intermittently since 2011 as special projects of the eastern Bering Sea (EBS) annual bottom trawl survey, and on the northern Bering Sea (NBS) bottom trawl survey in 2017. The present focus is on characterizing the spatial variation in juvenile abundance, growth and condition, and relating the variability to multi-year warm-cold thermal stanzas and the long-term trend in ocean warming.

Recent studies suggest that the latitudinal shift in the distribution of NRS juveniles was linked to thermal stanzas: in “warm” years, high densities of NRS juveniles have been observed around Nunivak Island (“north” habitat), whereas in “cold” years distribution was concentrated in the south in the Bristol Bay area (“south” habitat). The north and south habitats both had high prey abundance and similarly high summer bottom temperature during the present warm thermal stanza, which began around late 2013. Juvenile NRS appeared to grow faster in the south than in the north. This difference may be attributed to higher prey quality in the south, and more favorable thermal environment in the winter months for growth (Yeung and Yang, 2018). Thus, a northward shift in juvenile flatfish habitat may impact productivity.

The EBS experienced record high bottom water temperatures in 2016, during which the cold pool of $<2^{O}C$ bottom temperature almost entirely disappeared. The cold pool returned in 2017, but diminished drastically again in 2018. Results from the 2016 bottom-trawl survey indicate that the catches of juvenile YFS and NRS in 2016 were the highest in the past decade and remained high in 2017-18, supporting that there was strong juvenile recruitment during the warm stanza. The distribution of juvenile NRS also shifted north and their area of presence became wider during the warm stanza compared to the preceding cold stanza.

Juvenile (mostly age 1-4) samples have been collected since 2016 for diet and otolith analysis. Sample collection for analysis of lipids, fatty acids, and biomarkers as condition indicators began in 2017. Juveniles were collected with a beam trawl at between 12 to 21 standard bottom trawl survey stations in each year. The selected stations spanned the inner-shelf nearshore where juveniles were likely to be present based on past surveys. Benthic samples were also collected at about half of the beam trawl stations to assess prey dynamics.

The age 1-4 fish collected in 2018 would represent cohorts born during the present warm stanza, whereas the age 3-4 fish from 2016 and 2017 would represent cohorts born during the preceding cold stanza. The spatial patterns of condition, diet and growth of juveniles are being analyzed in conjunction with the prey community over the years for insights into the impacts of major changes in the thermal environment.

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

Yeung, C., Yang, M.S., 2018. Spatial variation in habitat quality for juvenile flatfish in the southeastern Bering Sea and its implications for productivity in a warming ecosystem. Journal of Sea Research 139:62-72.

Greenland turbot archival tag analysis - ABL

Greenland turbot were opportunistically implanted with Lotek archival tags on the AFSC sablefish longline survey from 2003–2012 in order to assess their vertical movement and temperatures experienced in the Bering Sea. Archival tag data were recovered from 18 Greenland turbot, spanning 19–1,859 days at liberty, with mean depths and temperatures for individual fish ranging from 448–753 m and 3.2–3.7 °C, respectively. Periodic movements were identified using a continuous wavelet analysis, and significant diel vertical migration occurred between 0–53% of time at liberty. Seasonal movement towards deeper water in the winter and shallower water in the summer was evident for fish that were at liberty for one or more years (n=13), and these annual movements were consistent over multiple years for fish that were at liberty two or more years (n=5). Sex-specific movements were identified during the putative spawning period (November–March). During this time, depth profiles of males indicate a regular vertical movement pattern with a 6–12 hour periodicity, covering hundreds of meters, and persisting for many weeks, whereas depth profiles of females indicate one prominent spawning rise from deeper water (~500–900 m), to below the mixed layer (~225-m depth), and returning to depth over a period of 1–2 hours (Figure 1). Some female Greenland turbot were found to occupy shallow depths (<200-m) accompanied with cool temperatures (<2°C), indicating use of the Bering Sea cold pool: one fish for three consecutive summers (2003, 2004, and 2005), one fish for two consecutive summers (2005, 2006), and another during the winter of 2011/2012. A manuscript analyzing these tags is in preparation.

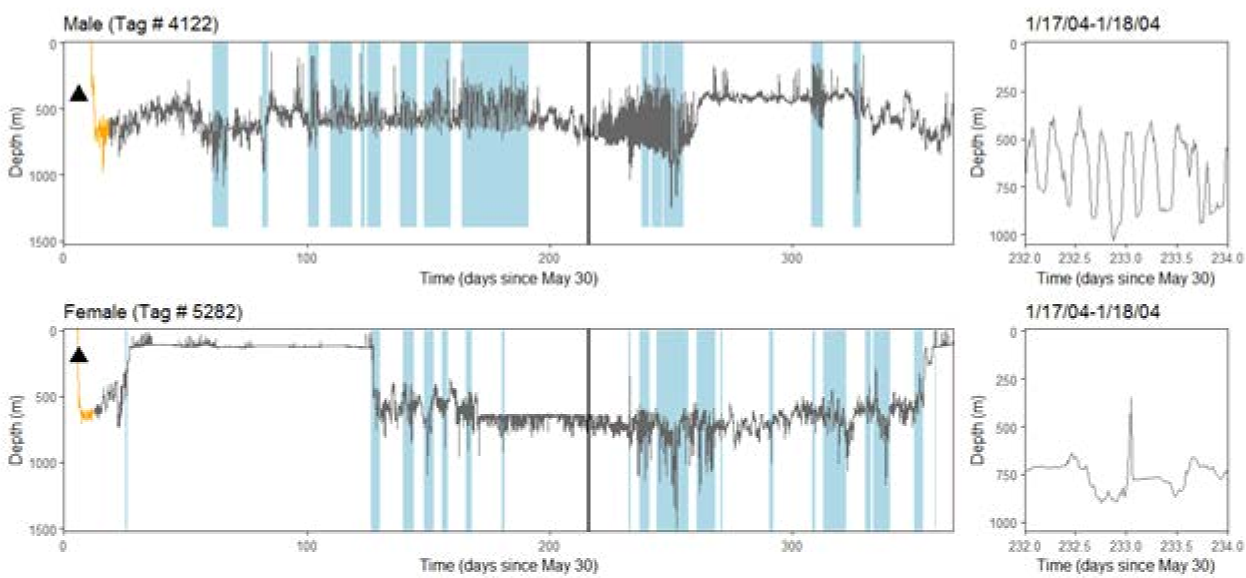

Figure 1. Example depth profiles of two Greenland turbot during the first year after release. The top panel is a male and bottom is a female. The x-axis is zeroed to 30 May 2003, approximately the date of release of both fish, and the y-axis is reversed so the surface of the water is at the top. The orange line shows an acclimation period of seven days post release that was removed before analysis. The solid black triangle indicates the depth of capture, light blue bars designate significant diel vertical migration, and the solid vertical black line demarks the start of 2004. Panels on the right are zoomed in for two days in January of 2004, a period of putative spawning behavior; the male is exhibiting a regular movement pattern and the female exhibits an isolated spawning rise.

This female utilizes the continental shelf each summer, during which time there is relatively little vertical movement.

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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. New data for 2018 include age data through 2017 and survey and catch data through 2018.

The assessment updates last year's with results and management quantities that are lower than the 2017 assessment primarily due to (1) the 2018 survey biomass point estimate is 32% lower than the 2017 estimate and (2) the assessment model estimated a slightly lower survey catchability. The projected female spawning biomass estimate for 2019 is 850,600 t, which is 1.85× BMSY. This is a 5.0% decrease from last year's 2018 estimate (895,600 t). A general slow decline in spawning biomass of approximately 6% per year has prevailed for the most part since 1985. The recommended 2019 ABC is 263,200 t and 2019 OFL is 290,000 t. The annual harvest of yellowfin sole remains below the ABC level.

Greenland turbot - Bering Sea and Aleutian Islands (REFM)
This assessment is conducted using Stock Synthesis. The only change to the base model is that ABL longline survey catchability is now a statistically estimated parameter. Data updates include 2018 NMFS EBS shelf bottom trawl survey and ABL longline survey estimates and size compositions, age data from the 2017 trawl survey, and fishery data though 2018 (including projected values for 2018).

The projected 2019 female spawning biomass is 54,244 t, which is a 7% decrease from last year's 2018 projection of 58,035 t. Female spawning biomass is projected to increase slightly to 52,743 t in 2020. The effects of the incoming 2007-2009 year classes are creating increases in both the female spawning biomass and total biomass estimates. These increases are also due, in part, to the increase in average weight at age with the inclusion of the 2015 length at age data.

The B40% value, using the mean recruitment estimated for the period 1978-2014, is 36,213 t. The projected 2019 female spawning biomass is 54,244 t, which is well above the estimate of B40% (36,213 t). The OFLs for 2019 and 2020 are 11,362 t and 10,476 t, respectively, and the corresponding maximum permissible ABCs are 9,658 t and 8,908 t, respectively. The author recommended setting ABC at the maximum permissible values for 2019 or 2020. Apportionment of ABC between the EBS and the Aleutian Islands was based on the assumption that 8% of the biomass is in the Aleutian Islands.

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Arrowtooth flounder - Bering Sea and Aleutian Islands (REFM)

Arrowtooth flounder are assessed biennially using an age-structured population dynamics model implemented in the software program AD Model Builder. The model used in 2018 was similar to those used in past years, with slight changes to the treatment of the age data and the exclusion of EBS slope survey from 1979-1991 based on concerns about methodology and species identification. New data included abundance and composition from the 2017 & 2018 EBS shelf surveys and the 2018 AI survey, survey age data through 2017, and fishery data through 2018 (with projected catches after October 19).

The projected age 1+ total biomass for 2019 is 892,591 t, an increase from the value of 782,840 t projected for 2019 in last year's assessment. The projected female spawning biomass for 2019 is 482,174 t which is an increase from last year's 2019 estimate of 472,562 t. The point estimates of B40% and F40% from this year's assessment are 242,495 t and 0.131, respectively. The projected 2019 spawning biomass is above B40%, so the authors recommend setting 2019 and 2020 maxABCs at 70,673 t and 71,411 t, respectively, and 2019 and 2020 OFLs at 82,939 t and 83,814 t. Arrowtooth flounder is a lightly exploited stock in the BSAI.

Arrowtooth flounder - Gulf of Alaska (REFM)
The arrowtooth flounder stock in the GOA is assessed biennially and 2018 was an "off year", so only the projection model was run with updated catch data. Based on the projection model results, recommended ABCs for 2019 and 2020 are 145,841 t and 140,865 t, respectively, and the OFLs are 174,598 t and 168,634 t. The new ABC and OFL recommendations for 2019 are similar to the 2017 ABCs and OFL developed using the 2017 full assessment model.

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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. Kamchatka flounder is assessed biennially using an age-structured population dynamics model implemented in the software program AD Model Builder. Structural changes were not made to the model for 2018. New data included abundance and composition from the 2017 & 2018 EBS shelf surveys and the 2018 AI survey, survey age data through 2017, and fishery data through 2018 (with projected catches in 2018).

The projected 2019 female spawning biomass is 54,779 t, above the B40% level of 43,069 t, and spawning biomass is projected to remain above B40% for the foreseeable future. The early shelf survey size composition data suggest that some significant recruitment events (assessed at age 2) occurred prior to 1991. Since 1991, the preferred assessment model estimates that the 2001, 2002, 2008, 2013, and 2014 year classes are all at least 80% above average. Female spawning biomass has been increasing since a drop in 2010 which coincided with the sharp peak of catch that same year. For the 2019 fishery, the recommended 2019 ABC is the maximum permissible value of 9,260 t. This value is a decrease of 5% from the 2018 ABC (9,737 t). The recommended 2019 OFL is 10,965 t, a 3% decrease from 11,347 t in 2018. Kamchatka flounder do not occur in the GOA.

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 modifications were made to the

assessment methodology for 2018. Data updates included survey biomass and composition data through 2018, catch data through 2018 with projected late-year 2018 catch, and age data through 2017.

The 2018 bottom trawl survey point estimate is a 21% decrease from the 2017 estimate. These two estimates are the lowest in the past 25 years and have the effect of lowering the assessment model time series abundance estimates relative to the last full assessment conducted in 2016. The model results indicate that the stock condition has been at a high and stable level but in a slow decline for the past 9 years. The female spawning biomass is now at a peak and is starting to decline as a result of the combination of strong recruitment from the 2001-2003 and 2005 year classes, which are presently at the age of maximum cohort biomass, and light fishery exploitation.The 2019 ABC harvest recommendation is 118,900 t (FABC = 0.144) and the 2019 OFL is 122,000 t (FOFL = 0.147). 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)
In 2018, the BSAI flathead sole assessment was transitioned to the Stock Synthesis modeling platform. Numerous alternative models were explored during this process. Appendix B of the SAFE report has a detailed explanation of the new model structure.

Age 3+ biomass declined by 31% from 1994 through 2015, but has increased by 14% since then. Spawning biomass has declined consistently since 1998 (a 33% decline as of 2018), although spawning biomass is projected to begin increasing in 2020. No year class has been more than 60% above average since the 1987 cohort, but the 2002, 2011, and 2014 year classes are all at least 40% above average. Current reference point values are B40%=84,824 t, F40%=0.38, and F35%=0.47. Because projected spawning biomass for 2019 (153,203 t) is above B40%, the authors and Team recommend setting ABCs for 2019 and 2020 at the maximum permissible values, which are 66,625 t and 68,448 t, respectively. The 2019 and 2020 OFLs are 80,918 t and 83,190 t, respectively.

Flathead sole - Gulf of Alaska (REFM)
This assessment is conducted using Stock Synthesis on a four-year schedule.This year 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 36,782 t from the updated projection. The FOFL is set at F35% (0.36) which corresponds to an OFL of 44,865 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. For 2018 a partial assessment was

presented because it was a scheduled “off-year”. Therefore, only the projection model was run, with updated catches.

Last year’s 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 current estimates are B40% = 126,900 t, F40% = 0.124, and F35% = 0.149. Given that the projected 2019 spawning biomass of 186,100 t exceeds B40%, the recommendations for 2019 are an ABC of 33,600 t and an OFL of 39,880 t.

Rex sole - Gulf of Alaska (REFM)
This stock is on a four-year assessment cycle and a full assessment is due in 2019. This year 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 14,692 t and an OFL of 17,889 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 2019. Harvest recommendations are made using Tier 5 methods (OFL = F * biomass, where F=M; ABC = 0.75 * OFL). 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 2019 OFL and ABC are 21,824 t and 16,368 t respectively.

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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. Last year, 2017, was the first year of the new schedule and a full assessment was completed. This year a partial assessment was done, and the projection model for northern and southern rock sole was re-run and updated with 2017 catch and catch estimates for 2018 and 2019.

The complex total 2019 biomass estimate was 343,755 t, which is a slight (1.4%) increase from the 2018 value of 339,152 t. This slight increase is due to updated biomass for northern and southern rock sole from the projection model. Overall, biomass for shallow water flatfish is stable. The resultant 2019 OFL and ABC are 68,309 t and 55,587 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 2018 only a partial 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 2019 OFL is 11,434 and 2019 ABC is 9,501 t; these are slight increases from the previous year's recommendation.

M. Pacific halibut

1. Research

Halibut bycatch management in the North Pacific: A prospective model of fleet behavior
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
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

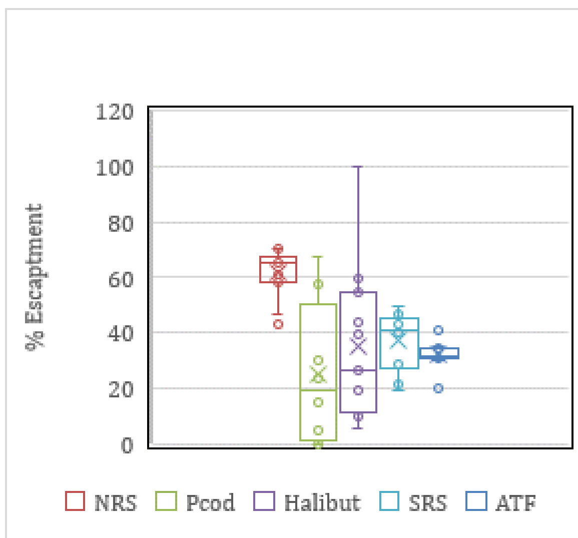
moving product to the increasingly fresh market for halibut. Based on findings from the review and subsequent discussion, the Council proposed that its IFQ Committee consider several specific issues with respect to the IFQ Program.

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.

N. 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).

At-Sea Experiments to Estimate Footrope Escapement for Rock Soles
During the past five years, we have conducted catch efficiency studies for the PNE bottom trawls used for the Gulf of Alaska and Aleutian Islands Bottom Trawl Survey. We are focused on empirically estimating survey catch ability for northern and southern rock soles (*Lepidopsetta polyxtra* and *L. bilineata*, respectively). Successful studies, supported with National Cooperative Research Program (NCRP) funds (FYs 2015 and 2018), led to the design, construction, and calibration of an auxiliary net fitted underneath the PNE intended to capture fish that escape under the footrope of the PNE. We used NCRP funds in 2018 to tune the new "underbag" design to critical survey net configurations and collect footrope escapement data during 12 successful trials. Preliminary results indicate a marked difference in escapement between southern and northern rock soles: 38% of southern rock sole escaped under the footrope while 58% of northern rock sole escaped (Figure 1). Selectivity functions are estimable based on these data, but with poor confidence. More data are needed to increase confidence about these results and to estimate effects of depth and habitat on the catch efficiency.



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

Joint Program Agreement with the Korean National Institute of Fisheries Bottom Trawl Survey Group

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 2018, Peter Munro traveled to South Korea to execute a study on footrope and bridle contact with the sea floor. During the summer, Dr. Jeong Jae Mook traveled to Alaska's Aleutian Islands to participate in the 2018 Bottom Trawl Survey. AFSC's Jason Conner traveled to the NIFS laboratory to design 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) project of the NMFS Alaska Fisheries Science Center (AFSC) (Noelle 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 2018, CE research focused on projects concerning salmon bycatch (primarily chum, Oncorhynchus keta, and Chinook, O. tshawytscha) in the Bering Sea walleye pollock ("pollock", Gadus chalcogrammus) trawl fishery. Because Chinook salmon are considered a prohibited species for the pollock fishery, allowable bycatch is restricted (Fissel et al. 2016). To avoid exceeding the bycatch limit, since 2003, members of the fishing and conservation engineering communities have worked to develop and improve upon bycatch reduction devices that permit salmon to escape out of the trawl after capture and before entering the codend (an 'excluder'; Gauvin, 2016; Gauvin et al., 2015, 2013, 2011; Gauvin and Gruver, 2008; Gauvin and Paine, 2004). Some fishermen have added artificial light around the escapement portal with the expectation that it attracts or guides salmon towards the exit. Increased escapement rates of Chinook salmon in the Pacific hake (Merluccius productus) midwater trawl fishery have been reported with the use of blue lights near the escapement portal (Lomeli and Wakefield 2012, 2014a, 2014b, 2016), and Bering Sea pollock industry representatives report that salmon escapement seems to increase with bright white artificial lights. Through the evolution of the salmon excluder in the pelagic pollock trawl net, salmon escapement has been variable among tows, trials, vessels, and fisheries (Gauvin et al. 2013, 2015). Research is ongoing to improve the salmon excluder design. Similarly, while results have been inconsistent with respect to the efficacy of utilizing artificial light to attract or guide salmon to an escape portal, lights continue to be used in this fishery with the goal of increasing escapement. To contribute to this on-going research, in 2018 CE conducted projects (1) to determine the visual range of Chinook salmon in their ocean residency; (2) to evaluate salmon behavior in response to artificial lights; and (3) to collaborate on an industry driven project evaluating salmon behavior around excluders. Additional projects included organizing an industry workshop focused on innovation in Alaska trawl fisheries, and determining optimal ways to record fish with cameras using artificial light that is not observed by the fish species of interest.

Salmon Vision

In March 2018, during a MACE survey aboard the NOAA Ship *Oscar Dyson* in Shelikof Strait (central Gulf of Alaska), AFSC scientists Lyle Britt and Rebecca Haehn collected the retinae from trawl caught Chinook salmon and pollock to determine the visual pigments of the photoreceptors. With these data we aim to explain what color these fish can see to inform both what lights can be tested to affect salmon behavior and what lights can be used to illuminate a camera's field of view without being detected by the salmon. The data from this cruise are still being analyzed.

Salmon Response to Artificial Light

CE conducted a laboratory study at the NWFSC Manchester Research Station, in collaboration with scientists at that location (Barry Berejikian, Jeff Atkins, and Brad Gadberry) and those at AFSC (Lyle Britt, Rebecca Haehn, Rick Towler, and Paul Irvin), to evaluate if artificial light can be used to attract Chinook salmon, and whether the behavior is dependent upon light intensity, color, or flicker rate.

In June 2017, 258 age-0 Chinook salmon were transported to the NOAA Northwest Fisheries Science Center Manchester Research Station (Manchester, WA) as smolts, and transitioned into seawater within a month of transfer. In April 2018, these fish were put into a holding tank that was covered with a 6 m x 6 m x 3 m black, vinyl tent, that was fabricated using heat sealing methods to prevent light seepage through seems. Three identical tanks (one additional tank for holding, two for trials) were set up. In the trial tanks, four eight-channel PAR RGBW DMX lights were hung with the center of the LED array 0.4 m from the tank bottom, flush against the tank wall and facing into the tanks, secured with weight on the bottom of the tank and the electrical cords tethered along the tank edge. The lights were placed such that each marked the center of four equally sized quadrants. The water inflow pipe was located along a shared boundary of two of the quadrants, and each subsequent light spaced equidistantly around the tank’s 15.7 m perimeter (3.93 m apart).

In May 2018, 24 trials were completed each in the two trial tanks, with five fish per trial. Four trials were conducted for three experiments: light intensity (for white light), light color (non-strobing), and light color (strobing). Each trial was completed twice, once in the morning and once in the afternoon. The trials and acclimation periods were recorded by camera. The video footage is currently being analyzed using animal behaviour software.

Collaboration on Industry-Led Excluder Research

In August 2017, John Gauvin (North Pacific Fisheries Research Foundation, NPFRF) 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 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 design modifications will focus on the location of the escapement portal, the design of the ramp to the portal, the number of portals, and the design of the trawl section around the excluder section. The project is a collaborative effort with John Gruver of United Catcher Boats Association, Ed Richardson of At-Sea Processors Association, the Amendment 80 fleet, other members of the pollock fishery, and the AFSC CE project. During several workshops in 2017, project collaborators came together to discuss salmon excluders that have been and are being used, and new, innovative ideas for modifying salmon excluders. Models of the new designs and those successfully being used were taken to a flume tank at the Marine Institute in St. John's, Newfoundland (November 2017). Together, fishermen, net makers, industry representatives, the CE lead, and collaborators on this project observed the model excluders in the flume tank and worked together to improve the designs. Based on what was learned at the flume tank, three of the most promising excluder designs were tested during commercial operations in winter 2018. After reviewing the video footage collected during these trials, adjustments were made and a different set of excluder designs were tested in winter 2019. Review of the 2019 research is underway and a final set of excluder designs will be selected for testing in 2020.

As a collaborator, CE has supported this research by being involved in the initial workshops for this project to discuss excluder designs and attending the flume tank workshop in November 2017, 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 2018 CE organized, with the help of a steering committee, the second Fisheries Innovation for Sustainable Harvest (F.I.S.H.) Workshop from three NOAA Alaska Fisheries Science Center (AFSC) locations (Newport, OR; Seattle, WA; Kodiak, AK), connected through video. The goal of these workshops is to provide an opportunity for fishermen and those working in the fishing industry to get together and learn about and provide feedback on current research and innovation related to North Pacific trawl fishing, to learn about tools that support gear innovation, and to workshop on common problems. This year, the workshop included an opportunity for industry participants to provide feedback on Alaska Pacific University (FAST Lab) graduate students' master's research. The workshop also included an evaluation of and discussion about underwater cameras used in trawl gear, featuring: a 'field guide' to using cameras in the trawl net, presentations by six camera companies, and a panel discussion focusing on obstacles to using underwater cameras and ways to increase the usefulness of cameras for fishermen. Feedback from the over 100 participants suggests that this event was successful in providing useful and interesting information to the attendees. 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.

Technology to Observe Fish Behavior

Through technological advancements in the salmon behavior study (described above), CE continued its work on the research and development of underwater imaging specific to bycatch mitigation in commercial fishing gear. Specifically, CE worked to develop technology to observe fish behavior in a trawl net without the use of visible camera lights. For the salmon behavior study, rather than using traditional cameras that illuminate the field of view with white light, we imaged with low light cameras using deep red light. The field of view was much broader and the image clearer than previous trials using near infrared. From these results (and preliminary results of the salmon vision study), we are working with a camera company to make ruggedized, underwater cameras that contain deep red LED lights. Further trials will take place in 2019.

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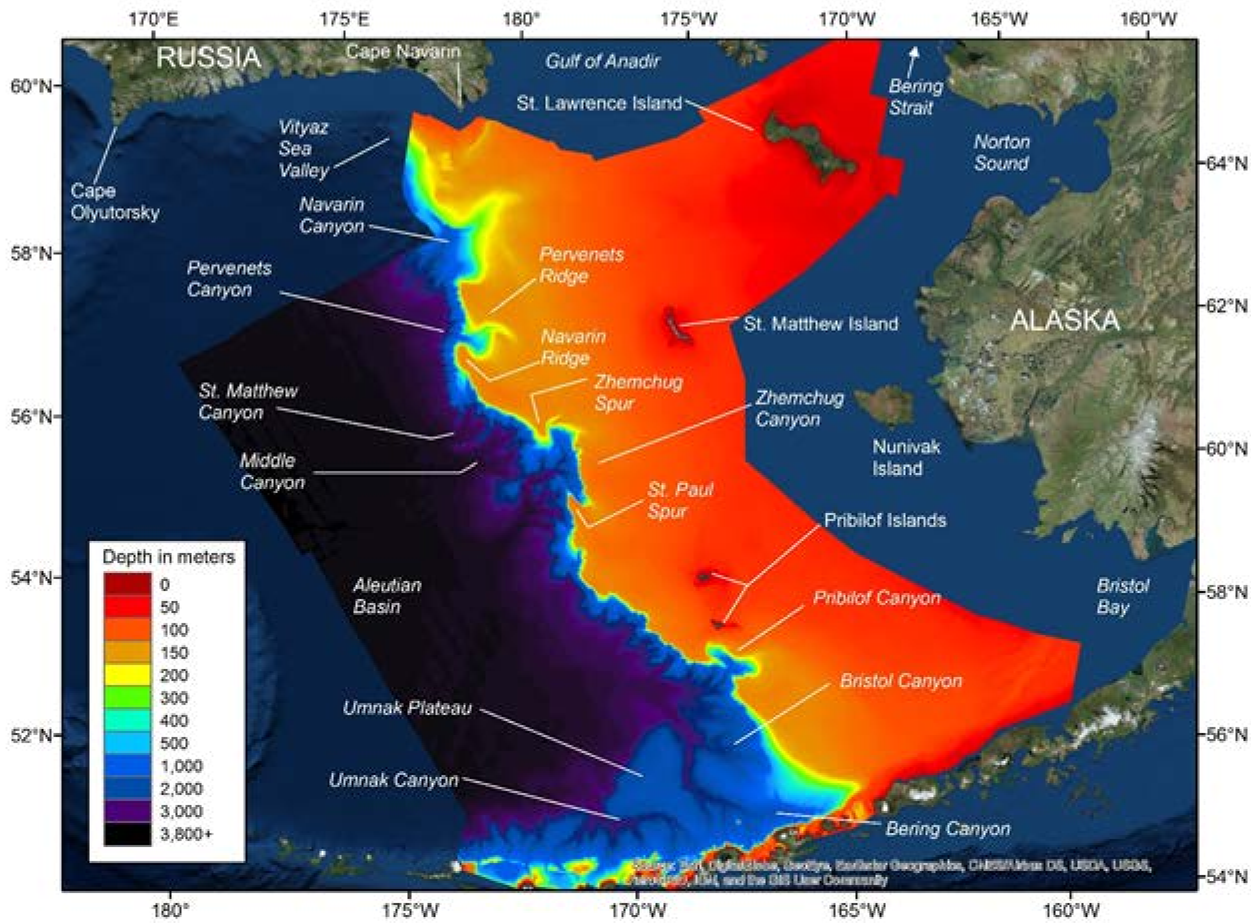
Bathymetry and Canyons of the Eastern Bering Sea Slope - RACE GAP

We created a new, 100 m horizontal resolution bathymetry raster (see below) and used it to define 29 canyons of the eastern Bering Sea (EBS) slope area off of Alaska, USA. To create this bathymetry surface we proofed, edited and digitized 18 million soundings from over 200 individual sources. We clearly defined the number and location of the area's canyons and provided the canyon centerlines, or thalwegs, as a derived product from our analysis. The legendary Zhemchug Canyon pinnacles were disproved – they were probably just schools of fish mistaken for the seafloor. We submitted 45 place name corrections, and new places names, for consideration to international, national and local seafloor naming authorities.



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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.

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The effect of random and density-dependent variation in sampling efficiency on variance of abundance estimates from fishery surveys.
Authors: Stan Kotwicki, Kotaro Ono

Abundance indices (AIs) provide information on population abundance and trends over time, while AI variance (AIV) provides information on reliability or quality of the AI. AIV is an important output from surveys and is commonly used in formal assessments of survey quality, in survey comparison studies, and in stock assessments. However, uncertainty in AIV estimates is poorly understood and studies on the precision and bias in survey AIV estimates are lacking. Typically, AIV estimates are "design-based" and are derived from sampling theory under some aspect of randomized samples. Inference on population density in these cases can be confounded by unaccounted for process errors such as those due to variable sampling efficiency (q). Here, we simulated fish distribution and surveys to assess the effect of q and variance in q on design-based estimates of AIV. Simulation results show that the bias and precision of AIV depends on the mean q and variance in q. We conclude that to fully evaluate the reliability of AI, both observation error and variability in q must be accounted for when estimating AIV. A decrease in mean q and an increase in the variance in q results in increased bias and decreased precision in survey AIV estimates. These effects are likely small in surveys with mean $q \geq 1$. However, for surveys where $q \leq 0.5$, these effects can be large. Regardless of the survey type, AIV estimates can be improved with knowledge of q and variance in q.

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

Principal Investigators: 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)

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.

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 collected on the back deck. 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 application is now used on all groundfish surveys.

Last summer, a specimen collection app was tested on one of the groundfish surveys. This application will be deployed on all groundfish surveys in the summer of 2017. A prototype catch weight recording application is scheduled to be tested in the summer of 2017. Future plans include establishing two-way communication between the tablets and a wheelhouse database computer, so all collected biological data can be fully integrated into a centralized database. This effort aims to allow us to collect more, and more accurate, biological data, in a more efficient way.

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Systematics Program - RACE GAP
Several projects on the systematics of fishes of the North Pacific have been completed or were underway during 2018. 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 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); and a partial revision of the agonid genus *Pallasina* (Stevenson, Orr). Work on the molecular phylogenetics and selected morphology of snailfishes (Orr, Spies, Stevenson, with NWFSC, Kyoto University, and UW, in press) was completed, as well as a study of the developmental osteology of the bathymasterid *Ronquilus jordani* (Hilton, Stevenson, and Matarese, 2018). Documentation of new records of skates in Alaska and British Columbia were completed (Orr, Stevenson, Spies, Hoff, and Royal BC Museum, in press) and the record of a species not previously recorded in the eastern North Pacific was published (Orr et al., 2018).

In addition to taxonomic revisions, descriptions of new taxa, and guides, the description and naming of a new snailfish, masquerading under the name of *Careproctus melanurus* in Alaska is underway (Orr, Stevenson, Spies, and UW). Descriptions of other new species of snailfishes, based on morphology and genetics, from Alaska, Canada, and the Arctic continues.

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, to be undertaken with NPRB support (Hoff, Stevenson, Spies, and Orr). Orr and Stevenson, with Spies, will also be examining the population genetics of Alaska's flatfishes using the same NextGen sequencing techniques. Orr, in collaboration with the UW, UCLA, and UWA, will be exploring the use of genomics in the population dynamics and ageing of rockfishes. Stevenson is also collaborating with Spies and other AFSC and UW authors on a genetic analysis of northward range expansion in Pacific cod (Spies et al., In prep), and will be collaborating with Spies on a total genomic analysis of walleye pollock. Molecular and morphological studies on *Bathyraja interrupta* (Stevenson, Orr, Hoff, and Spies), *Bathyraja spinosissima* and *B. microtrachys* (Orr, Hanke, Stevenson, Hoff, and Spies), *Lycodes* (Stevenson and Paquin), and snailfishes (Orr, Stevenson, 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 book of the fishes of the Salish Sea (Pietsch and Orr) to be published in June, and the biology of freshwater flatfishes (Orr, in press). Stevenson recently completed several studies documenting: the reliability of species identifications in the North Pacific Observer Program (Stevenson, 2018); changing fish distributions in the northern

Bering Sea (Stevenson and Lauth, 2018); and fishery interactions with skate nursery areas in the Bering Sea (Stevenson et al., 2018). Stevenson and Orr recently concluded a collaboration with Chris Rooper and others to develop a predictive model for skate nursery habitat in the eastern Bering Sea (Rooper et al., In press), and Stevenson recently initiated a collaboration with UW graduate student Kayla Hall on the early development of skate embryos.

Orr and Stevenson have also conducted work with invertebrates. On-deck guides have now been fully synchronized with the nomenclature of our 2016 *Checklist of the Marine Macroinvertebrates of Alaska*. In addition, collections are now being made to evaluate the population- and species-level genetic variation among populations of the soft coral *Gersemia* (Orr and Stevenson, with NWFSC).

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 baseline or 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. Where possible this would include a decision table to convey the performance and uncertainty between different modeled relationships. The final stage of the ESP process is to produce a long- and short-form standard report to effectively and efficiently communicate the results of the ESP process to a wide variety of user groups (Shotwell et al., *In Review*).

An update on the ESP process and products was recently submitted to the North Pacific Fishery Management Council (NPFMC) at the joint Groundfish Plan Team. This report summarizes responses to recent Scientific and Statistical Committee (SSC) or Plan Team comments regarding the ESPs and includes summaries on several new developments regarding manuscripts, workshops, and web pages aimed at defining and improving the ESP framework. Three manuscripts detail the four-step ESP baseline process with associated products and describe avenues for using integrated ecosystem research to enhance ESPs for high priority stocks. Additionally, three annual workshops are planned, starting in 2019, to fine-tune the national baseline ESP framework to a more regional version that addresses the needs of the AFSC. Finally, two web applications are in development to 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, these new developments 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.

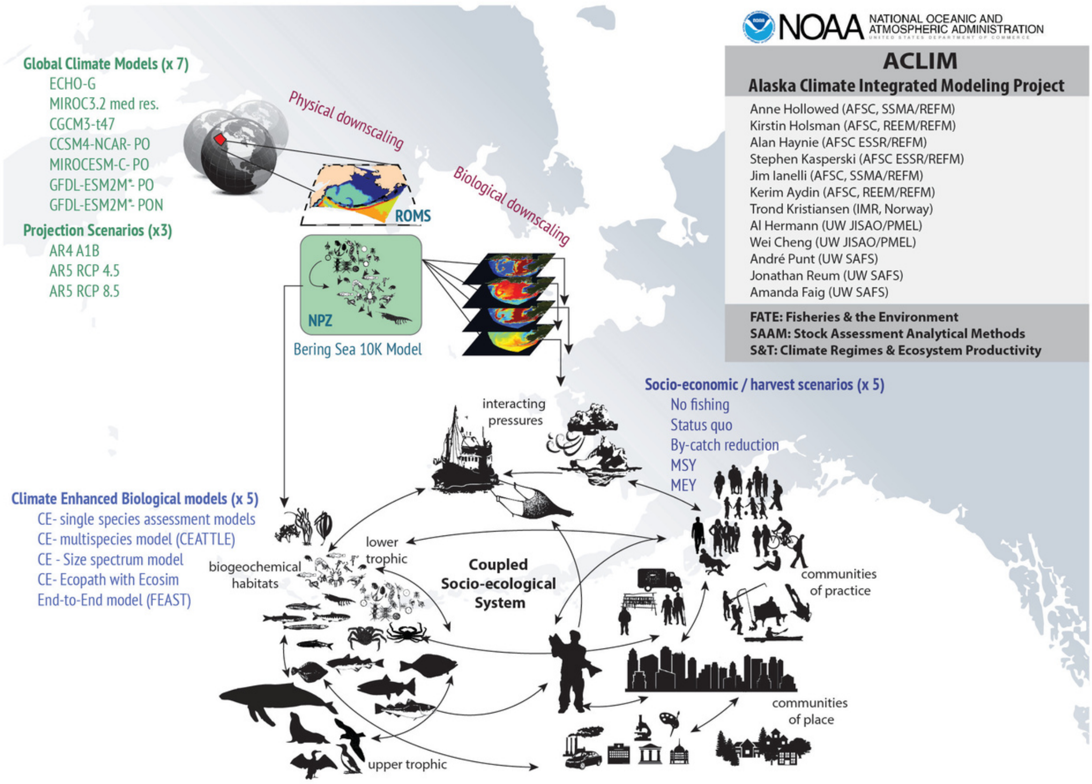
Please refer to the following reports for more details:

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.

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.



Gulf of Alaska Integrated Ecosystem Research Program

Scientists from the AFSC played an important role in the Gulf of Alaska Integrated Ecosystem Research Program (GOAIERP), which concluded in fall 2018. More than 50 scientists from 11 institutions took part in the $17.6 million Gulf of Alaska ecosystem study that examined the physical and biological mechanisms that determine the survival of juvenile groundfishes in the Gulf of Alaska. From 2010 to 2014, oceanographers, fisheries biologists and modelers studied the gauntlet faced by commercially and ecologically important groundfishes, specifically walleye pollock, Pacific cod, Pacific ocean perch, sablefish and arrowtooth flounder, during their first year of life as these fish are transported from offshore areas where they are spawned to nearshore nursery areas. Funding was provided by the North Pacific Research Board with substantial in-kind support from participating agencies, including National Oceanic and Atmospheric Administration (Alaska Fisheries Science Center and Pacific Marine Environmental Laboratory), U.S. Fish and Wildlife Service, and U.S. Geological Survey. More information can be found on the program website at https://www.nprb.org/gulf-of-alaska-project/about-the-project/, or contact Dr. Olav Ormseth (olav.ormseth@noaa.gov).

Understanding and predicting patterns in northeast Pacific groundfish species movement and spatial distribution in response to anomalously warm ocean conditions—AFSC

An international team of researchers investigated the influence of anomalous ocean conditions observed in the north Pacific in response to a marine heat wave (2013-2014) and a subsequent El Niño (2015). This work was supported by the North Pacific Research Board (Project #1509). Data from past and present summer bottom trawl surveys and acoustic mid-water trawl surveys were used to document groundfish movements and ocean conditions. Range statistics included centroids of abundance, as well as a new analytical approach that incorporated ontogenetic movements. These distribution indicators were statistically compared with indicators of ocean conditions. Relationships observed in 2015 (an extreme warm year) were compared with observations in cool, warm and average ocean conditions.

For a selected group of representative species (sablefish, gadids: Pacific hake, walleye pollock, rockfish: Pacific ocean perch, and flatfish: rock sole, arrowtooth flounder, and petrale sole), functional relationships between fish distribution and the environmental conditions were evaluated. Size groups were treated separately for all species. We originally planned to apply gradient forest approaches to assess the cumulative importance of different environmental predictors across a range of species in each region (as in Baker and Hollowed 2014). Upon review, a new alternative analytical approach was introduced that proved to be more useful than the gradient forest application.

Comparative assessment of indicators of species distributions in 2015 relative to other years was conducted to estimate the potential range extension possible during anomalous ocean conditions. Responses were evaluated regionally from southern California to the western Gulf of Alaska. Relationships between groundfish distribution and ocean conditions derived from the three approaches outlined above will be used to consider projected impacts of climate change on groundfish spatial distributions from California to the western Gulf of Alaska on future fisheries. In addition, we will contrasted emergent relationships derived from various data sources to evaluate how data type, observation error, and changes in species demographics may affect index values.

Two publications have been prepared:

Yang, Q., E.D. Cokelet, P.J. Stabeno, Li L., A.B. Hollowed, W.A. Palsson, N.A. Bond, and S.J. Barbeaux. In Press. How “The Blob” affected groundfish distributions in the Gulf of Alaska. Fisheries Oceanography 2019:1-20. DOI: 10.1111/fog.12422.

Lingbo Li, Anne Hollowed, Edward Cokelet, Steve Barbeaux, Nicholas Bond, Aimee Keller, Jackie King, Michelle McClure, Wayne Palsson, Phyllis Stabeno, and Qiong Yang. In Review. Sub-regional differences in groundfish distributional responses to anomalous ocean temperatures in the northeast Pacific. Global Change Biology.

Contact Anne Hollowed (Anne.Hollowed@noaa.gov) for further information.

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.

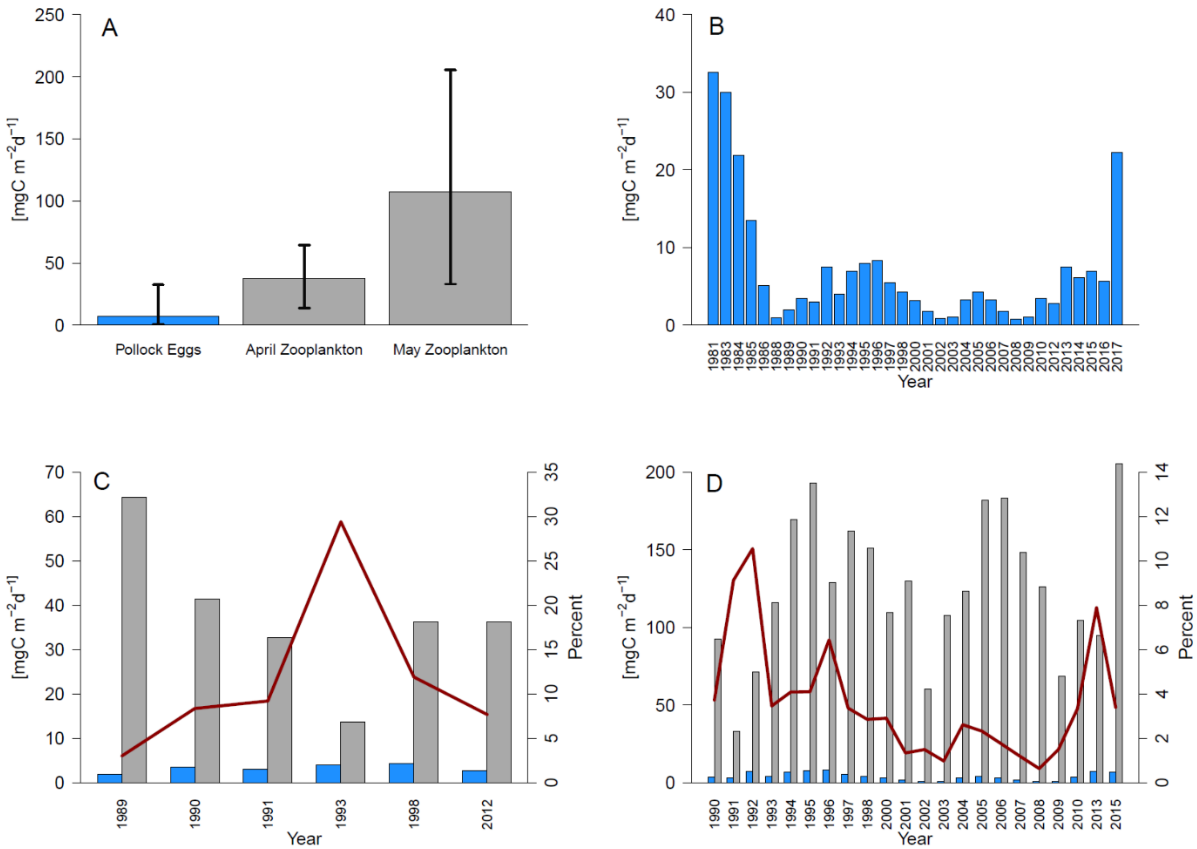


Fig 1: Estimates of, **A**) average production [mgC m^{-2} m^{-1}] of Walleye Pollock eggs deposited as energy, April and May zooplankton, **B**) annual egg production, and comparison of yearly Walleye Pollock egg production (blue) with **C**) April zooplankton (grey) and **D**) May (grey) zooplankton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

Forage fish speciation and population structure based in part on genetic data - ABL

<u>Capelin</u>

Species identification and population structure of capelin is being determined with microsatellite markers, DNA sequences, and morphology as a collaborative project with Jay Orr (RACE), Mayumi Arimitsu (USGS), and Kirsten Ressel and Trent Sutton (UAF). The Auke Bay Lab is preparing to use next-generation sequencing tools such as double-digest restriction associated DNA (ddRAD) to examine genetic variation of capelin collected 2013-2016 from Prince William Sound before and after the warm “blob” in the North Pacific Ocean, in collaboration with Mayumi Arimitsu (USGS).

Sandlance
Species identification of sandlance is an active area of international scientific inquiry. Additional analyses of genetic (microsatellite markers) and morphology characteristics are being used to support a previous study that described four species of sand lance in the North Pacific Ocean and its peripheral seas (Orr et al. 2015). The Auke Bay Lab is collaborating on a study of population structure of sand lance within Puget Sound (RACE, WDFW, UC Davis, UW, NWFSC, and Shoreline Comm. College).

References:
Orr, J. W., S. Wildes, Y. Kai, N. Raring, T. Nakabo, O. Katugin, and J. Guyon. 2015. Systematics of North Pacific sand lances of the genus *Ammodytes* based on molecular and morphological evidence, with the description of a new species from Japan. Fish. Bull. 113:129 156. doi: 10.7755/FB.113.2.3

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

Spatial and temporal trends in the distribution and abundance of forage fish in the south and north eastern Bering Sea during late summer, 2002-2017 – ABL

Abundance of forage fish in pelagic waters was estimated for the north and south eastern Bering Sea during late summer of 2002-2017. Samples were collected during the Alaska Fisheries Science Centers' (AFSC) Bering Arctic Subarctic Integrated Surveys (BASIS) survey using a trawl net towed in the upper 20 m. Surveys were not conducted in the south eastern Bering Sea (SEBS) during 2013, 2015 and 2017 and the north eastern Bering Sea (NEBS) during 2008. We estimated the abundance of forage fish in the north (≥60°N) and south (<60°N) eastern Bering Sea.

Common forage fish collected during the survey included age-0 pollock (*Gadus chalcogrammus*), age-0 Pacific cod (*G. macrocephalus*), capelin (*Mallotus villosus*), herring (*Clupea pallasii*), sand lance (*Ammodytes hexapterus*), juvenile Chinook salmon (*Oncorhynchus tshawytscha*), juvenile chum salmon (*O. keta*), juvenile pink salmon (*O. gorbuscha*), and juvenile sockeye salmon (*O. nerka*). Abundance (metric tonnes) of forage fish in the survey area was estimated using geostatistical modeling methods (Thorson et al. 2015) with the VAST package version 4_2_0 (Thorson 2015; Thorson et al. 2016a, b, c). The abundance index is a standardized geostatistical index for stock assessments.

There was an increase in the productivity of forage fish in the eastern Bering Sea from 2012-2016 (Figure 1). Peak abundances occurred during 2004 and 2014 in the NEBS and during 2004, 2005, and 2014 in the SEBS and overall were higher in the NEBS than the SEBS. A positive relationship was found between sea surface temperature and the estimated abundance of forage fish in the NEBS (R^2=0.33, P=0.034) and SEBS (R^2=0.45, P=0.012). These indices can be used in stock assessment for the sampled species and for their predators.

References
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, K. 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.

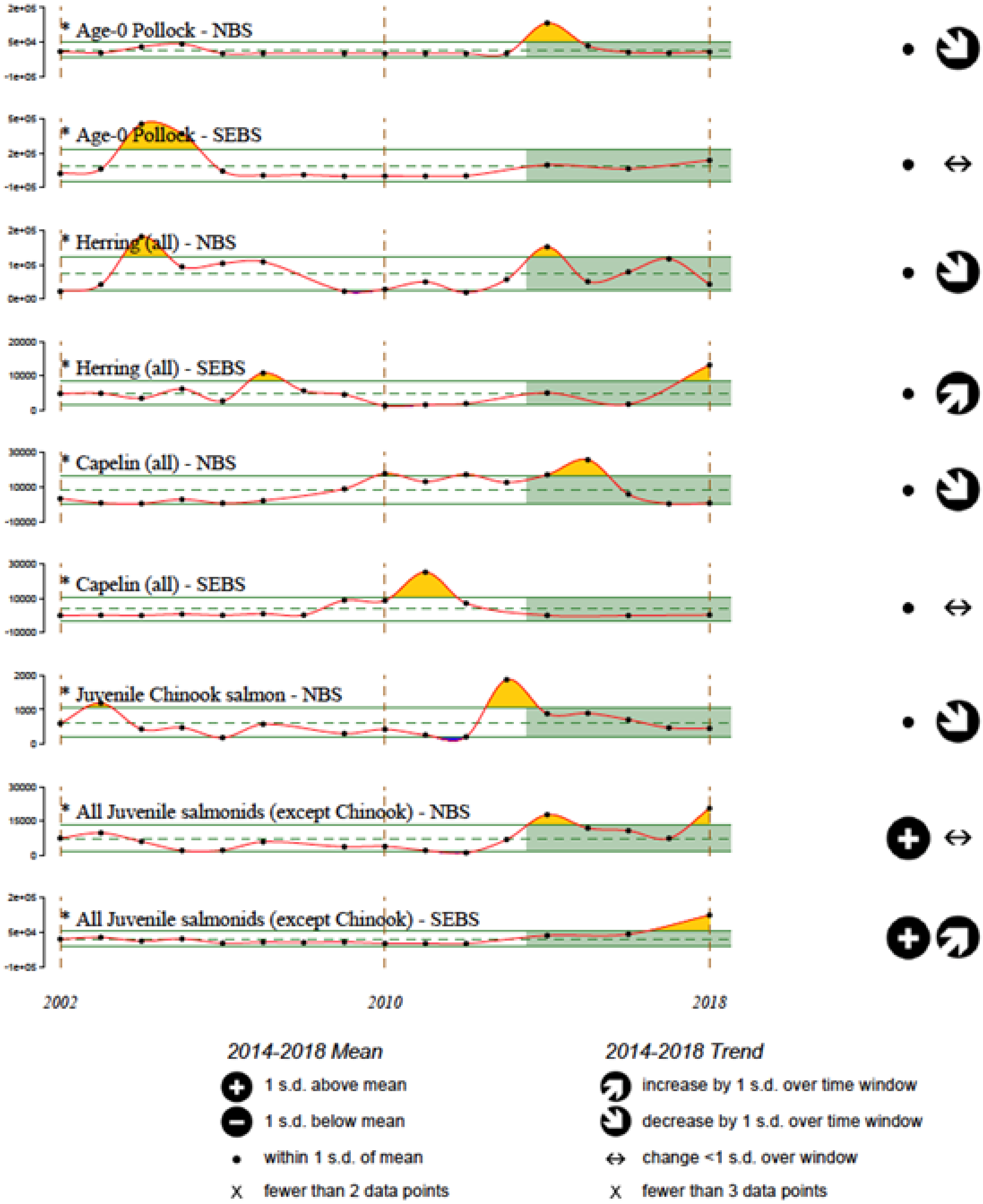


Figure 1: Relative abundance (metric tonnes) of forage fish in pelagic waters of the eastern Bering Sea during late summer, 2002-2018.

For more information contact Ellen Yasumiishi (Ellen.yasumiishi@noaa.gov).

Resource Ecology and Ecosystem Modeling Program (REFM)

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 2018: 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 Resource Ecology and Ecosystem Modeling (REEM) Program continued regular collection of food habits information on key fish predators in Alaska's marine environment. During 2018, samples were collected during the eastern Bering Sea, northern Bering Sea, and Aleutian Islands bottom trawl surveys. Analysis of samples was conducted aboard vessels and in the laboratory. In addition, bill-load and diet samples from seabirds were analyzed for the U.S. Fish and Wildlife Service, and 22 benthic grab samples were analyzed for an Essential Fish Habitat study.

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 2018 through December 2018 (AFSC authors in bold text)

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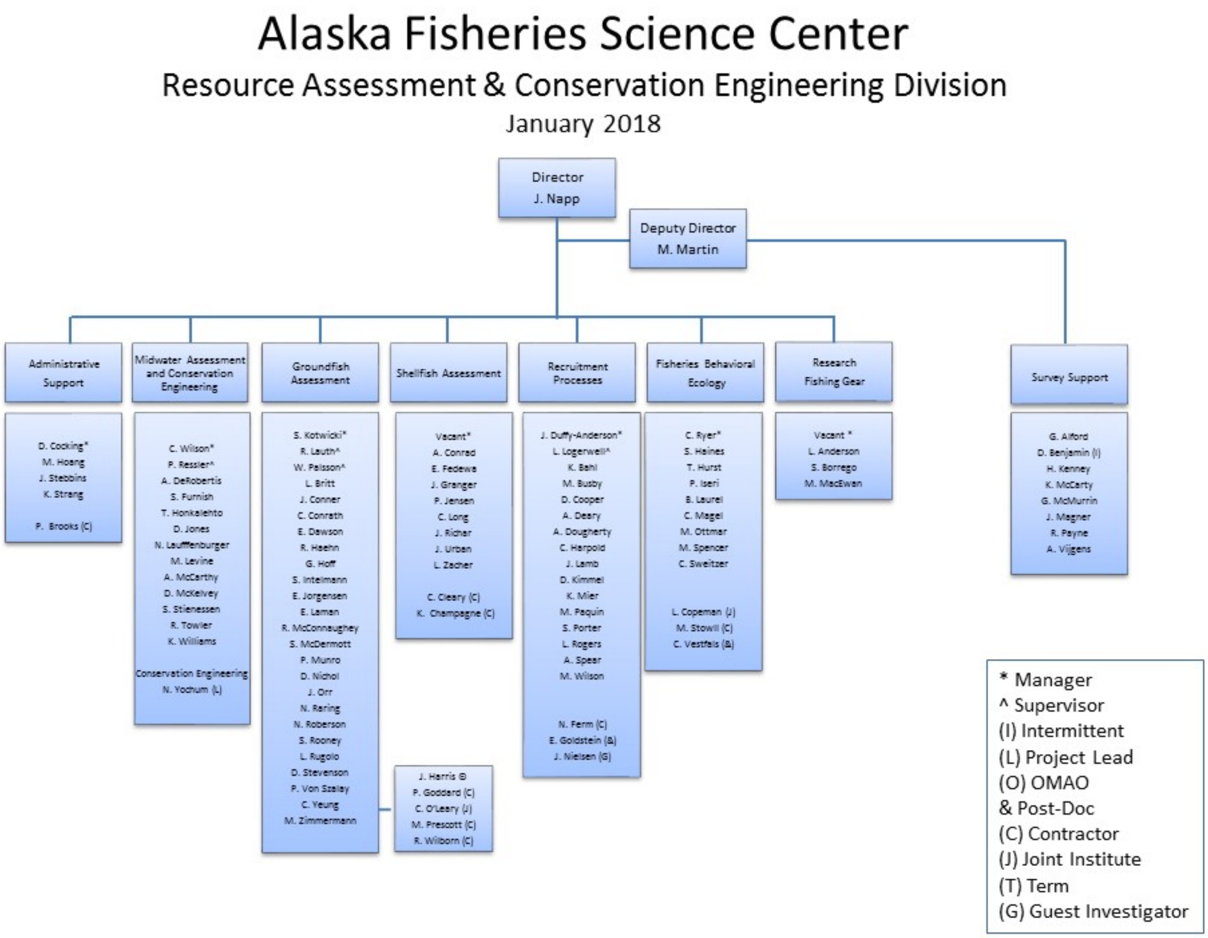
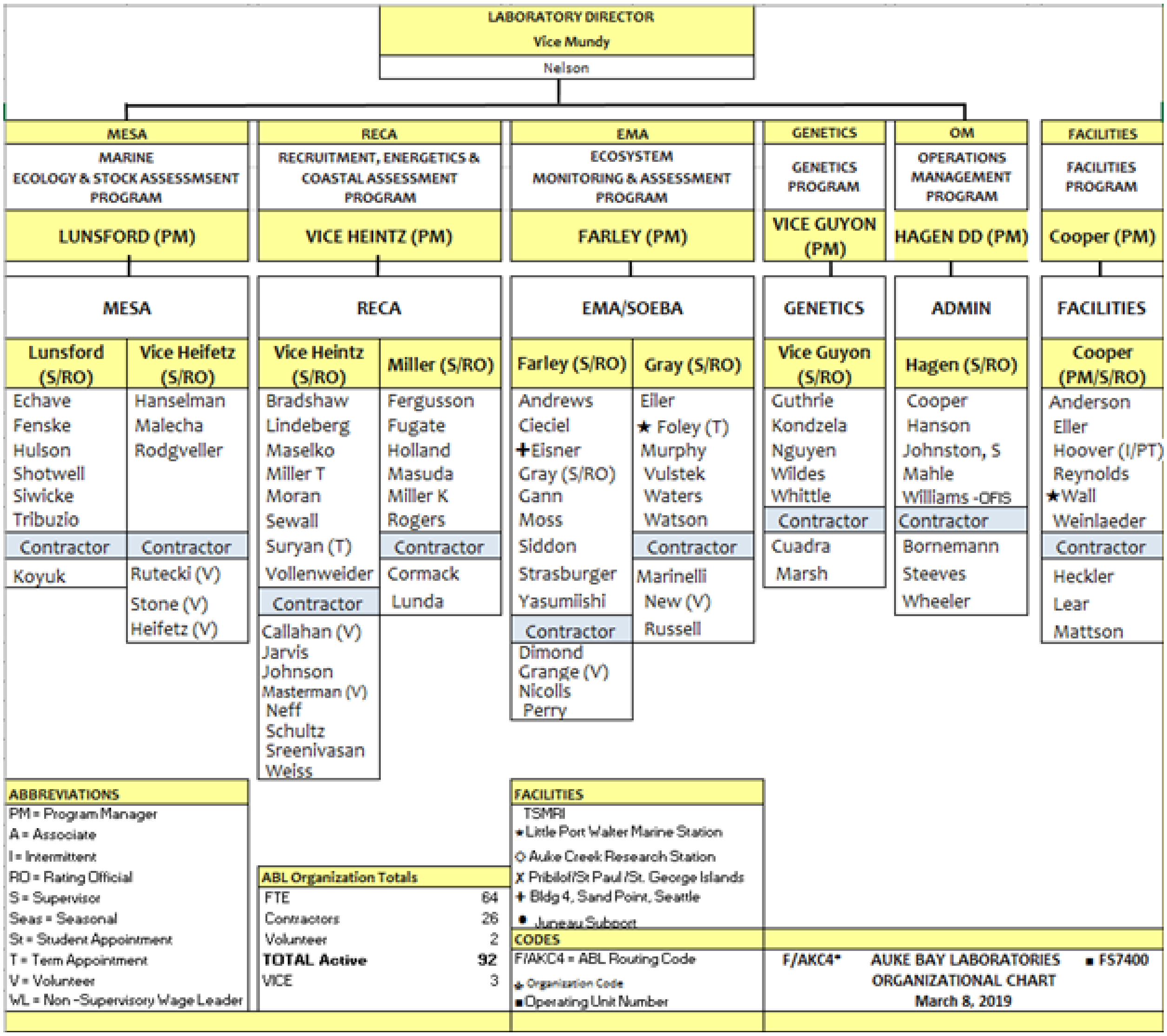
APPENDIX I. RACE ORGANIZATION CHART



APPENDIX II. REFM ORGANIZATION CHART

APPENDIX III – AUKE BAY LABORATORY ORGANIZATIONAL CHART



APPENDIX IV – FMA ORGANIZATIONAL CHART