Alaska Fisheries Science Center of the National Marine Fisheries Service

2017 Agency Report to the Technical Subcommittee of the Canada-US Groundfish Committee

April 2018

Compiled by Wayne Palsson, Tom Wilderbuer, and Jon Heifetz

VIII. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT IN 2017

I. Agency Overview

Essentially all groundfish research at the Alaska Fisheries Science Center (AFSC) is conducted within the Resource Assessment and Conservation Engineering (RACE) Division, the Resource Ecology and Fisheries Management (REFM) Division, the Fisheries Monitoring and Analysis (FMA) Division, and the Auke Bay Laboratories (ABL). All Divisions work closely together to accomplish the missions of the Alaska Fisheries Science Center. A review of pertinent work by these groups during the past year is presented below. A list of publications pertinent to groundfish and groundfish issues is included in Appendix I. Yearly 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.

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). All surveys provide a rich suite of environmental data that are key to practicing an ecosystem approach to fishery management. In addition, the Division works collaboratively with Industry toto investigate ways to reduce bycatch, bycatch mortality, and the effects of fishing on habitat. The 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 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, Groundfish Assessment Program (GAP), Midwater Assessment and Conservation Engineering (MACE), Recruitment Processes Program (RPP), Shellfish Assessment Program (SAP), and Research Fishing Gear/Survey Support. These Programs operate from three locations in 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 2017 three Alaskan bottom trawl surveys of groundfish and invertebrate resources were conducted during the summer by RACE Groundfish Assessment Program (GAP) scientists: the annual eastern Bering Sea Shelf Bottom Trawl Survey, the biennial Gulf of Alaska Bottom Trawl Survey, and a new northern Bering Sea shelf 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 summer). A collaborative cruise to test the efficacy of different types of travel excluders was accomplished, as well. The MACE and GAP are working jointly to design an acoustical-optical survey for fish in untrawlable grounds. Once implemented, the survey will reduce bias in our survey assessments of particular taxa such as rockfish.

RACE scientists from multiple programs will continue research in 2018 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.

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

B. REFM DIVISION

The research and activities of the Resource Ecology and Fisheries Management Division (REFM) are designed to respond to the needs of the National Marine Fisheries Service regarding the conservation and management of fishery resources within the US 200-mile Exclusive Economic Zone (EEZ) of the northeast Pacific Ocean and Bering Sea. Specifically, REFM's activities are organized under the following Programs: Age and Growth Studies, Economics and Social Sciences Research, Resource Ecology and Ecosystem Modeling, and Status of Stocks and Multispecies Assessment. REFM scientists prepare stock assessment documents for groundfish and crab stocks in the two management regions of Alaska (Bering Sea/Aleutian Islands and Gulf of Alaska), conduct research to improve the precision of these assessments, and provide management support through membership on regional fishery management teams.

For more information on overall REFM Division programs, contact Division Director Ron Felthoven at (206) 526-4114.

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 and studies on benthic habitat. Presently, the program is staffed by 13 scientists. ABL's Ecosystem Monitoring and Assessment Program (EMA), Recruitment Energetics and Coastal Assessment Program (RECA), Genetics Program also conduct groundfish-related research.

In 2017 field research, ABL's MESA Program, in cooperation with the AFSC's RACE Division, conducted the AFSC's annual longline survey in Alaska. Other field and laboratory work by ABL included: 1) continued juvenile sablefish studies, including routine tagging of juveniles and electronic archival tagging of a subset of these fish; 2) satellite tagging and life history studies of spiny dogfish and sablefish; 3) recompression experiments on rougheye and blackspotted rockfish; 4) age of maturity and reproductive of sablefish; 5) large-scale, integrated ecosystem surveys of Alaska Large Marine Ecosystems (LME) including the Gulf of Alaska, southeastern Bering Sea and northeastern Bering Sea conducted by the EMA Program; 6) analysis of juvenile groundfish collected on AFSC surveys to assess their growth, nutritional condition and trophodynamics conducted by the RECA Program; and 7) tagging of a small number of age-0 sablefish in the Gulf of Alaska and capture of 500+ live age-0 fish for use in laboratory energetics experiments.

Ongoing analytic activities in 2017 involved management of ABL's sablefish tag database, analysis of sablefish logbook and observer data to determine fishery catch rates, and preparation of eleven status of stocks documents for Alaska groundfish: Alaska sablefish, Gulf of Alaska Pacific ocean perch (POP), northern rockfish, dusky rockfish, rougheye/blackspotted rockfish, shortraker rockfish, "Other Rockfish", thornyheads, and sharks and Eastern Bering Sea sharks. Integrated ecosystem research focused on the impact of climate change and variability on Alaska LME's and response of fishes (walleye pollock, sablefish, POP, Pacific cod, arrowtooth flounder, Pacific salmon) to variability in ecosystem function.

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.

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

2017 Eastern and Northern Bering Sea Continental Shelf Bottom Trawl Surveys – RACE GAP

The thirty-sixth annual standardized eastern Bering Sea (EBS) continental shelf bottom trawl survey was extended northward using the same standardized survey methods (Stauffer 2004) to include 144 additional stations in an area bounded by the Bering Strait, Norton Sound, and the U.S.–Russia Maritime Boundary (Figure 1). The EBS shelf and "Northern Bering Sea" (NBS) bottom trawl surveys were conducted aboard the chartered commercial stern-trawlers F/V *Alaska Knight* and F/V *Vesteraalen*. The NBS extension of the survey is a fundamental part of the NOAA Fisheries Alaska Fisheries Science Center (AFSC) Loss of Sea Ice (LOSI) Research Plan, the primary purpose of which is to study the impacts of diminished sea ice on the marine ecosystem. The NBS is a region of critical importance for increased scientific monitoring because it is a transitional zone between the EBS and Arctic Ocean that is transforming with the changing climate. The scale and extent of fish and crab movements can vary from year to year in response to a variety of biological or environmental processes causing large scale changes in distribution that extend well beyond the standard EBS survey boundary. The 2017 survey represents the second sampling year for a new time series of the NBS that is planned to continue on a biennial basis. Results from the 2017 combined EBS and NBS survey will be valuable for comparing snapshots of fish and crab distributions with those from the 2010 survey that was conducted during the same time of year using identical gear, methods and sampling design to see how the various demersal macrofauna have responded to climate change.

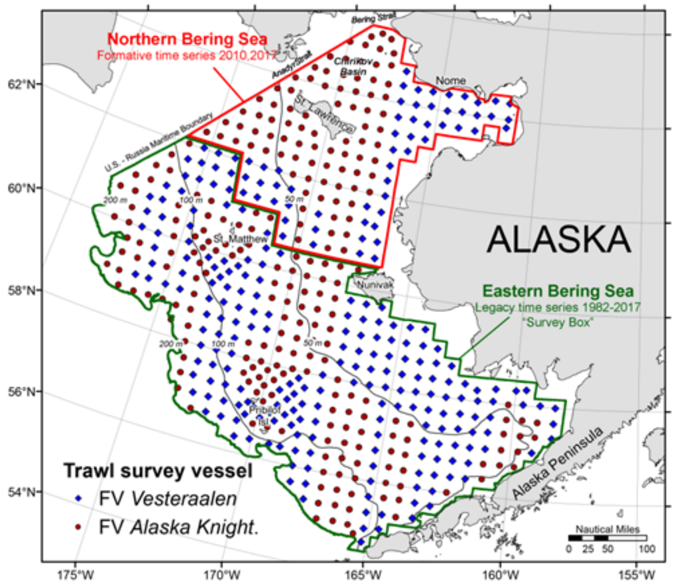


Fig. 1. Map showing survey stations sampled during the 2017 eastern and northern Bering Sea shelf bottom trawl survey.

After the completion of the EBS shelf survey, which started for both vessels in Dutch Harbor on 1 June 2017, 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 01 August to 26 August, and the F/V *Alaska Knight* from 01 August to 2 September. A total of 520 stations in the combined EBS and NBS were successfully sampled in 2017, and there was a total of 111 fish taxa and 260 invertebrate taxa identified from bottom trawl catch samples.

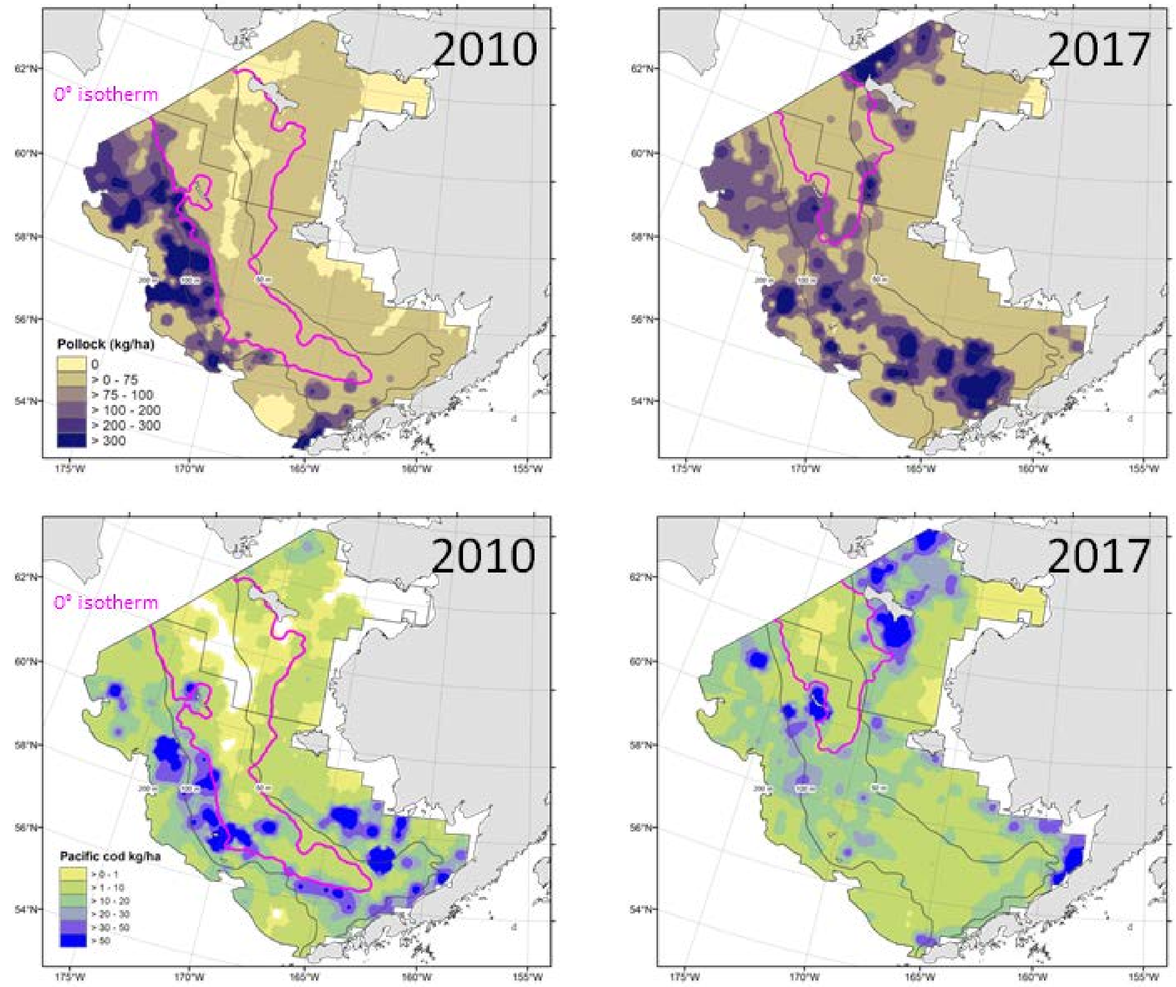


Fig. 2. Spatial distribution of large gadids, in terms of mean CPUE (kg/ha), observed during the 2010 and 2017 bottom trawl surveys of the EBS and NBS: Top left is walleye pollock in 2010, and top right is walleye pollock in 2017; bottom left is Pacific cod in 2010, and bottom right is Pacific cod in 2017. The pink line represents the 0°C isotherm.

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 right). 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 right). 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 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. right). 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 both 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 2017 were 2.79 million mt for yellowfin sole, 1.33 million mt for northern rock sole, 424 thousand mt for arrowtooth flounder, and 126.7 thousand mt for Pacific halibut. Compared to 2016 levels, there was an overall general decrease in survey biomass for the major species: walleye pollock biomass decreased 2%, Pacific cod 35%, yellowfin sole 3%, northern rock sole 9%, arrowtooth flounder 11% and Pacific halibut 18%.

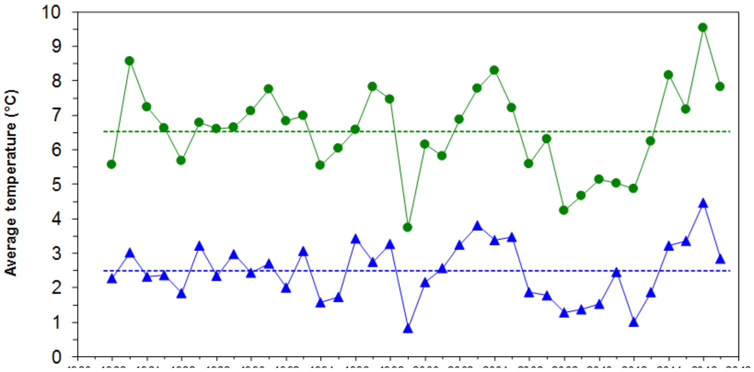


Fig. 1. Graph of mean annual surface and bottom temperatures for the eastern Bering Sea shelf bottom trawl survey.

Surface and bottom temperature means for the 2017 eastern Bering Sea shelf decreased from 2016 estimates, but both were still warmer than the long-term time-series mean (Fig. 3). The 2017 mean surface temperature was 7.8°C, which was 1.7°C lower than 2016 and 1.4°C above the time-series mean (6.5°C). The mean bottom temperature was 2.8°C, which was 1.7°C lower than 2016, but 0.4°C above the time-series mean (2.5°C). The 'cold pool', defined as the area where temperatures <2°C, extended from the northern-most port of the survey (latitude 62°N) south-east to latitude 54° N between 50 and 100 m bottom depth. This extent was significantly more developed than in 2016, when the cold pool was confined to the upper middle shelf, but was generally less extensive compared to 2007-2013 when overall temperatures were colder.

For further information, contact Robert L. Lauth, (206)526-4121, Bob.Lauth@noaa.gov.

2017 Biennial Bottom Trawl Survey of Groundfish and Invertebrate Resources of the Gulf of Alaska – RACE GAP

The National Marine Fisheries Service Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering (RACE) Division chartered the fishing vessels *Ocean Explorer* and *Sea Storm* to conduct the 2017 Gulf of Alaska Biennial Bottom Trawl Survey of groundfish resources. This was the fifteenth survey in the series which began in 1984, was conducted triennially for most years until 1999, and then biennially since. The two vessels were each chartered for 76 days. The cruise originated from Dutch Harbor, Alaska on May 23rd and concluded at Ketchikan, Alaska on August 8th. After the vessels were loaded and other preparations (*e.g.*, wire measuring, wire marking, and test towing) were made before the first survey tows were conducted on 26 May. The vessels surveyed from the Island of Four Mountains (170° W longitude) proceeded eastwards through the Shumagin, Chirikof, Kodiak, Yakutat, and Southeastern management areas (Figure 1). Sampled depths ranged from approximately 15 to 700 m. The cruise was divided into four legs with breaks in Sand Point, Kodiak, and Seward to change crews and re-provision.

A primary objective of this survey is to continue the data time series begun in 1984 to monitor trends in distribution and abundance of important groundfish species. During these surveys, we measure a variety of physical, oceanographic, and environmental parameters while identifying and enumerating the fishes and invertebrates collected in the trawls. Specific objectives of the 2017 survey include: define the distribution and estimate the relative abundance of principal groundfish and important invertebrate species that inhabit the Aleutian archipelago, measure biological parameters for selected species, and collect age structures and other samples. 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 based 54 strata of depths and regions and applied to a grid of 5x5 km^2 cells. Stations that were previously identified as untrawlable were excluded from the sampling frame. Stations were allocated amongst the strata using a Neyman scheme weighted by stratum areas, cost of conducting a tow, past years' data, and the ex-vessel values of key species. Stations were sampled with the RACE Division's standard four-seam, high-opening Poly Nor'Eastern survey trawl equipped with rubber bobbin roller gear. This trawl has a 27.2 m headrope and 36.75 m footrope consisting of a 24.9 m center section with adjacent 5.9 m "flying wing" extensions. Accessory gear for the Poly Nor'Eastern trawl includes 54.9 m triple dandylines and 1.8 ´ 2.7 m steel V-doors weighing approximately 850 kg each. The charter vessels conducted 15-minute trawls at pre-assigned stations. Catches were sorted, weighed, and enumerated by species. Biological information (sex, length, age structures, individual weights, stomach contents, etc.) were collected for major groundfish species. Specimens and data for special studies (*e.g.*, maturity observations, tissue samples, photo vouchers) were collected for various species, as requested by researchers at AFSC and other cooperating agencies and institutions. Specimens of rare fishes or invertebrates, including corals, sponges, and other sessile organisms were collected on an opportunistic basis.

Biologists completed 536 of 550 planned stations in the entire shelf and upper slope to a depth of 700 m. Biologists collected 161 fish taxa that weighed 251 mt and numbered 456,000 individuals. There were 468 invertebrate taxa collected that weighed a total of 5.7 mt. During the 2017 survey, biologists collected 152 taxa of fish and invertebrates as 313 vouchered lots for identification, permanent storage, or other laboratory studies. Other collected samples included over 11,200 otoliths for ageing, special collections for ecological studies, and others samples for life history characterization. A validated data set was finalized on 30 September (https://www.afsc.noaa.gov/RACE/groundfish/survey_data/data.htm), and final estimates of abundance and size composition of managed species and species groups were delivered to Groundfish Plan Team of the NPFMC. The survey data and estimates are also available through the AKFIN system (www.psmfc.org). The Plan Team incorporated these survey results directly into Gulf of Alaska stock assessment and ecosystem forecast models that form the basis for groundfish harvest advice for ABCs and TAC for 2017. Of particular note during this survey was an approximate 80% decline in the survey biomass estimate of Pacific cod. This result combined with others in the stock assessment led to substantial reductions in the amount of fish available for commercial fisheries in the Gulf of Alaska (see Pacific cod stock assessment below).

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

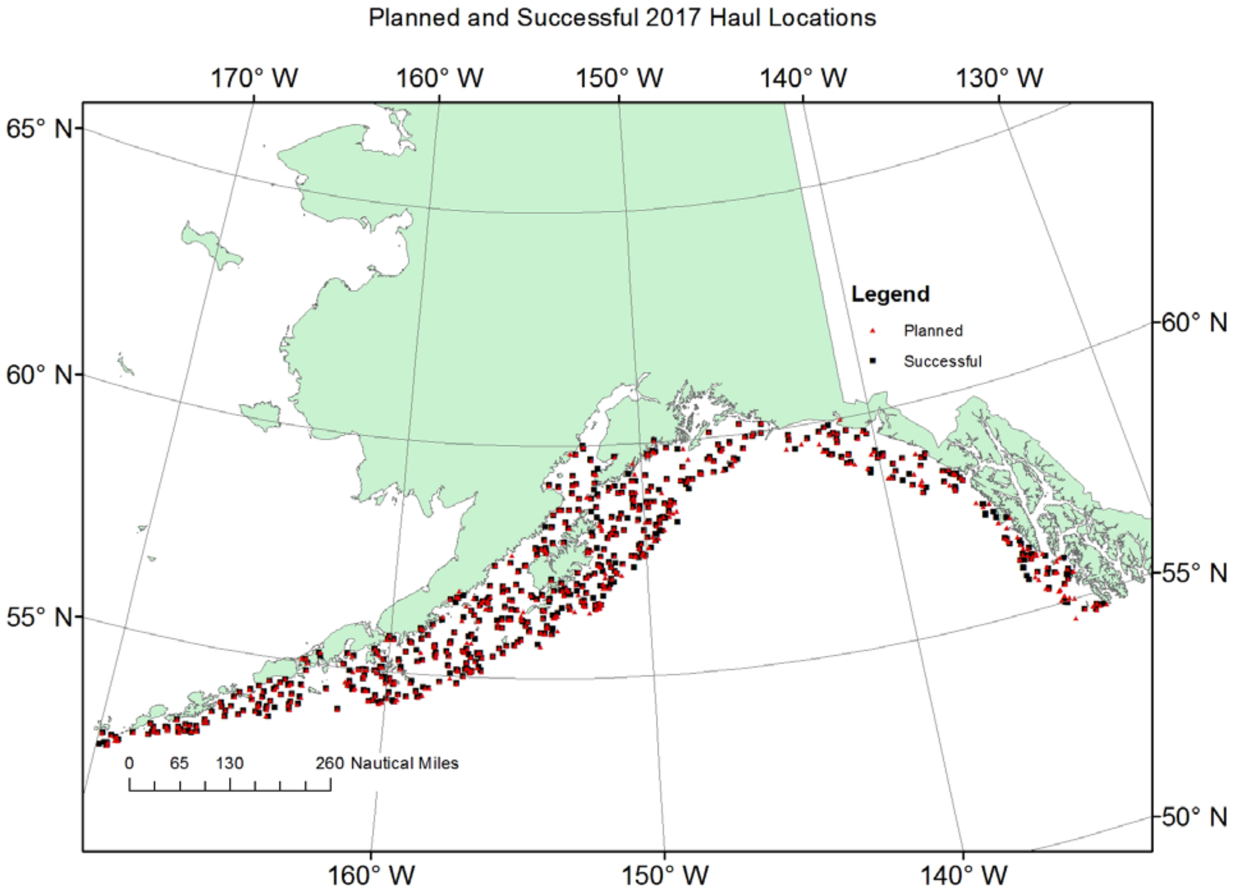


Figure 1. Planned and occupied stations during the 2017 Gulf of Alaska Biennial Bottom Trawl Survey.

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

Three cruises were conducted to survey several GOA walleye pollock (*Gadus chalcogrammus*) spawning areas in the winter of 2017. The first cruise (DY2017-01) surveyed the Shumagin Islands area (i.e., Shumagin Trough, Stepovak Bay, Renshaw Point, Unga Strait, and West Nagai Strait; 8-11 February), Sanak Trough (11 February), Morzhovoi Bay (12 February), and Pavlof Bay (13-14 February). The second cruise (DY2017-02) covered the Kenai Bays (i.e., Port Dick, Nuka Bay, Nuka Passage, Harris Bay, Aialik Bay, Resurrection Bay, Auk Bay, Port Bainbridge, and Knight Passage; 2-5 March), PWS (5-7 March), and the outer PWS region (Hinchinbrook Trough and Middleton Island areas; 7-9 March). The third cruise (DY2017-03) covered the Shelikof Strait (18-24 March), Marmot Bay (14-15 and 26 March) and the Chirikof shelf break (24-25 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 was sampled using an Aleutian Wing 30/26 Trawl (AWT) and a a poly Nor’eastern (PNE) bottom trawl to estimate the abundance of walleye pollock. Backscatter data were also collected at 4 other frequencies (18-, 70-, 120-, and 200-kHz) to support multi-frequency 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 723 km (390.4 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 were between 35 and 50 cm fork length (FL), with a predominant length mode at 42 cm FL, which is characteristic of age-5 walleye pollock, and suggests the continued success of the 2012 year-class. This size range accounted for 99.9% of the numbers and effectively 100% of the biomass of all pollock observed in this area. These walleye pollock were present in Unga Strait, near the mouth of Stepovak Bay, and in the Northern portion of West Nagai Strait. Although adult pollock > 45 cm FL have historically been detected off Renshaw Point, they were absent from this area in 2017. The majority of the pollock were scattered throughout the water column between 50-150m depth within 50m of the bottom, and occasionally formed small, very dense (i.e., “cherry ball”) schools. The maturity composition of males > 40 cm FL (n = 119) was 0% immature, 8% developing, 50% pre-spawning (mature), 40% spawning, and 3% spent. The maturity composition of females > 40 cm FL (n = 136) was 0% immature, 7% developing, 85% pre-spawning, 4% spawning, and 4% spent. The biomass estimate of 29,621 t (with a relative estimation error of 9.8%), based on data from acoustic transects and specimens collected from eight AWT hauls, is 43% greater than the 2016 estimate (20,706 t) and 39% of the historical mean of 75,901 t for this survey.

In Sanak Trough, acoustic backscatter was measured along 167 km (89.9 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 10 and 60 cm FL with a dominant length mode between 35 and 50 cm FL. This mode accounted for 95% of the numbers and 99.9% of the biomass of all pollock observed in Sanak Trough and likely represents age-5 fish. The majority of walleye pollock biomass was located in the southeastern portion of the surveyed trough and distributed throughout the water column below 50 m. The maturity composition for males > 40 cm FL (n = 22) was 0% immature, 0% developing, 77% pre-spawning, 14% spawning, and 9% spent. The maturity composition for females > 40 cm FL (n = 31) was 0% immature, 9% developing, 73% pre-spawning, 0% spawning, and 18% spent. The biomass estimate of 957 t (with a relative estimation error of 19.6%) is 27% of last year’s estimate of 3,556 t, and represents only 2% of the historic mean of 39,812 t for this survey.

In Morzhovoi Bay, acoustic backscatter was measured along 68 km (36.9 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 29 and 55 cm FL in Morzhovoi Bay, and accounted for 99% of the numbers and 99.9% of the biomass in this area. More adults > 50 cm FL were observed in Morzhovoi Bay than in the Sanak and Shumagins regions and accounted for 10% of the pollock biomass in this area. The majority of walleye pollock was located in the southern portion of the surveyed area and was scattered throughout the water column around 85 m from the surface. The maturity composition of males > 40 cm FL (n = 70) was 0% immature, 4% developing, 4% pre-spawning, 89% spawning, and 3% spent. The maturity composition for females longer than

40 cm FL (n = 24) was 0% immature, 17% developing, 58% pre-spawning, 4% spawning, and 21% spent. The biomass estimate of 3,932 t, based on data from acoustic transects and specimens collected from two AWT hauls (with a relative estimation error of 6.5%), is comparable to the biomass estimates generated between 2007 and 2013 (mean = 2,259 t; standard deviation = 397 t).

In Pavlof Bay, acoustic backscatter was measured along 65 km (34.8 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 10 and 60 cm FL with a dominant length mode between 35 and 50 cm FL. This mode accounted for 84% of the numbers and 99% of the biomass of all pollock observed in Pavlof Bay and likely represents age-5 fish. More pollock < 15 cm FL were detected in Pavlof than in any of the other areas, although very few of these presumed age-1 fish were seen during DY1701. This small size group represented 1% of the total number of fish caught in the DY1701 survey, and 0.4% of the biomass in Pavlof. 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 40-100m from the surface. The maturity composition for males > 40 cm FL (n = 18) was 0% immature, 6% developing, 67% pre-spawning, 0% spawning, and 28% spent. The maturity composition for females > 40 cm FL (n = 22) was 0% immature, 9% developing, 77% pre-spawning, 0% spawning, and 14% spent. The biomass estimate of 2,228 t (with a relative estimation error of 14.7%) based on data from acoustic transects and specimens collected from two AWT hauls is very similar to the 2016 estimate of 2,130 t, and is the second estimate generated for this area. Surveys of Pavlof Bay were also conducted in 2002 and 2010, but an equipment malfunction and inclement weather, respectively, prevented trawling.

The Kenai Bays, specifically Port Dick, Nuka Passage, Nuka Bay, Harris Bay, Aialik Bay, Resurrection Bay, Day Harbor, Port Bainbridge, and Knight Passage, were surveyed from 2-5 March. Acoustic backscatter was measured along 552 km (298 nmi) of zig-zag transects. The walleye pollock in the Kenai Bays ranged between 35 and 55 cm FL, in a unimodal distribution with the mode at 42 cm FL, which is characteristic of age-5 fish, and shows the continued success of the 2012 year-class. The majority of the walleye pollock biomass (FL ≥ 30 cm) in the Kenai Region was located in Nuka Bay, Aialik Bay, Resurrection Bay (32%), and Port Bainbridge (17%). There was less than one ton of biomass estimated for fish < 30 cm. Most of the walleye pollock backscatter was located in schools in the upper water column, between 50 m and 150 m. The maturity composition for males > 40 cm FL (n = 266) was 0% immature, 2% developing, 72% pre-spawning, 26% spawning, and 0% spent. The maturity composition for females > 40 cm FL (n = 181) was 0% immature, 2% developing, 94% pre-spawning, 4% spawning, and 0% spent. The biomass estimate of 72,797 t based on data from acoustic transects and specimens collected from eleven AWT hauls is 10% less than the estimate from the winter 2015 survey (80,965 t), and 35% less than the winter 2010 survey estimate of 111,200 t. Neither the 2015 or 2010 estimates included Knight Passage.

Prince William Sound (PWS) was surveyed from 5-9 March. Acoustic backscatter was measured along 533 km (288 nmi) of parallel transects spaced 4.6 km (2.5 nmi) apart. The walleye pollock in the PWS ranged between 35 and 65 cm FL, with a primary mode at 42 cm FL (indicative of age-5 fish), and a few older fish. The majority of the walleye pollock biomass in PWS was distributed along the eastern side of the main channel. Most fish were detected around 350m deep and 100 m off bottom. The maturity composition for males > 40 cm FL (n = 241) was 0% immature, 0% developing, 26% pre-spawning, 74% spawning, and 0% spent. The maturity composition for females > 40 cm FL (n = 106) was 0% immature, 1% developing, 83% pre-spawning, 15% spawning, and 1% spent. The biomass estimate of 107,517 t (with a relative estimation error of 5.8

%) based on data from acoustic transects and specimens collected from seven AWT hauls is slightly less than the estimate from the winter 2010 GOA survey estimate of 111,200 t. Less than 0.5 t were attributed to fish < 30 cm.

Hinchinbrook Trough (i.e., S. of Hinchinbrook Island to GOA Shelf) and the shelf break near Middleton Island (collectively the Hinchinbrook region) were survey March 7-9. Acoustic backscatter was measured along 338 km (182 nmi) of parallel transects spaced 13.9 km (7.5 nmi) apart and along 151 km (82 nmi) of zig-zag transects. The walleye pollock in the Hinchinbrook region ranged between 38 and 57 cm FL with a mode at 42 cm FL (indicative of age-5 fish). The majority of the walleye pollock biomass in the Hinchinbrook region was distributed along the western ends of the northern transects in Hinchinbrook Trough. A little biomass was also estimated east of Middleton Island in deep water. Most of the walleye pollock backscatter in Hinchinbrook was located between 100 m and 200 m deep. Pollock backscatter near Middleton Island was about 400 m deep, and between 200-300m off the bottom. The maturity composition for males > 40 cm FL (n = 115) was 0% immature, 1% developing, 42% pre-spawning, 56% spawning, and 2% spent. The maturity composition for females > 40 cm FL (n = 100) was 0% immature, 3% developing, 95% pre-spawning, 2% spawning, and 0% spent. The biomass estimate of 36,563 t (with a relative estimation error of 14.9 %) based on data from acoustic transects and specimens collected from six AWT hauls is the first for this region in the winter.

In the Shelikof Strait sea valley, acoustic backscatter was measured along 1510 km (815 nmi) of transects spaced 13.9 km (7.5 nmi) apart. The majority of walleye pollock in Shelikof Strait were between 35 and 50 cm FL with a length mode centered around 42cm FL (Fig. 41). This size range accounted for 90% of the numbers and 97% of the biomass of all pollock observed in this area. This size range indicates the continued success of the 2012 year class. Smaller fish (10-15cm) made up a very small portion of the biomass (0.23%) and numbers (10%), and large adults (≥ 51 cm) also contributed little (2.6%) to overall biomass in 2017. Walleye pollock were observed throughout the surveyed area and were most abundant in the central part of the surveyed area. They were detected in the midwater between 50 and 160 m depth, and as a thick, uniform layer around 210 m deep. Dense midwater pollock aggregations of 35-50 cm FL pollock were encountered throughout the survey area. Spawning aggregations, historically observed in the northwestern part of the Strait, were not seen in 2017 or in 2016, in contrast to previous years. The maturity composition of > 40 cm FL (n = 311) was 0% immature, 3% developing, 5% pre-spawning, 83% spawning, and 8% spent. The maturity composition of females > 40 cm FL (n = 404) was 0% immature, 5% developing, 63% pre-spawning, 7% spawning, and 26% spent. The biomass estimate of 1,489,723 t (with a relative estimation error of 4.3%), based on acoustic data and specimens collected from 16 AWT hauls and one PNE haul, is more than twice that observed in 2016 and more than twice the historic mean of 665,474 t. The 2017 biomass estimate approaches biomass values not seen since the mid-1980s.

In Marmot Bay, acoustic backscatter was measured along 322 km (174 nmi) of transects spaced 1.75 km (1.0 nmi) apart in inner Marmot Bay and Spruce Island Gully, and 3.7 km (2.0 nmi) apart in outer Marmot Bay. Inner Marmot Bay and Spruce Island Gully were surveyed 14-15 March, and outer Marmot Bay was surveyed 26 March. Walleye pollock ranged between 34 and 60 cm FL with a clear mode at 42 cm. This size range accounted for 99.9% of the biomass of all pollock observed in this area. Smaller fish (< 34 cm FL) made up a very small portion of the biomass (<0.1%). There were no age-1 pollock caught in Marmot Bay for the second year in a row, and no adults (> 60 cm) captured in 2017. The majority of walleye pollock biomass occurred in aggregations in

Spruce Gully and on the first 2 transects of outer Marmot. These aggregations were near the bottom in deeper water and often included a diffuse mixture of pollock, juvenile herring, and eulachon. The maturity composition of males > 40 cm FL (n = 128) was 0% immature, 2% developing, 4% pre-spawning, 41% spawning, and 53% spent. The maturity composition of females > 40 cm FL (n = 93) was 1% immature, 2% developing, 61% pre-spawning, 8% spawning, and 28% spent. The biomass estimate of 14,259 t (with a relative estimation error of 7.9%), based on data from acoustic transects and specimens collected from five AWT hauls which was about a third of last year's estimate of 37,161.

Along the Chirikof Shelf Break, acoustic backscatter was measured on 307 km (166 nmi) of transects spaced 13.9 km (7.5 nmi) apart. Chirikof was surveyed 24-25 March. Walleye pollock ranged from 38 to 57 cm FL. No larger or smaller fish were observed the survey. The size range was narrower this year than in 2015. Walleye pollock schools composing the majority of pollock biomass in Chirikof were scattered sparsely along the shelf break, mainly in shallow waters (60-100m depth). The maturity composition of males > 40 cm FL (n = 15) was 0% immature, 60% developing, 7% pre-spawning, 13% spawning, and 20% spent. The maturity composition of females > 40 cm FL (n = 57) was 0% immature, 0% developing, 14% pre-spawning, 0% spawning, and 86% spent. The biomass estimate of 4,007 t (with a relative estimation error of 24.0%), based on data from acoustic transects and specimens collected from four AWT hauls, was less than a third of last year's estimate of 12,685 t.

Summer acoustic-trawl survey of walleye pollock in the Gulf of Alaska--MACE

The MACE Program completed a summer 2017 acoustic-trawl (AT) survey of walleye pollock (*Gadus chalcogrammus*) across the Gulf of Alaska (GOA) shelf from the Islands of Four Mountains eastward to Yakutat Trough aboard the NOAA ship Oscar Dyson. The summer GOA shelf survey also included smaller-scale surveys in several bays and troughs. Previous surveys of the GOA have also been conducted during the summers of 2003 (partial), 2005 (partial), 2011, 2013, and 2015 by MACE. Mechanical issues during the second leg of the summer 2017 survey required that the ship return to port early and plans for the third leg had to be altered to assure that the survey covered the entire shelf to Yakutat Trough. Altered plans included increased spacing of transects in Chiniak and Barnabas Troughs (from 3 nmi to 6 nmi) and dropping surveys of Kenai Peninsula Bays and Prince William Sound.

Midwater and near-bottom acoustic backscatter was sampled using an Aleutian Wing 30/26 Trawl (AWT), and on-bottom backscatter was sampled with a poly Nor'eastern (PNE) bottom trawl. A trawl-mounted stereo camera ("CamTrawl") was used during the survey to aid in determining species identification and size of animals encountered by the AWT at different depths. A Methot trawl was used to target midwater macro-zooplankton. Forty seven conductivity-temperature-depth (CTD) casts were conducted to characterize the physical oceanographic environment across the surveyed area. During nighttime operations small scale grid surveys were performed across the shelf based on the AFSC bottom trawl survey trawlability grid. Trawlable (n=16) and untrawlable (n=13) grids were surveyed using the EK60 acoustic system (18, 38, 70, 120, and 200 kHz) and a Simrad ME70 multibeam sonar to assess the trawlability designation of the grid. Grid sampling was augmented with lowered stereo-video camera deployments (n=76) to estimate species abundance and groundtruth bottom classification.

Large numbers of age-0 pollock were observed on CamTrawl images during fishing activities. They were present throughout the summer survey area, particularly around the vicinity of the

Shumagin Islands, the surrounding shelf areas, and in Shelikof Strait. Age-0 pollock were often located in the water column along with larger pollock. Age-0 pollock are not included in our pollock biomass estimates because they are poorly retained by the large survey trawl so accurate estimations of abundance are not possible, though we do account for their acoustic contribution. All biomass estimates reported here are for age-1+ pollock.

The age-1+ biomass estimate for the entire survey area was 1,343,570 t. The majority of the walleye pollock observed during the survey were located on the continental shelf (84%), Shelikof Strait (5%), near Mitrofania Island (3%), and south east of Kodiak Island in Chiniak (2%) and Barnabas Troughs (4%). The vast majority (86%) of the biomass for the entire survey was from age-5 fish (38-56 cm fork length, mean 44 cm FL). Surface water temperatures across the GOA shelf averaged 11.6° C, overall approximately 0.6° C cooler than in 2015.

The survey of the GOA shelf and shelf break was conducted between 12 June and 14 August 2017 and consisted of 41 transects spaced 25 nautical miles (nmi) apart. Walleye pollock distribution was patchy across the shelf with areas of greatest density between Unimak Pass and Sanak Island in the Davidson Bank area, between the Shumagin Islands and Shelikof Strait south of Mitrofania Island, and east of Kodiak Island on the western portion of Portlock Bank. Based on catch data from 47 AWT, and 7 PNE hauls, a major length group of walleye pollock was observed on the GOA shelf ranging from 36 to 58 cm FL with a mode of 44 cm FL, and a smaller length group ranged from 17 and 23 cm FL with a mode of 20 cm FL. The walleye pollock biomass estimate for the GOA shelf of 1,125,801 t from the 1,785 nmi of trackline surveyed was approximately 84% of the total walleye pollock biomass observed for the entire survey and is roughly equivalent to the 2015 estimate.

Sanak Trough was surveyed 19 June along transects spaced 4 nmi apart. The sparse backscatter attributed to walleye pollock in Sanak Trough was patchy and scattered throughout the 47 nmi of transects surveyed. Pollock captured in the two AWT hauls in Sanak Trough were primarily 37 to 56 cm FL with a major mode at 42 cm FL, resulting in a biomass estimate of 3,710 t, approximately 20% higher than what was seen in 2015.

Morzhovoi Bay was surveyed 19-20 June along transects spaced 4 nmi apart. Backscatter in Morzhovoi Bay attributed to walleye pollock was light and evenly scattered throughout the bay. Walleye pollock captured in one AWT haul in Morzhovoi Bay ranged from 37 to 56 cm with a major mode at 47 cm FL. The biomass estimate for the 23 nmi of trackline surveyed in Morzhovoi Bay was 1,606 t, approximately one third of the amount that was seen in Morzhovoi Bay in 2015. Pavlof Bay was surveyed 21 June along transects spaced 4 nmi apart. The acoustic backscatter attributed to walleye pollock in Pavlof Bay was light but evenly scattered throughout the survey area. Walleye pollock captured in Pavlof Bay from one AWT were predominately 36 to 50 cm FL, with a mode at 44 cm FL. The biomass estimate in Pavlof Bay from the 29 nmi of trackline surveyed was 1,397 t, approximately half of what was seen there in 2015.

The Shumagin Islands area was surveyed on 23-26 June along transects spaced 3.0 nmi apart in West Nagai Strait, Unga Strait, and east of Renshaw Point, and 6 nmi apart in Shumagin Trough. In the Shumagin Islands walleye pollock were most abundant in the Unga Strait and Shumagin Trough areas. Walleye pollock from 5 AWT hauls were divided between two major groups, one ranging from 13 to 19 cm FL and the other from 37 to 53 cm FL with respective modes at 16 and 43 cm FL. The biomass estimate for the Shumagin Islands along the 190 nmi of tracklines surveyed was

15,288 t, similar to the amount seen there in 2015.

Mitrofania Island was surveyed 25 June along transects spaced 8 nmi apart. The acoustic backscatter attributed to walleye pollock was relatively high on all transects in the Mitrofania Island area. Lengths of walleye pollock captured in the one AWT haul near the island were divided between two groups, one ranging from 13 to 19 cm FL and the other from 37 to 48 cm FL with respective modes at 16 and 43 cm FL. The biomass estimate in Mitrofania along the 32 nmi of tracklines surveyed was 41,996 t, approximately three times greater than in 2015 estimate for the area.

Shelikof Strait was surveyed from 3-10 July along transects spaced 15 nmi apart. Walleye pollock were predominantly distributed throughout the western and central area of Shelikof Strait from Portage Bay to Katmai Bay area. In the central portion of the Strait large aggregations of predominately age-1 pollock formed a dense layer in the midwater. Additionally, age-0 pollock were present throughout the entire Strait from the surface to depths as deep as 150 m in some areas. Lengths were obtained from nine AWT and two PNE trawls hauls and were divided between two groups, one ranging from 13 to 19 cm FL and the other from 29 to 58 cm FL with respective modes at 16 and 44 cm FL. The biomass estimate for the 533 nmi of trackline surveyed in Shelikof Strait was 70,152 t, is less than a quarter of the 2015 estimate, is the lowest estimate for this area in the summer survey time series, and only accounted for approximately 5% of the entire GOA summer survey pollock biomass.

Nakchamik Island was surveyed 9 July along transects spaced 8 nmi apart. Backscatter attributed to walleye pollock near Nakchamik Island was lightly distributed across the 25 nmi of surveyed transects. Walleye pollock captured in the one AWT haul near Nakchamik Island ranged from 37 and 48 cm with a mode of 43 cm FL. The biomass estimate for the Nakchamik Island area was 379 t, the lowest seen in this region in the summer survey time series and approximately only 4% of the 2015 estimate.

Alitak and Deadman Bays were surveyed 12-13 July along a zig-zag pattern into the narrow inner bay area. From one AWT and one PNE haul conducted in the area walleye pollock ranged in length predominantly from 39 to 58 cm FL with a major mode at 47 cm FL. The biomass estimate along the 40 nmi of trackline surveyed in Alitak/Deadman Bay area was 813 t, the lowest seen in this region in the summer survey time series and approximately only 11% of the 2015 estimate.
Chiniak Trough was surveyed 28-29 July along transects spaced 6 nmi apart. Patchy, dense aggregations of adult walleye pollock were detected primarily in the northern transects in Chiniak Trough. Walleye pollock caught in 4 AWT hauls in Chiniak Trough ranged in length predominantly from 39 to 57 cm FL, with a mode at 44 cm FL. The biomass estimate for the 55 nmi of trackline surveyed in Chiniak Trough was 30,156 t, 14% lower than the 2015 estimate.

Barnabas Trough was surveyed 14 to 15 July before mechanical issues required the ship to return to port before completing the survey. Once repairs were completed Barnabas Trough was completely surveyed from 31 July thru 1 Aug along transects spaced 6 nmi apart. Aggregations of adult walleye pollock were detected primarily in the central transects in Barnabas Trough. Walleye pollock caught in an initial three AWT and one PNE haul, and upon returning seven AWT trawls in Barnabas Trough ranged in length predominantly from 38 to 50 cm FL and were dominated by a single mode at 44 cm FL. The biomass estimate for the 151 nmi of trackline surveyed in Barnabas Trough was 49,846 t, approximately 4% of the entire GOA summer survey biomass estimate and almost half of the estimated biomass for this area in 2015.

Marmot Bay was surveyed 3-4 Aug. along transects spaced 2 nmi apart in the inner bay and Spruce Gully, and 4 nmi apart in the outer bay. Walleye pollock backscatter was light in Marmot Bay with the greatest amounts found in the outer bay. Walleye pollock predominately ranged in length from 37 to 56 cm FL with a primary mode at 40 cm FL. The biomass estimate for Marmot Bay along the 108 nmi of trackline surveyed was 2,426 t, the lowest estimate for this area in the summer survey time series and only approximately 5% of the 2015 estimate.

Summer 2016-2017 acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye pollock--MACE

In an effort to obtain annual information for midwater walleye pollock (*Gadus chalcogrammus*), acoustic backscatter at 38 kHz collected by the chartered AFSC bottom trawl survey vessels from near surface to 3 m off bottom was used to develop an abundance index that was strongly correlated with the total estimated AT survey pollock biomass ($r2 = 0.90$, $p = 0.0011$, 2006-2014). This midwater pollock abundance index from ‘vessels of opportunity’ (AVO) has been estimated annually since 2006. It is an important component of the Bering Sea pollock stock assessment because it provides information on midwater pollock in years when the AT survey is not conducted. Every two years, AVO index estimates are provided to pollock stock assessment scientists and also summarized in a report available on the AFSC website.

The most recent AVO index results are from 2016-2017. The 2016 AVO index decreased 19% from the 2015 index value, and 14% from 2014. The 2017 AVO index decreased slightly (6%) from 2016. Both estimates (2016, 2017) were similar to a number of previous years in the series (2006, 2010, 2012-2013) based on overlapping 95% confidence intervals. Most pollock backscatter appeared to be distributed broadly across the shelf between 50 and 200 m isobaths in 2016 and 2017. The percentage of pollock backscatter east of the Pribilof Islands (east of 170○ W longitude) in the AVO index was 22% in 2016 and 19% in 2017. This is much greater than the percentage in summers 2010-2012 (range 4-9%), slightly less than that observed in 2013 (26%) and 2015 (25%), and much less than that observed in 2014 (33%). After a sharp increase in 2013-2014, the relative and absolute biomass of midwater pollock east of the Pribilof Islands has been slowly declining. Because the AVO index did not increase in 2016 as did the AT survey time series, comparison of the AVO index and AT survey time series shows a reduced correlation for 2016 ($r2 = 0.76$, $p = 0.015$). Classification of AVO backscatter was more difficult in summer 2017 due to the presence of questionable backscatter (QBS) in some parts of the 2017 AVO index area, increasing the uncertainty in the 2017 AVO index.

The AT survey time series has historically measured the presence of walleye pollock found in midwater down to 3 meters off bottom (“historic” AT time series). In 2016, this time series was altered to include pollock found down to 0.5 m off bottom (“new” AT time series; Honkalehto et al. in press). Preliminary analysis indicates the AVO index is equally well correlated to the new AT time series ($r2 = 0.76$, $p = 0.015$).

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 2017. 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 2017, the fortieth annual longline survey of the upper continental slope of the Gulf of Alaska and Bering Sea was conducted. One hundred and fifty-six longline hauls (sets) were completed during June 1 – August 26 by the chartered fishing vessel *Ocean Prowler*. Total groundline set each day was 16 km (8.6 nmi) long and contained 160 skates and 7,200 hooks except in the eastern Bering Sea where 18 km (9.7nmi) of groundline composed of 180 skates with 8,100 hooks were set.

Sablefish (*Anoplopoma fimbria*) was the most frequently caught species, followed by giant grenadier (*Albatrossia pectoralis*), Pacific cod (*Gadus macrocephalus*), shortspine thornyhead (*Sebastolobus alascanus*), and Pacific halibut (*Hippoglossus stenolepis*). A total of 84,417 sablefish, with an estimated total round weight of 216,431 kg (477,149lb), were caught during the survey. This represents an increase of 10,278 sablefish over the 2016 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 2,261 sablefish. Killer whales (*Orcinus orca*) depredating on the catch occurred at two stations in the western Gulf of Alaska and eleven stations in the Bering Sea. Sperm whales *(Physeter macrocephalus)* were observed during survey operations at 18 stations in 2017. Sperm whales were observed depredating on the gear at one station in the western Gulf of Alaska, four stations in the central Gulf of Alaska, three stations in the West Yakutat region, and nine stations in the East Yakutat/Southeast region.

Several special projects were conducted during the 2017 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. Sperm whale observations and photo identifications were conducted in collaboration with a separate vessel at two stations during Leg 3. Yelloweye rockfish (*Sebastes ruberrimus*) samples were collected for a study developing hormone profiles in bony structures that may be used to reconstruct reproductive life histories. Finally, tissue samples from five groundfish species were collected for a stable isotope analysis.

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). Catch per unit effort (CPUE) information and relative population numbers (RPN) by depth strata and management regions are provided. These estimates are available for all species caught in the survey. Previously RPN's were only available for depths that corresponded to sablefish habitat but in 2013 these depths were expanded to 150m - 1000m. Inclusion of the shallower depths provides expanded population indices for the entire survey time series for species such as Pacific cod, Pacific halibut, and several rockfish species.

For more information, contact Pat Malecha at (907) 789-6415 or pat.malecha@noaa.gov or Chris Lunsford at (907) 789-6008 or chris.lunsford@noaa.gov.

Northern Bering Sea Integrated Ecosystem Survey – ABL

Auke Bay Labs has conducted surface trawling and biological and physical oceanography sampling in the Northern Bering sea annually since 2002. The 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 Alliance will continue to conduct a the survey Aug 27 to Sep 20, 2018 aboard a chartered fishing vessel and include 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, 3) sample collections within Region 2 of the Distributed Biological Observatory.

Physical and biological data are typically collected from 50 stations and oceanographic 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.

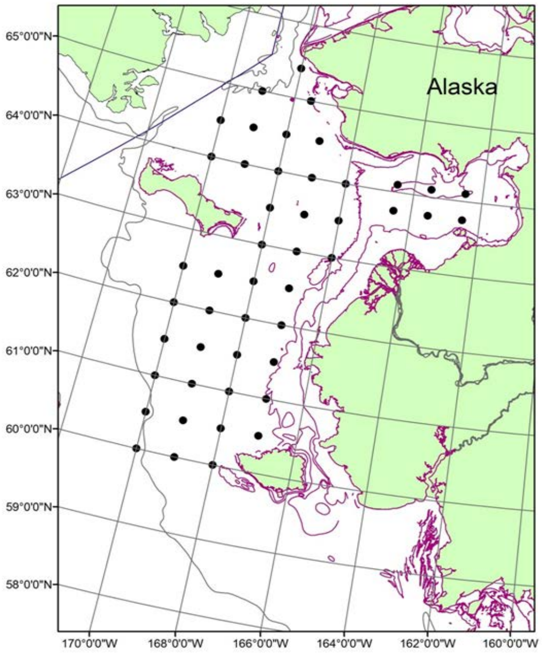


Figure 1. Stations planned to be sampled during the August 27 to September 20, 2018 integrated ecosystem survey in the northern Bering Sea.

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

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

This survey was not conducted in 2017 therefore we provide plans for 2018. Scientists from the Recruitment Processes Alliance (RPA) of the Alaska Fisheries Science Center (AFSC) will conduct a fisheries-oceanographic survey in the southeastern Bering Sea (SEBS) during the early fall aboard the NOAA Vessel Oscar Dyson from August 20 to September 17, 2018. Prior to the RPA surveys, fisheries-oceanographic surveys were conducted annually (2002-2012, 2014-2016) as part of the Bering-Aleutian Salmon International Survey (BASIS) and the Bering Sea Project (BSP). The survey includes the SEBS shelf between roughly the 50 m and 200 m isobaths, from 160º W to 175º W (Figure 1). A surface trawl (top 20 m) and a midwater trawl towed obliquely (200 m maximum) will be conducted at each station. During this survey, trawl catch and ecosystem data is collected with a priority to provide a mechanistic understanding of the factors that influence recruitment of walleye pollock (*Gadus chalcogrammus*) and Pacific cod (*Gadus macrocephalus*).

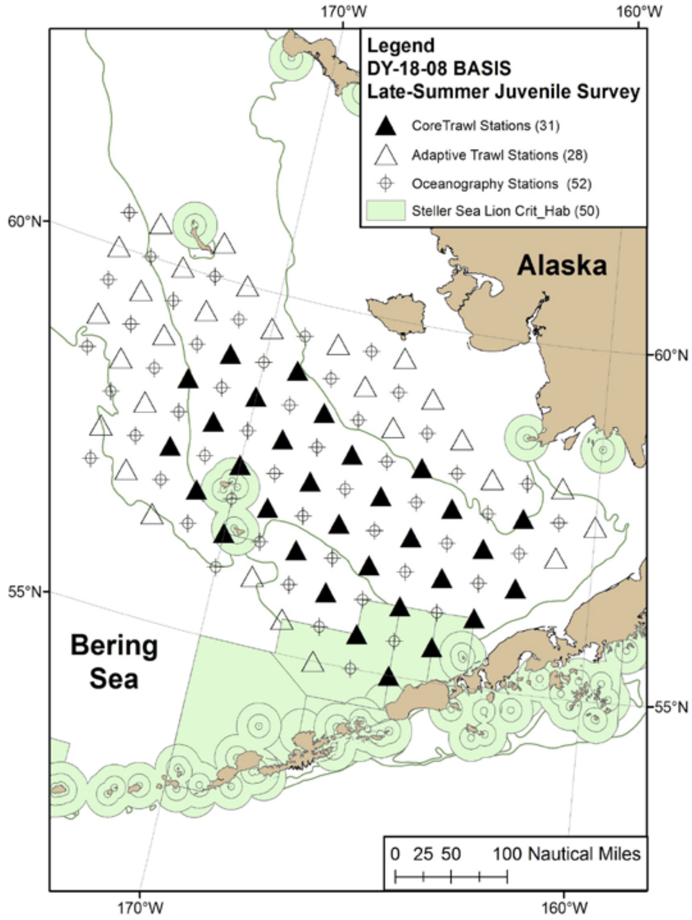


Figure 1. Station locations for the August to September 2018 southeastern Bering Sea integrated ecosystem survey also known as BASIS.

For more information contact Alex Andrews at (907) 789-6655 or Alex.Andrews@noaa.gov

North Pacific Groundfish and Halibut Observer Program (Observer Program) – FMA

The North Pacific Observer Program (Observer Program) provides the regulatory framework for NMFS-certified observers to obtain information necessary to conserve and manage the groundfish and halibut fisheries in the Gulf of Alaska (GOA) and the Bering Sea and Aleutian Islands (BSAI) management areas. Data collected by well-trained, independent observers are a cornerstone of management of the Federal fisheries off Alaska. These data are needed by the North Pacific Fishery Management Council (Council) and NMFS to comply with the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson-Stevens Act), the Marine Mammal Protection Act, the Endangered Species Act, and other applicable Federal laws and treaties.

Observers collect biological samples and fishery-dependent information used to estimate total catch and interactions with protected species. Managers use data collected by observers to manage groundfish and prohibited species catch within established limits and to document and reduce fishery interactions with protected resources. Scientists use observer data to assess fish stocks, to provide scientific information for fisheries and ecosystem research and fishing fleet behavior, to assess marine mammal interactions with fishing gear, and to assess fishing interactions with habitat. Although NMFS is working with the Council and industry to develop methods to collect some of these data electronically, currently much of this information can only be collected independently by human observers.

The current Observer Program was implemented in 2013 when the previous Observer Program was restructured to address sampling issues associated with non-random observer deployment on some vessels and fisheries. At that time, observer coverage was expanded to include vessels that were previously unobserved, and increased the number of vessels in the full observer coverage category with the overall goal to improve estimates of catch and bycatch. The Council has recommended several amendments to the Observer Program to clarify and refine which vessels are in the full coverage category and which are in the partial coverage.

The following regulatory and FMP amendments have been implemented since 2013 to modify observer coverage requirements for specific groups of vessels under North Pacific Observer Program:

- BSAI Amendment 112 and GOA Amendment 102 revised observer coverage requirements for certain small catcher/processors (81 FR 17403, March 29, 2016). Effective March 29, 2016.
- BSAI Amendment 109 revised observer coverage requirements for catcher vessels less than or equal to 46 ft LOA when groundfish CDQ fishing (81 FR 26738, May 4, 2016). Effective June 3, 2016.
- A regulatory amendment revised observer coverage requirements for BSAI trawl catcher vessels (81 FR 67113, September 30, 2016). Effective October 31, 2016.
- Under the restructured Observer Program, all vessels and processors in the groundfish and halibut fisheries off Alaska are assigned to one of two observer coverage categories (1) a full coverage category; or (2) a partial coverage category.

Full Coverage Category

Vessels and processors in the full observer coverage category must have comply with observer coverage requirements at all times when fish are harvested or processed. Specific requirements are defined in regulation at 50 CFR § 679.51(a)(2). The full coverage category includes:

- catcher/processors (with limited exceptions),
- motherships,
- catcher vessels while participating in programs that have transferable prohibited species catch (PSC) allocations as part of a catch share program,
- catcher vessels using trawl gear that have requested placement in the full coverage category for all fishing activity in the BSAI for one year, and
- inshore processors when receiving or processing Bering Sea pollock.

Independent estimates of catch, at-sea discards, and PSC are obtained aboard all catcher/processors and motherships in the full observer coverage category. At least one observer on each catcher/processor eliminates the need to estimate at-sea discards and PSC based on industry provided data or observer data from other vessels.

Catcher vessels participating in programs with transferable PSC allocations as part of a catch share program also are included in the full coverage category. These programs include Bering Sea pollock (both American Fisheries Act and Community Development Quota [CDQ] programs), the groundfish CDQ fisheries (CDQ fisheries other than halibut and fixed gear sablefish), and the Central GOA Rockfish Program.

Inshore processors receiving deliveries of Bering Sea pollock are in the full coverage category because of the need to monitor and count salmon under transferable PSC allocations.

Partial Coverage Category

The partial observer coverage category includes:

- catcher vessels designated on a Federal Fisheries Permit when directed fishing for groundfish in federally managed or parallel fisheries, except those in the full coverage category;
- catcher vessels when fishing for halibut individual fishing quota (IFQ) or sablefish IFQ (there are no PSC limits for these fisheries);
- catcher vessels when fishing for halibut CDQ, fixed gear sablefish CDQ, or groundfish CDQ using pot or jig gear (because any halibut discarded in these CDQ fisheries does not accrue against the CDQ group's transferable halibut PSC allocation);
- catcher/processors that meet criteria that allows assignment to the partial coverage category;
- shoreside or stationary floating processors, except those in the full coverage category;
- no selection pool which contains two categories of vessels:

o Fixed gear vessels less than 40 ft LOA and vessels fishing with jig gear.

o Vessels that are voluntarily participating in EM innovation research.

Electronic Monitoring Program (EM Trip Selection Pool)

Vessels in the partial coverage category had the option to "Opt in" to a voluntary Electronic Monitoring (EM) Program for the year in 2016 and again in 2017. The overall goal of the two year EM pre-implementation plan and the cooperative research was to assess the efficacy of using EM, in combination with other tools, for catch accounting of retained and discarded catch, and to identify key decision points related to operationalizing and integrating EM systems into the Observer Program for fixed gear vessels in a strategic manner. The experience and results from the data collected during this pre-implementation and research phase was used to implement a fully regulated EM Program.

On August 8, 2017, the final rule to integrate electronic monitoring into the North Pacific Observer Program published in the Federal Register. This represents a major milestone in transitioning from a voluntary, cooperative research effort to a fully operational and regulated program beginning January 1, 2018. It also represents a major new addition to the way in which the observer program collects and processes data for management in North Pacific groundfish and halibut fisheries. This is a "first-of-its-kind" approach of using EM to enumerate and identify retained and discarded species from fixed gear vessels and the data is provided to the Alaska Regional Office for catch accounting purposes.

A New FMA Director

Chris Rilling, FMA Director, retired on January 5, 2018. Jennifer Ferdinand was selected as the next Director of the Fisheries Monitoring and Analysis Division in December 5, 2017.

For more information on the North Pacific Observer Program contact Jennifer Ferdinand at (206) 526-4076 or Jennifer.ferdinand@noaa.gov.

III. Reserves

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

A. Hagfish

B. Dogfish and other sharks

1. Research

Spiny Dogfish Ecology and Migration - ABL
A tagging program for spiny dogfish was begun in 2009, with 183 pop-off satellite archival tags (PSATs) deployed between 2009 - 2013. Data were recovered from 153 of those tags, 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 9 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 model based on these tag data and incorporating environmental variables (e.g. temperature/depth profiles and sea-surface temperature).

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.

In 2016 staff at ABL began collaborating on a project examining stress physiology in spiny dogfish by collecting blood samples from captured animals. In 2017 we deployed three PSATs on the sampled fish and plan to deploy 18 more during the 2018 longline survey. Eight of the tags will be the same model as those previously used (for a total of 11 physiology study fish tagged) and 10 will be testing a new short-term mortality tag, that records data for only 96 days, but transmits high resolution behavior data once it surfaces. These tags may be used in the future for a skate discard mortality study in collaboration with UAF.

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.

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. Beginning in 2017, many assessments adopted new schedules and the GOA shark assessment was delayed so that both shark assessments would be conducted in the same year. 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 most recent assessments (2016), catch estimates from 2003-2016 were updated from the NMFS Alaska Regional Office's Catch Accounting System. In the GOA, total shark catch in 2016 was 2,016 t, which was up from the 2015 catch of 1,414 t. One impact of observer restructuring (beginning in 2013) was that estimated shark catches in NMFS areas 649 (Prince William Sound) and 659 (Southeast Alaska inside waters) for Pacific sleeper shark and spiny dogfish by the halibut target fishery increased. Second, the average Pacific sleeper shark and spiny dogfish catch in NMFS areas 649 and 659 was 67 t and 135 t, respectively, compared to the historical average of < 1 t and ~14 t (SD = 23), respectively. There were approximately 2 t of salmon shark and other shark catch estimated in these areas as well. The catch in NMFS areas 649 and 659 does not count against the federal TAC, but if it were included the total catch of sharks in 2016 would be 2,238 t (instead of 2,016), which would still be below the ABC and OFL.

The last GOA trawl survey was in 2017, but no assessment was conducted in 2017. The prior survey, 2015 is the most recent survey used in the assessment. 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 that the biomass was nearly three times greater, and such variability in annual estimates is not unexpected due to the patchy distribution of this species. The trawl survey biomass estimates are used only for ABC and OFL calculations for spiny dogfish and are not used for other shark species. The random effects model for survey averaging was used to estimate the 2015 GOA biomass for spiny dogfish (56,181 t), which was used for “Tier 5” calculations of spiny dogfish ABC and OFL.

For the GOA assessment, all sharks are managed under “Tier 6” as a complex. However, spiny dogfish ABC and OFL are calculating using “Tier 5” methods. They are not managed separately as a “Tier 5” species because of the “unreliable” nature of their biomass estimates. All other sharks in the GOA have species-specific ABC and OFLs set under “Tier 6” rules. 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 = 4,514 t and OFL = 6,020 t for 2018 and 2019 (carried over from the previous assessment). Total catch of sharks in the GOA for 2017 was 1,632 t. Catch in inside waters is not managed by either federal or state agencies, but it is reported in the assessment. 2017 reported the largest catch in inside waters of the time series, 720 t, comprised mostly of Pacific sleeper shark.

Because the survey biomass estimates on the BSAI are highly uncertain and not informative, all shark species are considered “Tier 6”. In 2016 the “Tier 6” calculations in the BSAI are now based on the maximum catch of all sharks from the years 2003-2015 (changed from the years 1997-2007). The resultant recommended values for 2017 and 2018 were ABC = 517 t and OFL = 689 t. In the BSAI, estimates of total shark catch from the Catch Accounting System from 2016 were 185 t, which is not close to the ABC or OFL. Pacific sleeper shark are usually the primary species caught, however in 2017 salmon shark catch (114 t) was nearly double that of Pacific sleeper shark (60 t). These catch estimates incorporate the restructured observer program, but the impact appears to be minimal for BSAI sharks.

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

C. Skates

1. Research

Skate Nurseries as Unique Habitats in the Eastern Bering Sea-RACE

Gerald Hoff, Duane Stevenson, Ingrid Spies, Chris Rooper, and James Orr

Recent HAPC designation of 8 skate nursery sites in the eastern Bering Sea by the North Pacific Fisheries Management Council has highlighted the recognition of these important habitats. This study focuses the uniqueness of the nursery habitats and the impact of fisheries encounters on nursery sites.

Currently there are approximately 8 nursery sites known in the eastern Bering Sea for the most abundant skate species, the Alaska skate. We are studying three aspects of its nursery habitat:

1) Using a predictive model to determine the most likely skate nursery habitat in the eastern Bering sea using environmental and benthic habitat data sets

2) Examining the genetic conductivity amongst nursery sites to determine if sites are vectors for population structure within a large marine ecosystem

3) Determining the impact fisheries may have on nursery sites by determining the species of skate eggs most encountered and the frequency of viable eggs vs empty cases. This aspect is conducted through the FMA observer program.

For further information, contact Gerald Hoff, (206)526-4580, Jerry.Hoff@noaa.gov.

2. Assessment

Bering Sea

The skate assessment for 2017 was a partial assessment in accordance with the new prioritization schedule. New information included: updated 2015 – 2017 catch data and 2017 Bering Sea shelf survey data. The 2017 biomass estimates from the EBS shelf survey for the aggregate skate complex increased from 4% from 2016. In the case of Alaska skates, survey biomass estimates decreased slightly from 2016, though variable, are basically trendless since species identification began in 1999.

No changes were made to the assessment model in the partial assessment. The projection model for Alaska skate was re-run with the most recent catch data. The 2017 EBS shelf survey data were presented in the chapter for informational purposes but were not used for status determination since the Tier 5 random effects model was not re-run for the ”other skates” component of the assemblage. Model estimates of Alaska skate total biomass have declined for the last three years that the model covers (1992-2016). Since 2011, the Alaska skate portions of the ABC and OFL have been specified under Tier 3, while the “other skates” portions have been specified under Tier 5. Because the projected spawning biomass for 2018 (107,136 t) exceeds $B_{40\%}$ (72,222 t), Alaska skates are managed in sub-tier “a” of Tier 3. Other reference points are $maxF_{ABC} = F_{40\%} = 0.079$ and $F_{OFL} = F_{35\%} = 0.092$. The Alaska skate portions of the 2018 and 2019 ABCs are 31,572 t and 29,447 t, respectively, and the Alaska skate portions of the 2018 and 2019 OFLs are 36,655 t and 34,189 t. The “other skates” component is assessed under Tier 5, based on a natural mortality rate of 0.10 and a biomass estimated using the random effects model. The “other skates” portion of the 2018 and 2019 ABCs is 7,510 t for both years and the “other skates” portion of the 2017 and 2018 OFLs is 10,013 t for both years.

For the skate complex as a whole, OFLs for 2018 and 2019 total 46,668 t and 44,202 t, respectively, and ABCs for 2018 and 2019 total 39,082 t and 36,957 t, respectively. Alaska skate, which may be viewed as an indicator stock for the complex, is not overfished and is not approaching an overfished condition. The skate complex is not being subjected to overfishing.

Gulf of Alaska

Skates are assessed on a biennial schedule with full assessments presented in odd years to coincide with the timing of survey data. A full assessment was completed for 2017. There were no changes in methodology but possible shifts in distribution were explored more thoroughly.

The 2017 survey biomass estimates for big skates declined substantially from 2015, there were fewer large-sized big skates encountered in the survey and fisheries with more small big skates in CGOA and fewer in EGOA. The biomass of the Other Skates declined also, mostly in the CGOA. The longnose skate biomass estimates increased from 2015 to 2017 with estimates increasing in the WGOA and CGOA. Fewer large-sized big skates were caught in the survey and in the fisheries during 2016 and 2017; the population is dominated by smaller individuals. Also, there may be shifts in abundance of big skates to the CGOA from EGOA. For longnose skates, they seem to have moved shallower in the water column. New inputs this year were the biomass estimates and length composition data from the 2017 GOA bottom trawl survey, updated groundfish fishery catch data, and fishery length composition data through 2017. The application of the RE model to the survey data for each skate category continues to provide reasonable results for biomass estimates.

The catches of big skates are substantially lower than in the years preceding 2014 (particularly 2009-2013). This decrease likely is due to prohibitions on retention of big skates in the CGOA (beginning in 2013), which discouraged "topping-off" behavior that resulted in high levels of catch, particularly for big skates in the CGOA. In January 2016, the Alaska Regional Office indefinitely reduced the maximum retainable amount for all skates in the GOA. Skates are managed in Tier 5. Applying M=0.1 and 0.75*M to the estimated biomass from the random effects models for each stock component, gives stock specific OFLs and ABCs. This approach was also used in the 2016 assessment. Catch as currently estimated does not exceed any gulf-wide OFLs, and therefore, none of the skate stocks are subject to overfishing. It is not possible to determine the status of stocks in Tier 5 with respect to overfished status.

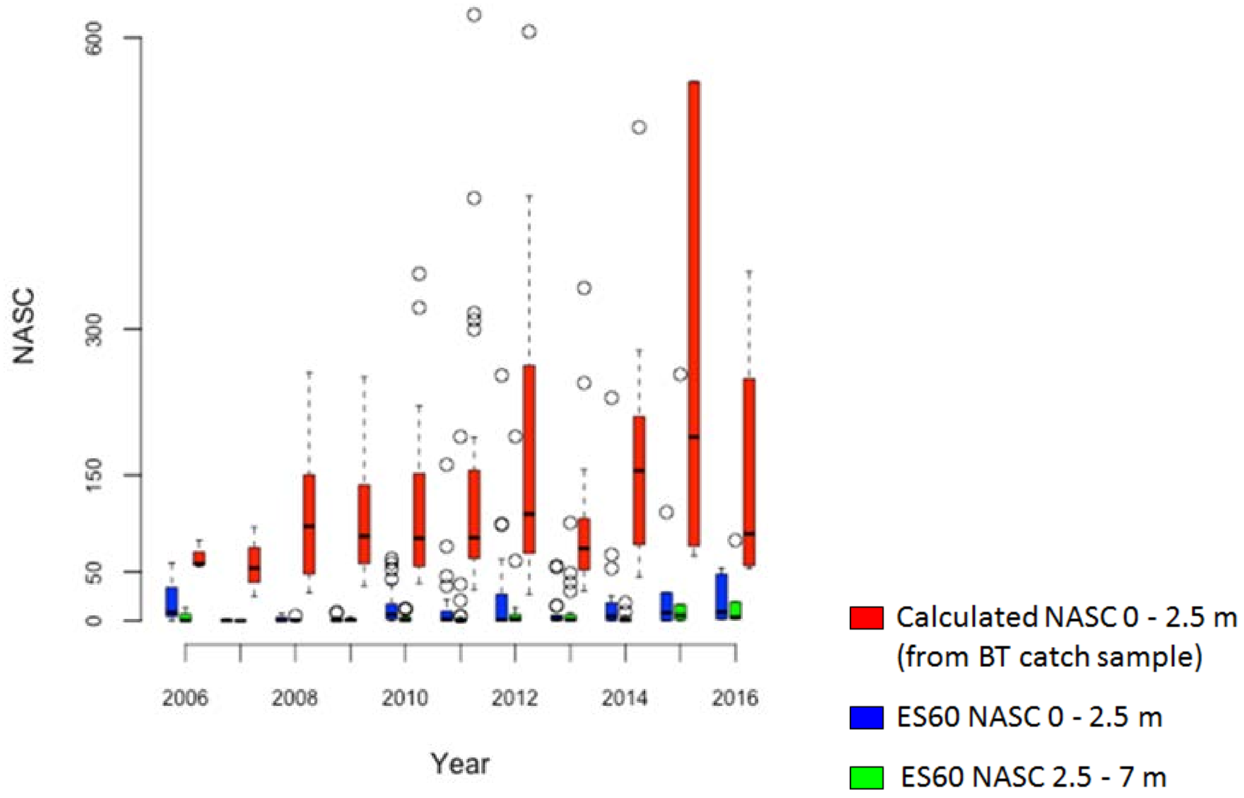
The assessment continued the use of the random effects (RE) model to estimate survey biomass for each managed group and for each regulatory area. Big and longnose skates have area-specific ABCs and gulf-wide OFLs; other skates have a gulf-wide ABC and OFL.

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

D. Pacific Cod

1. Research

Examining the no-vertical-response assumption of Pacific cod to survey bottom trawls--GAP
Pacific cod stock assessment assumes a catchability of 47.3% (fish length = 60 – 81 cm) in the Bering Sea. This value was based upon an archival tag study (Nichol et al, 2007). Ten years of acoustic data gathered during summer Bering Sea Shelf surveys have been analyzed to investigate the assumption of a 'no-vertical-response' of Pacific cod to vessel noise or oncoming net. Acoustic data consist of calibrated 38 kHz Simrad ES60 echosounder data, corresponding to trawl catches exceeding 100 kg of Pacific cod, where other air-bladdered fish were <15% by weight. Nautical area scattering coefficients (NASC) values calculated for the 0 – 2.5 m regions of each tow were compared to those from 2.5 – 7 m regions. There is no empirical evidence to support a no-vertical-response assumption in Pacific cod in the Bering Sea.



For further information, contact Elaina Jorgensen, (206)526-4562, Elaina.Jorgensen@noaa.gov.

Climate Change and Location Choice in the Pacific Cod Longline Fishery-REFM/ESSR

Alan Haynie* and Lisa Pfeiffer

**For further information, contact Alan.Haynie@NOAA.gov*

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. This manuscript is being revised and will be submitted to a scientific journal in December 2016.

2. Stock Assessment

Bering Sea

Survey abundance in 2017 (346,693,000 fish) unexpectedly declined by 46% from 2016 (640,359,000 fish) and biomass in 2017 (598,260 t) was 37% less than in 2016 (944,621 t). In the 2016 assessment, the female spawning biomass was expected to increase. The following changes were made to the input data for the EBS Pacific cod assessment.

For the 2017 assessment, catch data for 1991-2016 were updated, and preliminary catch data for 2017 were incorporated. The commercial fishery size composition data for 1991-2016 were updated, and preliminary size composition data from the 2017 commercial fishery were incorporated. Size composition data from the 2017 EBS shelf bottom trawl survey were incorporated and the numeric abundance estimate from the 2017 EBS shelf bottom trawl survey were added (the 2017 estimate of 347 million fish was down about 46% from the 2016 estimate). Age composition data from the 2016 EBS shelf bottom trawl survey were incorporated. Age composition data from the 2013-2016 fisheries were also incorporated into some of the models.

Many changes have been made or considered in the stock assessment model since the 2016 assessment. Ten models were reviewed by the BSAI Plan Team Subcommittee on Pacific Cod Models at its June meeting, and seven models were presented in this year's preliminary assessment as requested at the conclusion of the June Subcommittee meeting. After reviewing the preliminary assessment, the BSAI Plan Team and SSC requested that a number of models from the preliminary assessment and one new model be presented in this final assessment. The model used in setting harvest specifications for 2018 and 2019 is unchanged from the previous year.

As estimated in the present model, spawning biomass is above $B_{40\%}$ and has been increasing since 2009 due to a number of strong year-classes beginning in 2006. However, spawning biomass is projected to begin declining again in the near future.

The Bering Sea Pacific cod stock is assigned to Tier 3a. The maximum 2018 ABC in this tier as calculated using the present model fit is 201,000 t, however, the Plan Team recommended the ABC be reduced to 188,000 t due to concerns related to the dramatic declines in the EBS shelf survey index, recent poor environmental conditions, lack of incoming recruitment, and recent small size-at-age of young Pacific cod . An ABC of 170,000 t was recommended for the preliminary 2019 ABC. The 2018 OFL from this new calculation is 238,000 t, which is less than the projected OFL from the previous assessment. The 2019 projected OFL is 201,000 t. The EBS Pacific cod stock is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

Gulf of Alaska

Both the longline survey and trawl survey indices in 2017 had unexpected, steep declines. The 2017 trawl survey biomass estimate was the lowest in the time series and was 58% lower than the 2015 estimate. The longline survey RPN dropped 53% from 2016 to 2017. The 2016 assessment projected an 8% increase in female spawning biomass for 2017.

New information for the assessment included: The fishery catch data was updated for 2016 and 2017 (projected 2017 catch). Fishery size composition data were updated for 2016, preliminary fishery size composition were included for 2017, and weight and age at length and age compositions for the 2015 bottom trawl survey were included. The AFSC 2017 longline and bottom trawl survey indices of abundance and their corresponding length composition data were also included. Length composition data from ADF&G port sampling program were used to augment pot fishery catch composition data where observer data were not present.

The author evaluated several models and presented a subset of models that included the model configuration from 2016 with updated data. Model 17.08.35 was recommended by the author as it had the best fit to the data and had reasonable retrospective patterns. A major feature of this model that differed from last year's model was having natural mortality (M) estimated in two time blocks; 1) 1977-2014 and 2017 and 2) 2015 and 2016. This feature allowed the model to fit the recent steep declines in the longline and trawl survey indices of abundance that was likely due to temperature related mortality. The protracted warm conditions from 2014-2016 may have resulted in increased metabolic demands for Pacific cod that potentially lead to starvation and mortality. The estimate of M=0.49 during the 1977–2014 and 2017 block was similar to Model 17.08.25 (M=0.47). The estimate of M was 0.71 for the 2015-2016 block.

Another feature of this model was specifying the AFSC longline RPN index to be conditioned on water temperature. This feature allowed the model to be consistent with changing availability of small fish to the longline survey due to bottom temperatures. Smaller fish are encountered more frequently in this survey in warm years than in cold years.

The $B_{40\%}$ estimate was 67,433 t, with projected 2018 spawning biomass of 36,209 t. Recruitment was generally above average for the 2005-2012 period and below average for 2013-2016. Spawning biomass is expected to decline sharply in the near future.

This stock is in Tier 3b because the 2018 spawning biomass is estimated to be at B21%. The F35% and F40% values are 0.82 and 0.66, respectively. The Tier 3b FOFL and FABC values are 0.42 and 0.34, respectively. The OFL is 23,565 t and the maximum permissible ABC is 19,401 t. The authors recommended that the FABC value be reduced to 0.31 to help ensure that the stock stays above the B20% value. If the Pacific cod stock is projected to be equal to or below B20%, directed fishing is prohibited due to Steller sea lion regulations. The Plan Team concurred with the author's recommended ABC and OFL values. The recommended ABC is 18,000 t for 2018 which is an 80% decrease from the 2017 ABC of 88,342 t. The stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

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

Average Energy Content (AEC; kJ/fish) is the product of the average individual mass and average energy density of age-0 Walleye Pollock (*Gadus chalcogrammus*; hereafter pollock) collected during the late-summer BASIS survey in the southeastern Bering Sea (SEBS). Fish were collected from surface trawls in all years except 2015 when oblique (water column) trawls were used. The average individual mass is calculated by dividing the total mass by the total number of age-0 pollock caught in each haul. The average energy density is estimated in the laboratory from multiple (2-5) fish within ± 1 standard deviation of the mean length (see Siddon et al., 2013a for detailed methods). The haul-specific energy value is weighted by catch to estimate average energy density per station. The product of the two averages represents the average energy content for an individual age-0 pollock in a given year.

We relate AEC to the number of age-1 recruits per spawner (R/S) using the index of adult female spawning biomass as an index of the number of spawners. Relating the AEC of age-0 pollock to year class strength from the age-structured stock assessment indicates the energetic condition of pollock prior to their first winter predicts their survival to age-1.

Energy density (kJ/g), mass (g), and standard length (SL; mm) of age-0 pollock have been measured annually since 2003 (except 2013 when no survey occurred). Over that period, energy density has varied with the thermal regime in the SEBS. Between 2003 and 2005 the SEBS experienced warm conditions characterized by an early ice retreat. Thermal conditions in 2006 were intermediate, indicating a transition, and ice retreated much later in the years 2007-2013 (i.e., cold conditions). Warm conditions returned in 2014 through late-summer 2016.

The transition between warm and cold conditions is evident when examining energy density over the time series (Fig. 1). Energy density was at a minimum in 2003 (3.63 kJ/g) and increased to a maximum of 5.26 kJ/g in 2010. In contrast, the size (mass or length) of the fish has been less influenced by thermal regime. The AEC of age-0 pollock in 2003-2015 accounts for 25% of the variation in the number of age-1 recruits per spawner (Fig. 2). Strong year classes occurred in 2008 and 2012 and this indicator does not capture those events well. With 2008 and 2012 removed from the model, the AEC accounts for 59% of the variability in age-1 survival (Fig. 2).

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 (Heintz and Vollenweider, 2010) as well as prey conditions during the age-0 period. Late summer represents a critical period for energy allocation in age-0 pollock (Siddon et al., 2013a) and their ability to store energy depends on water temperatures, prey quality, and foraging costs (Siddon et al., 2013b).

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 (Hunt et al., 2011). Zooplankton taxa available in cold years are generally higher in lipid content, affording age-0 pollock a higher energy diet than that consumed in warm years. Lower water temperatures also optimize their ability to store lipid (Kooka et al., 2007).

The full model (all years) indicates that the 2016 year-class is predicted to have above average survival to age-1, while the constrained model (2008 and 2012 removed) predicts intermediate survival comparable to that of the 2014 and 2015 year classes. The SEBS experienced warm conditions through late-summer 2016, although age-0 pollock in 2016 seem to have mitigated harsh environmental conditions by utilizing the cold pool (which may act as a thermal refuge) and consuming more lipid-rich euphausiid prey (Duffy-Anderson et al., 2017).

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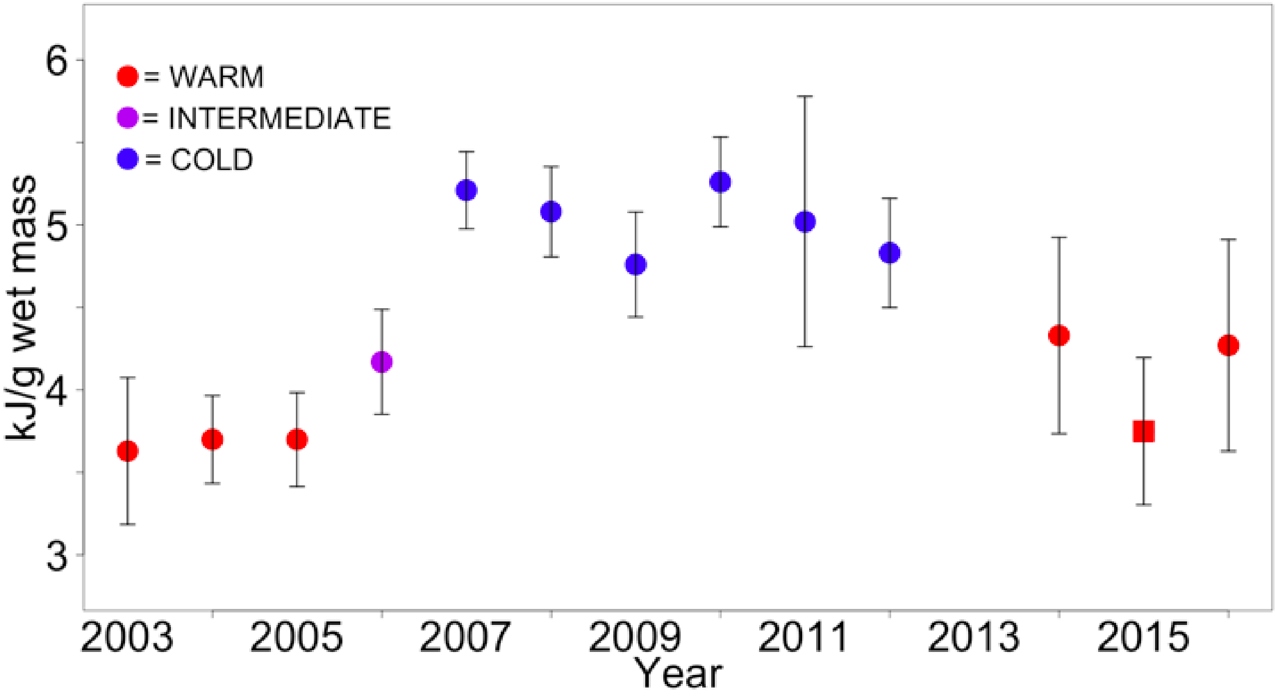

Figure 1. Average energy density (kJ/g) of age-0 Walleye pollock (*Gadus chalcogrammus*) collected during the late-summer BASIS survey in the eastern Bering Sea 2003-2016. Fish were collected with a surface trawl in all years except in 2015 when an oblique trawl was used.

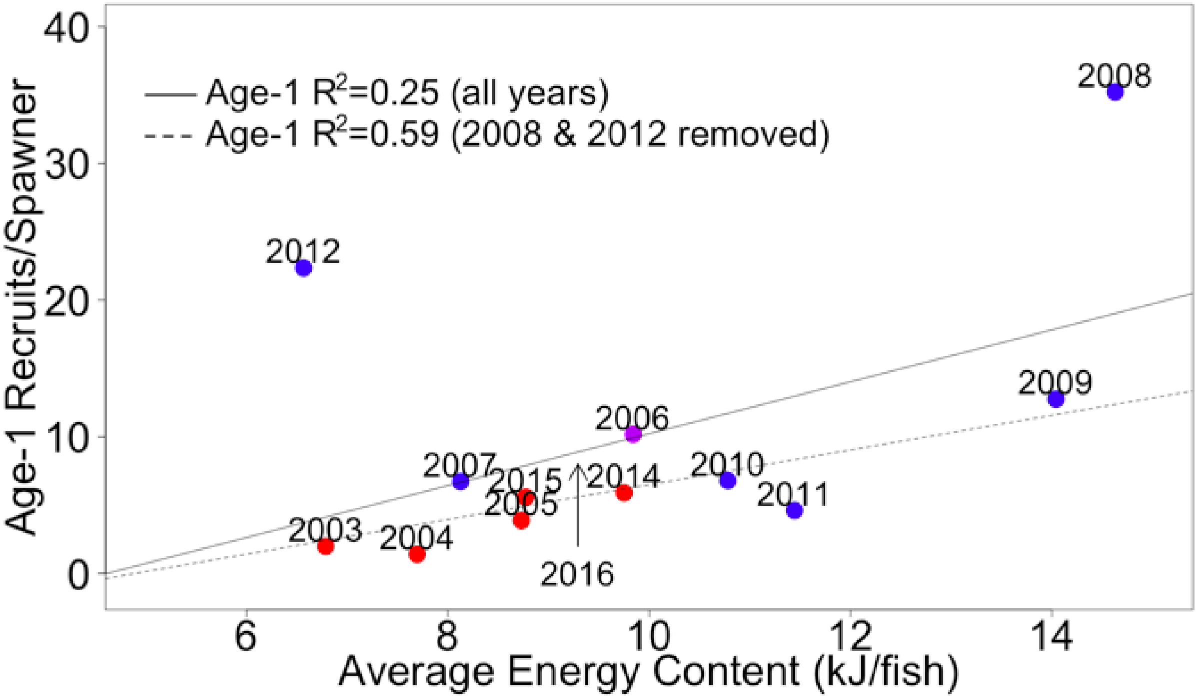

Figure 2. Relationship between average energy content (AEC) of individual age-0 Walleye pollock (*Gadus chalcogrammus*) and the number of age-1 recruits per spawner from the 2016 stock assessment (Ianelli et al., 2016). Fish were collected with a surface trawl in all years except in 2015 when an oblique trawl was used.

For more information, contact Elizabeth Siddon (907) 789-6055, Elizabeth.Siddon@noaa.gov

Spatial Overlap of Age-0 Walleye Pollock and Foraging Landscapes Predicts Survival and Recruitmet Success - ABL

Age-0 Walleye pollock (*Gadus chalcogrammus*) abundance was estimated from the Bering-Arctic-Subarctic Integrated Survey (BASIS) conducted during late summer in 2003-2014. Zooplankton was sampled contemporaneously and provides information on available foraging landscapes. Year-, station-, and taxa-specific zooplankton biomass were weighted by year (or stanza)- and taxa-specific lipid values in order to determine spatially explicit estimates of prey availability.

The spatial overlap between age-0 pollock and prey availability was quantified using the Proportional Similarity Measure (Slobodchikoff and Schulz 1980) (Fig. 1). Index values range from 0-1, with higher values indicating greater proportion of overlap between age-0 pollock and lipid-rich zooplankton prey. This index of spatial overlap forecasts pollock cohort strength (as age-1 recruits per spawner; Ianelli et al. 2016) and indicates that different mechanisms may govern survival in warm versus cold years (Fig. 2).

The eastern Bering Sea experienced above-average (warm) conditions characterized by an early ice retreat and small or retracted cold pool between 2003-2005. Thermal conditions in 2006 were intermediate, indicating a transition, and ice retreated much later in the years 2007-2013 (i.e., cold conditions). Warm conditions returned in 2014. No clear pattern exists between the index of spatial overlap and thermal conditions (Fig. 1). However, a strong correlation between the overlap index and recruitment exists by climate stanza (warm versus cold years). In warm years (2003-2005, 2014), the overlap with lipid-rich prey accounts for 93% of the variation in the number of age-1 recruits per spawner. In cold years (2007-2012), overlap explains 68% of the variability (Fig. 2).

In the eastern Bering Sea, bottom-up processes shape foraging landscapes that ultimately determine the energetic condition and overwinter survival of age-0 pollock (Heintz et al., 2013). Additionally, timing of sea ice retreat and the spatial extent of the cold pool affect the distribution of age-0 pollock and also impact the distribution of adult pollock and other predators (e.g., Arrowtooth flounder, *Atheresthes stomias*) (Hollowed et al., 2013).

Multiple-year climate stanzas of warm conditions precipitate a trophic cascade that leads to a restructuring of the prey base, reduced energetic condition of age-0 pollock, and reduced overwinter juvenile pollock survival success (Duffy-Anderson et al., 2017). Under cold conditions, zooplankton prey are both larger and more lipid-rich; juvenile pollock are better provisioned going into winter; and have greater overwinter survival (Heintz et al., 2013). Therefore, survival (and subsequent recruitment) of age-0 pollock may be governed by different mechanisms in warm (bottom-up) and cold (bottom-up and top-down) years.

The spatial overlap of age-0 pollock and foraging landscapes helps to explain recruitment variability in the eastern Bering Sea. During periods of warm conditions, bottom-up processes affecting prey availability and condition (i.e., lipid content) appear to have a greater influence on survival and recruitment strength. Under cold conditions, bottom-up processes are important, while top-down processes that delineate the spatial overlap with predators also contribute.

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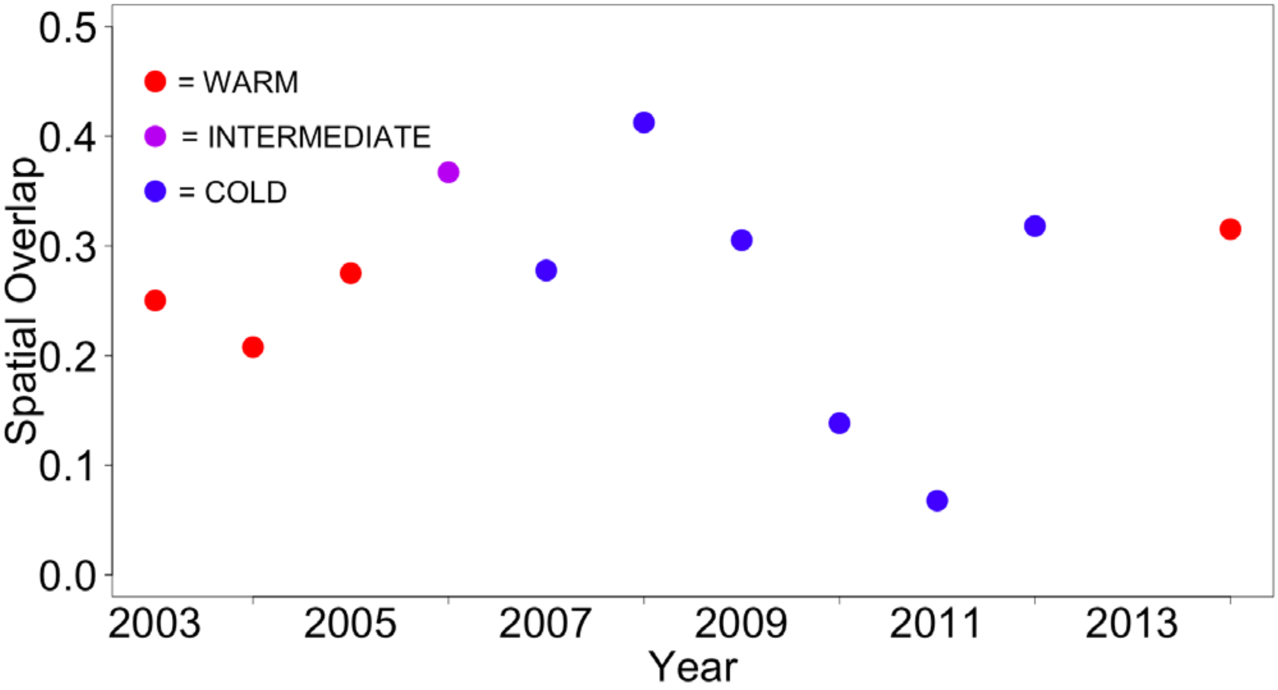

Figure 1. Index of spatial overlap for 2003 – 2014 (no survey in 2013). Values range 0-1 with higher values indicating greater proportion of overlap between age-0 Walleye pollock (*Gadus chalcogrammus*) and available zooplankton prey.

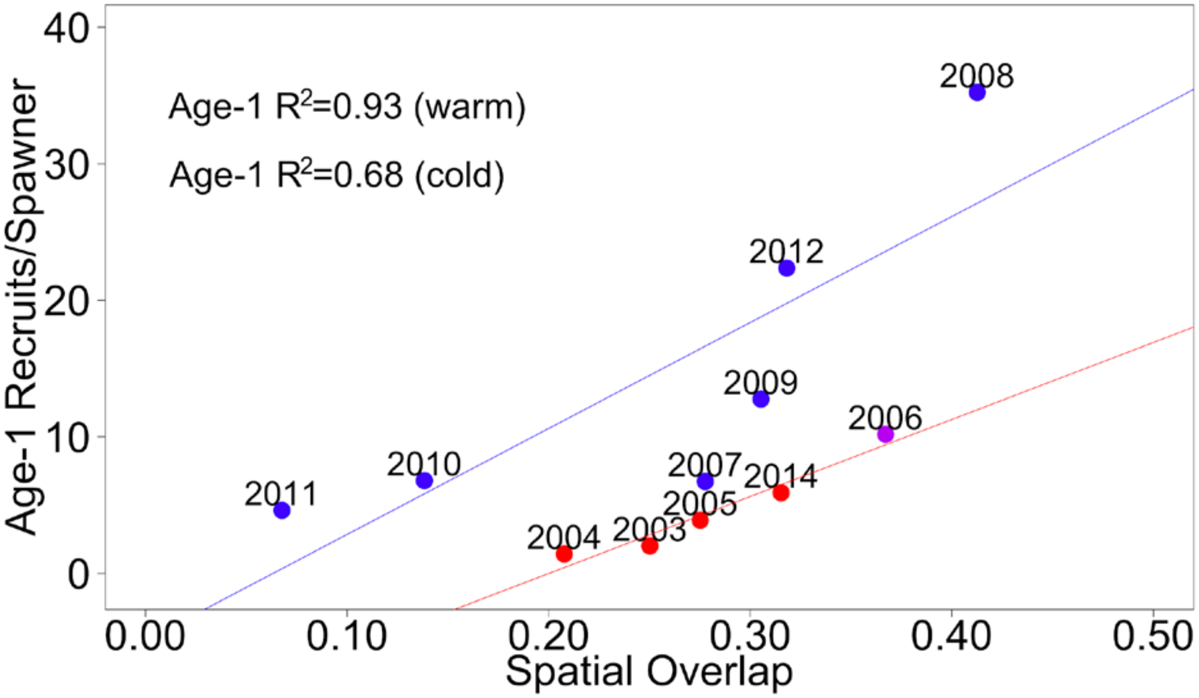

Figure 2. Relationship between the index of spatial overlap and the number of age-1 recruits per spawner from the 2016 stock assessment (Ianelli et al., 2016). The intermediate year (average thermal conditions; 2006) was not included in either relationship. No survey occurred in 2013.

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

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

Status and trends: The 2017 TC index value is -6.16, lower than the 2016 TC index value of -3.19, indicating a decrease in conditions for pollock survival from age-0 and age-1 from 2016 to 2017, respectively. The decrease in expected survival is due to the larger difference in sea temperature from late summer (warmer) to the following spring (cooler). However, both the late summer sea surface temperature (13.0 °C) in 2016 and spring sea temperatures (6.4 °C) in 2017 were warmer than the long-term average of 9.7 °C in late summer and 5.1 °C in spring since 1949. The TC index was positively correlated with subsequent recruitment of pollock to age-1 through age-4 from 1964 to 2016, but not significantly correlated for the shorter period (1995-2016).

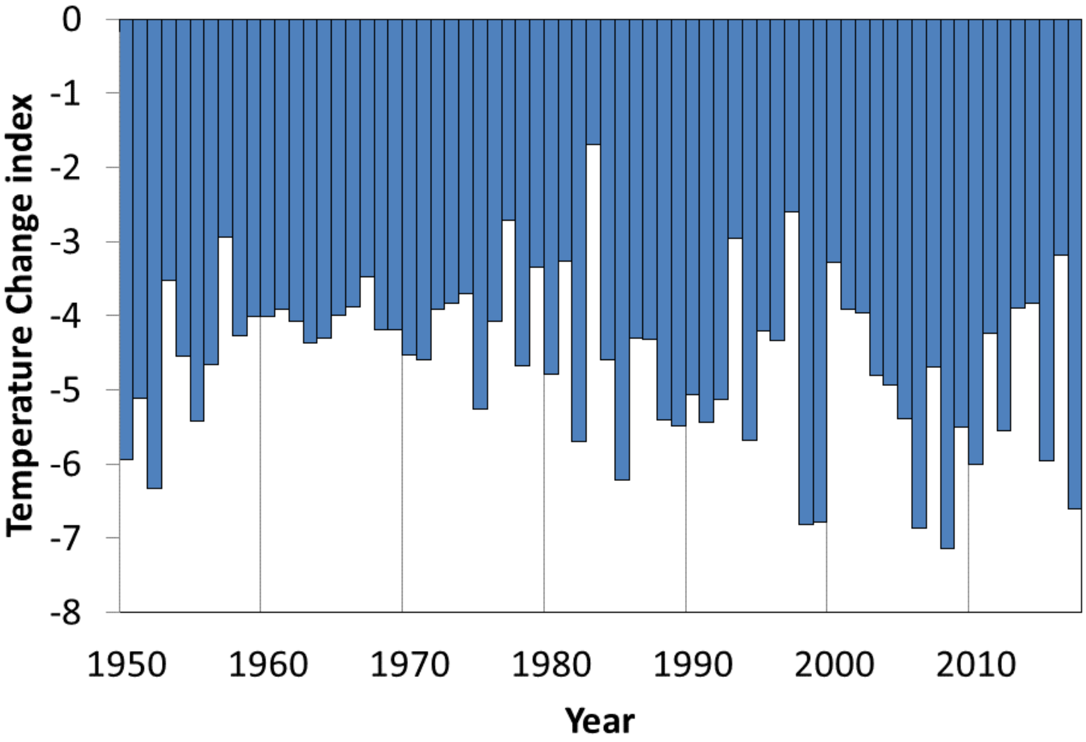

Figure 1: The Temperature Change index values from 1949 to 2017.

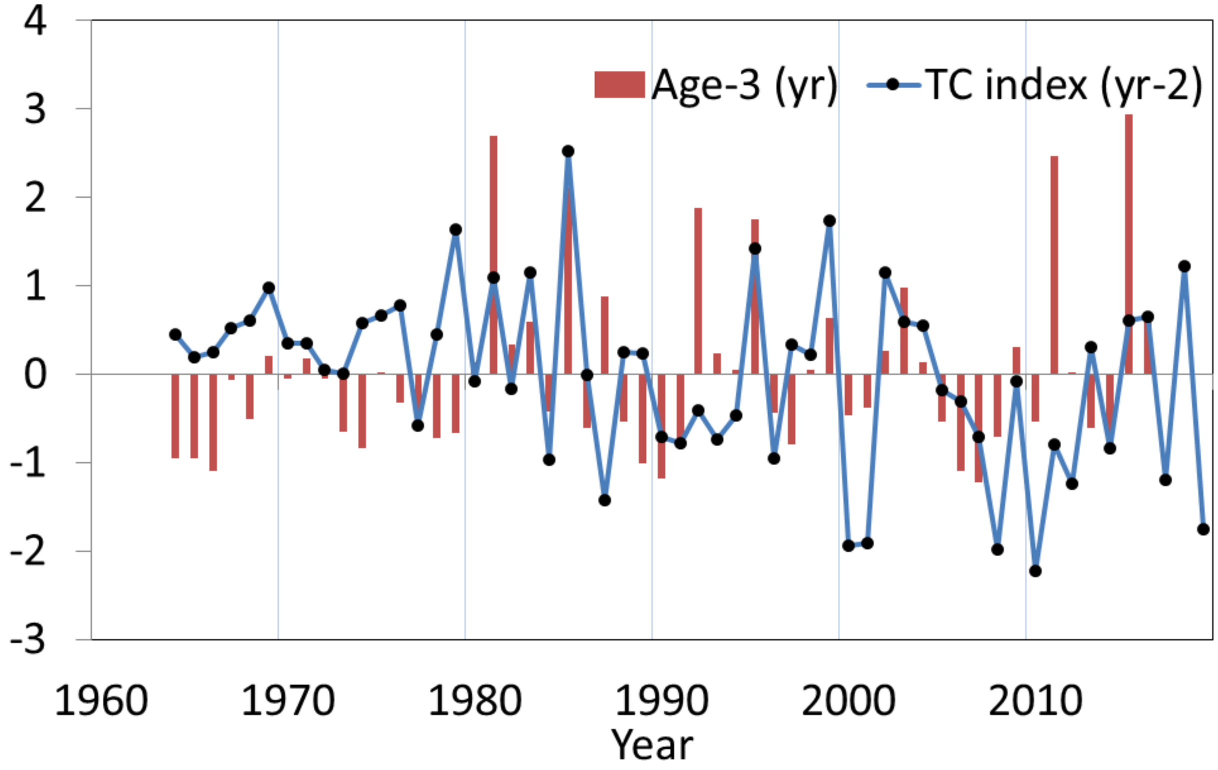

Figure 2: Normalized time series values of the temperature change index (t-2) from 1964-2019 indicating conditions experienced by the 1961-2016 year classes of pollock during the summer age-0 and spring age-1 life stages. Normalized values of the estimated abundance of age-3 walleye pollock in the eastern Bering Sea from 1964-2016 (t) for the 1961-2013 year classes. Age-3 walleye pollock estimates are from Table 1.30 in Ianelli et al. 2016. The TC index indicate above average conditions for the 2015 year class and below average conditions for the 2014 and 2016 year classes of pollock.

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
1964-2015	**0.34**	**0.34**	**0.32**	0.27	0.23	0.21
1996-2015	0.35	0.31	0.31	0.38	0.37	0.36

Factors causing observed trends: According to the original Oscillating Control Hypothesis, warmer spring temperatures and earlier ice retreat led to a later oceanic and pelagic phytoplankton bloom and more food in the pelagic waters at an optimal time for use by pelagic species (Hunt et al., 2002). The revised OCH indicated that age-0 pollock were more energy-rich and have higher over wintering survival to age-1 in a year with a cooler late summer (Coyle et al., 2011; Heintz et al., 2013). Therefore, the colder later summers during the age-0 phase followed by warmer spring temperatures during the age-1 phase are assumed favorable for the survival of pollock from age-0 to age-1. The 2016 year class of pollock experienced a warm summer during the age-0 stage and a cool spring in 2017 during the age-1 stage indicating poor conditions for over wintering survival from age-0 to age-1.

*Implications***:** 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. The 2015 TC index value of -5.96 was below the long-term average, therefore we expect slightly below average recruitment of pollock to age-3 in 2017 from the 2014 year class.

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

Large zooplankton abundance as an indicator of pollock recruitment to age-1 and age-3 in the southeastern Bering Sea - ABL

Description of indicator: Interannual variations in large zooplankton abundance (sum of most abundant large taxa, typically important in age 0 pollock diets, Coyle et al. 2011) were compared to age-1 and age-3 walleye pollock (*Gadus chalcogrammus*) abundance (millions of fish for the 2002-2014 year classes on the southeastern Bering Sea shelf (south of 60°N, < 200 m bathymetry). Zooplankton samples were collected with oblique bongo tows over the water column using 60 cm, 505 µm mesh nets for 2002-2011 data, and 20 cm, 153 µm mesh and 60 cm, 505 µm nets, depending on taxa, for 2012, 2014, and 2015 data. Taxa included in the index are large copepods (copepodite stage 3-adult), *Calanus marshallae/glacialis*, *Eucalanus bungii*, *Metridia pacifica*, and *Neocalanus* spp., the chaetognath, *Parasaggita elegens*, and the pteropod, *Limacina helicina* (505 µm net only). Data were collected on BASIS fishery oceanography surveys during mid-August to late September, for four warm years (2002-2005) followed by one average (2006), six cold (2007-2012) and two warm years (2014 and 2015) using methods in Eisner et al. (2014). Zooplankton data was not available for 2013. Pollock abundance was available from the stock assessment report for the 2002-2015 year classes (Ianelli et al., 2016).

Status and trends: A positive significant (P = 0.002) linear relationship was found between mean abundances of large zooplankton during the age-0 stage of pollock and stock assessment estimates of abundance of age-1 pollock for the 2002-2015 year classes and age-3 pollock for the 2002-2013 year classes and of age-1 from Ianelli et al. (2016) (Figure 1).

For the prediction of age-1 pollock abundance, a model relating zooplankton abundance to the stock assessment estimates of the abundance of age-1 pollock for the 2002-2014 year classes () and large zooplankton abundance in 2015 (32.75) predicted 9,895 million (standard error =4,619 million) age-1 pollock in 2016 from the 2015 year class, below age-1 pollock abundance for the time series. For the prediction of age-3 pollock abundance, a model relating zooplankton abundance (2002-2012) to the stock assessment estimates of the abundance of age-3 pollock in 2005-2015 for the 2002-2012 year classes () and large zooplankton abundance in 2014 (185) predicted 8,389 million (standard error =1,1816 million) age-3 pollock in 2017 from the 2014 year class, average abundance for the time series. The model and large zooplankton abundance in 2015 (32.75) predicted 2,704 million (standard error=1,188 million) age-3 pollock in 2018 from the 2015 year class, below average abundance for the time series.

Factors influencing observed trends: Increases in sea ice extent and duration were associated with increases in large zooplankton abundances on the shelf (Eisner et al., 2014, 2015), increases in large copepods and euphausiids in pollock diets (Coyle et al., 2011) and increases in age-0 pollock lipid content (Heintz et al., 2013). The increases in sea ice and associated ice algae and phytoplankton blooms may provide an early food source for large crustacean zooplankton reproduction and growth (Baer and Napp 2003; Hunt et al., 2011). These large zooplankton taxa contain high lipid concentrations (especially in cold, high ice years) which in turn increases the lipid content in their predators such as age-0 pollock and other fish that forage on these taxa. Increases in energy density (lipids) in age-0 pollock allow them to survive their first winter (a time of high mortality) and eventually recruit into the fishery. Accordingly, a strong relationship has been shown for energy density in age-0 fish and age-3 pollock abundance (Heintz et al., 2013).

Implications: Our results suggest that decreases in the availability of large zooplankton prey during the first year at sea in 2015 were not favorable for age-0 pollock survival and recruitment to age 1 and 3. If the relationship between large zooplankton and age 3 (age 1) pollock remains significant in our analysis, the index was used to predict the recruitment of pollock three (one) years in advance of recruiting to age 3 (age 1), from zooplankton data collected three (one) years prior. This relationship also provides further support for the revised oscillating control hypothesis that suggests as the climate warms, reductions in the extent and duration of sea ice could be detrimental large crustacean zooplankton and subsequently to the pollock fishery in the southeastern Bering Sea (Hunt et al., 2011).

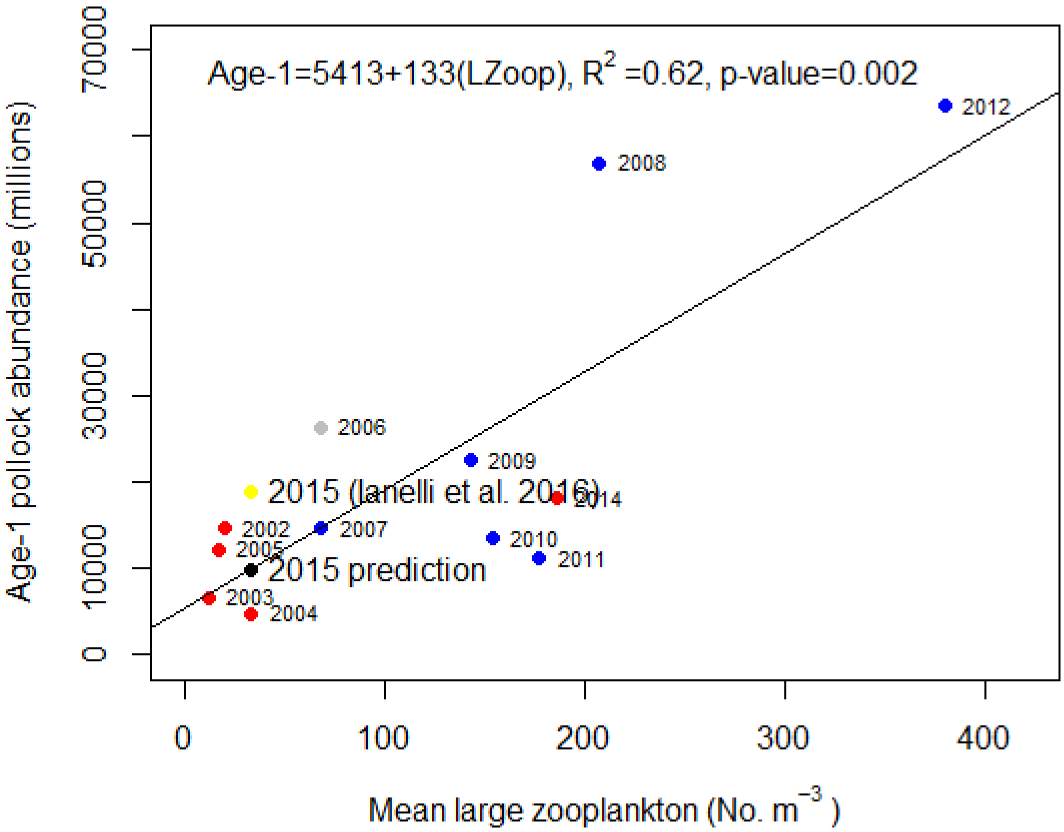

Figure 1. Linear relationships between mean large zooplankton abundance during the age-0 life stage of pollock and the estimated abundance of age-1 pollock abundance of the year class (2002-2015) from Ianelli et al. (2016). In the age-1 figure, the 2015 points are the “observed” stock assessment estimates of age-1 pollock from Ianelli et al. (2016) and the predicted numbers of age-1 pollock from our regression model and the large zooplankton values for 2015 (32.75). Points are labeled with year class. Red points are warm (low ice) years, blue are cold (high ice) years, gray is an average year and black is the predicted 2014 and 2015 year classes value from the model. No

zooplankton data was available for 2013.

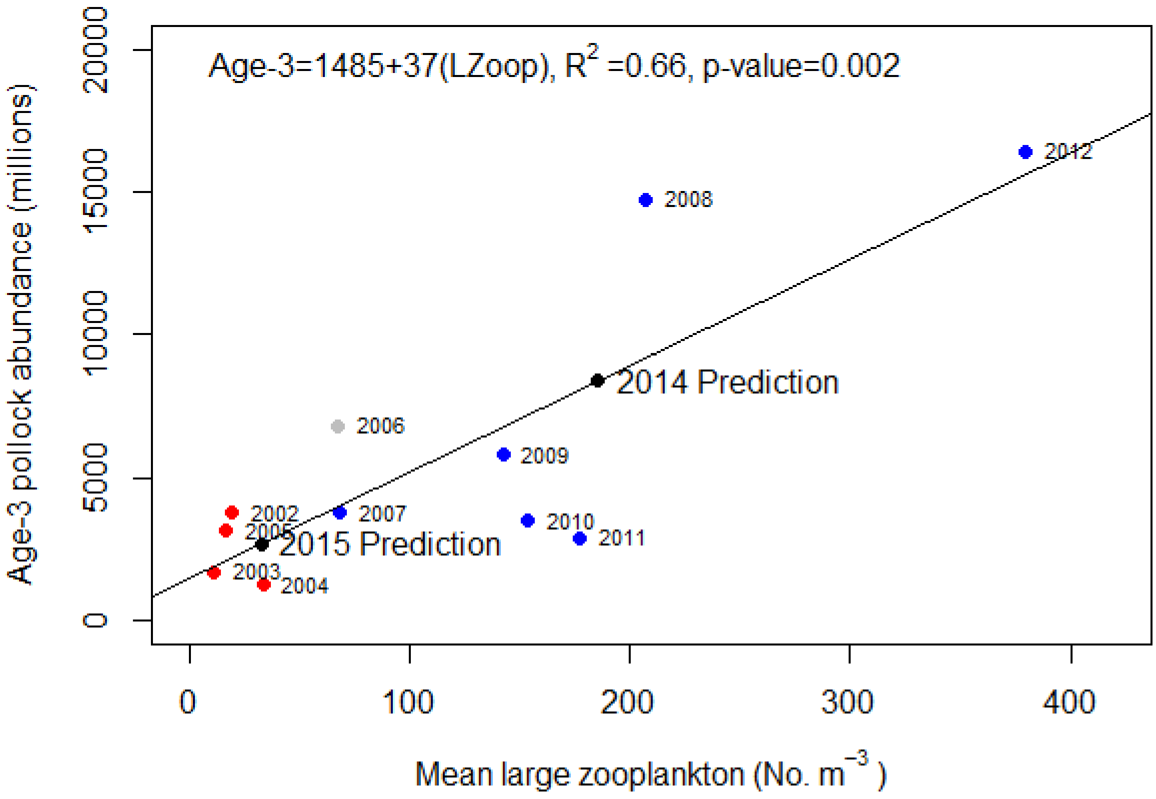

Figure 2. Fitted values and standard errors of the abundance of pollock estimated from the linear regression model relating the estimate pollock abundance from Ianelli et al. (2016) to the estimated abundance of large zooplankton the southeast Bering Sea during the age-0 life stage of pollock. Red symbols are stock assessment estimates of pollock abundance from Ianelli et al. (2016). Our regression models parameters and estimated abundance of large zooplankton in 2014 predicted an abundance of 9,805 million age-1 pollock with a standard error of 4,619 million for the 2014 year class and an abundance of 8,389 million age-3 pollock with a standard error of 1,116 million (blue) for the 2014 year class and 2,704 million age-3 pollock with a standard error of 1,188 million for the 2015 year class (blue).

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For more information contact Lisa Eisner at (206) 526-4060, lisa.eisner@noaa.gov

RACE Recruitment Processes Program (RPP)

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

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

Gulf of Alaska

Shifting Spawn Timing in Gulf of Alaska Walleye Pollock - RPP

Lauren Rogers and Annette Dougherty

The timing of spawning in marine fishes is key for delivering larval offspring to suitable habitats at a time when sufficient prey are available. While spawning time is relatively fixed in some species, others show flexibility depending on thermal conditions, as well as variation among individuals within a population. Such interannual and intrapopulation variation in spawn timing can have consequences for match or mismatch of first-feeding larvae with production of prey, and subsequent recruitment success. We used 30+ years of data from larval surveys to reconstruct timing of walleye pollock spawning in Shelikof Strait, the primary pollock spawning grounds in the Gulf of Alaska. We then considered potential climatic and demographic drivers of changes in spawn timing for this stock.

Ichthyoplankton surveys have been conducted by the NOAA AFSC EcoFOCI program on an annual or biennial basis since 1979, specifically targeting offspring of pollock spawning in Shelikof Strait, and focused in late-May. From these surveys, hatch dates of larvae were back-calculated by using information on larval size-at-age (from otoliths), larval length distributions, CPUE, and a mortality correction (Bailey et al. 1996) to account for different ages of larvae caught during the surveys. Spawn dates were back-calculated from hatch dates using temperature-dependent egg development rates (Blood, Matarese and Yoklavich 1994).

We found evidence that the mean date of spawning has varied by three weeks over the last three and a half decades. Most of the interannual variation in mean spawn date can be explained by mean age of the spawning stock and temperature during spawning, with an older spawning stock and warmer temperatures leading to early spawning. Duration of the spawning season also increased in warmer years and when the spawning stock was older, which has the potential to reduce recruitment variability through a portfolio effect (i.e. though a broader distribution of larval hatch dates). These results demonstrate that both climate conditions and demography influence spawn timing in walleye pollock, with further implications for the winter prespawning survey and the roe fishery.

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For more information, contact Lauren Rogers at Lauren.Rogers@noaa.gov

Otolith chemistry of juvenile walleye pollock *Gadus chalcogrammus* in relation to regional hydrography: evidence of spatially split cohorts - RPP

Matthew T. Wilson, Annette Dougherty, Mary Elizabeth Matta, Kathryn L. Mier, and Jessica A. Miller

Spatial and temporal variation in production is fundamental to the ecology and management of marine fish populations. Within populations, a cohort (year class) can be structured spatially into contingents that occupy different habitat and contribute differently to overall population productivity, stability, and resilience to environmental change. Spatial structure has been suggested within populations of walleye pollock, which support some of the world’s largest fisheries. We demonstrate, using otolith microchemistry, that Age-0 juveniles from habitats that differ in exposure to the Alaska Coastal Current, within the western Gulf of Alaska, were separated for ≥3-7 weeks prior to collection (Figure 1). The duration of spatial separation explained demographic differences in growth rate and body size between the Kodiak and Semidi populations. We hypothesize that the existence of a Kodiak contingent buffers the western GOA population against losses due to density-dependent mechanisms in and downstream transport from the putative main nursery, which is inhabited by the Semidi contingent.

Wilson et al. (2018) Mar Ecol Prog Ser 588:163-178 (https://doi.org/10.3354/meps12425).

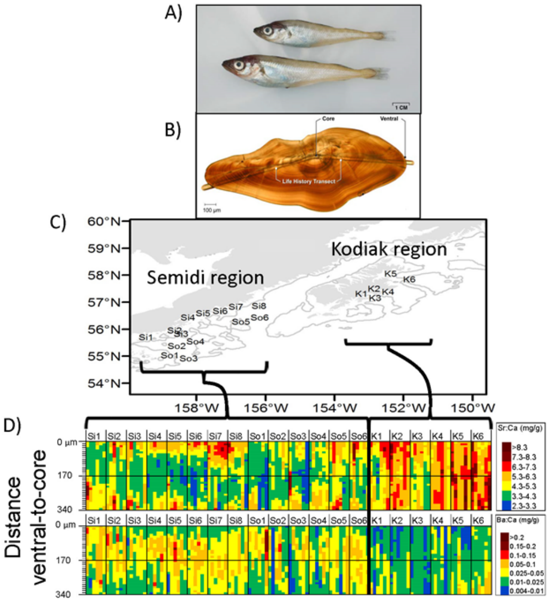

Figure 1. Age-0 walleye pollock (A) saccular otoliths (i.e. sagittae) (B) were collected from the western Gulf of Alaska during October 2011 (C) to examine element ratios along otolith life history transects. For Sr:Ca (D, top) and Ba:Ca (D, bottom), each column of pixels represents the ratios along a life history transect from the ventral edge inward 340 µm; "Semidi" fish had low Sr:Ca and high Ba:Ca relative to "Kodiak" fish.

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

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 Pollock (n=503) were found southwest of Kodiak Island (Region A) and larger, less numerous 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 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.

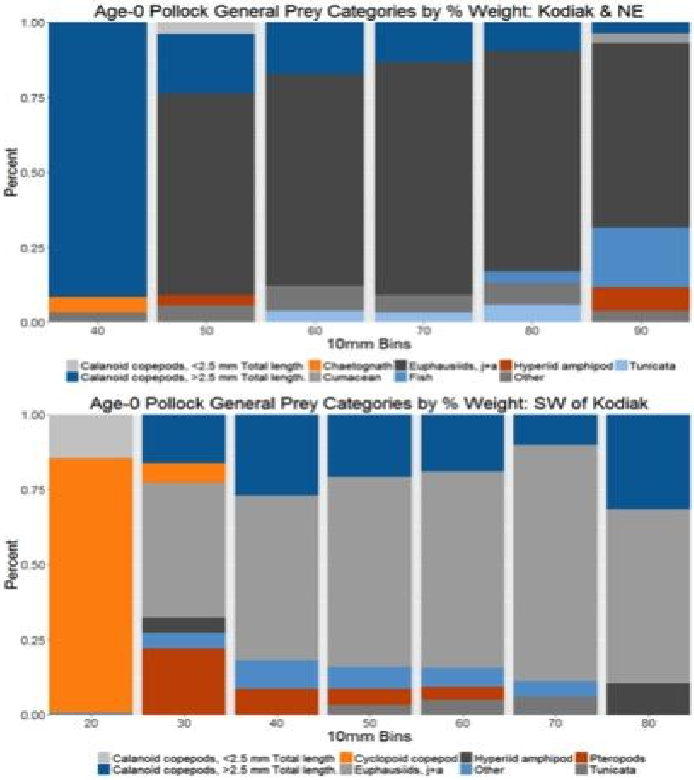

Figure 1. Age-0 pollock diet composition (percent weight) by 10mm length bins. The “Other” prey category was the sum total of prey categories that comprised less than 3% of the total prey weight in both regions.

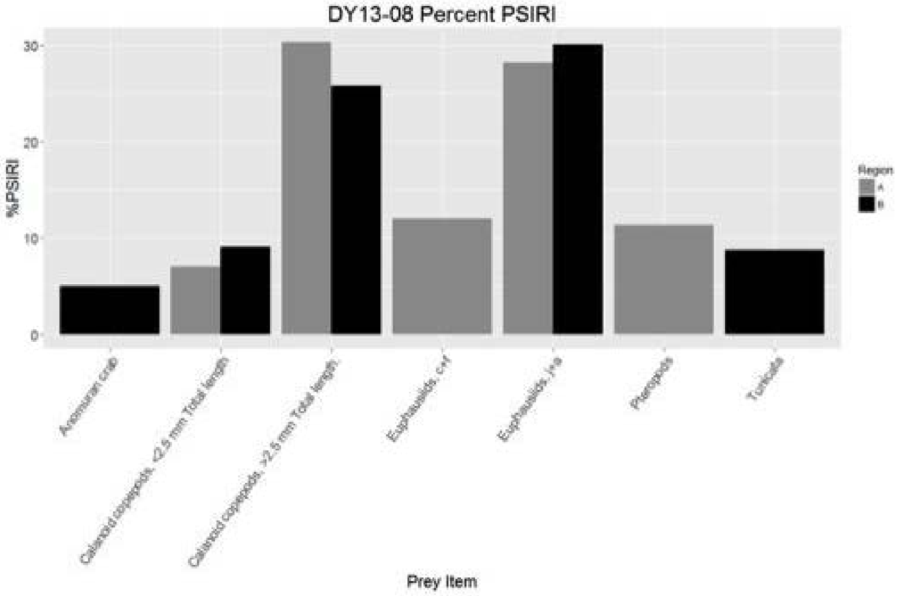

Figure 2. The top five selected prey taxa as determined by the PSIRIfor stations southwest of Kodiak Is. (Region A) and stations surrounding and to the northeast of Kodiak Is. (Region B).

For more information please contact Jesse Lamb at: Jesse.F.Lamb@noaa.gov

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.

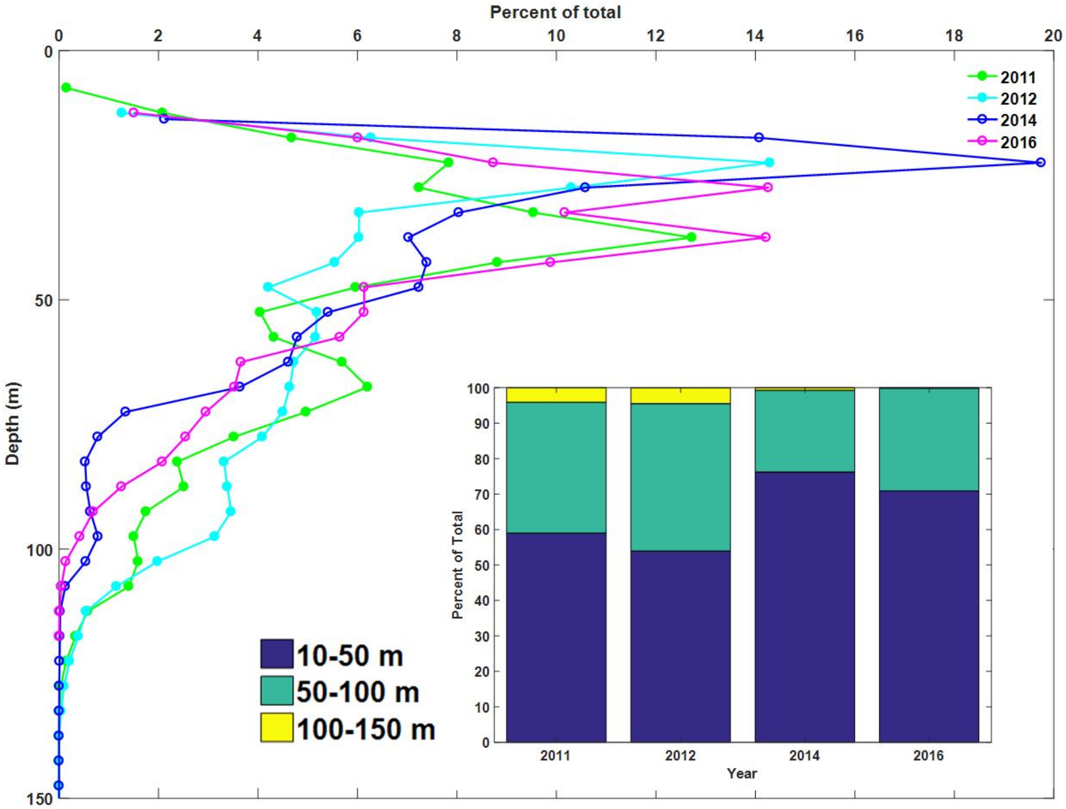

Figure 1. Depth distribution as percent of total abundance (fish nmi^{-2}) of age-0 pollock estimated by acoustic-trawl methods in 2011,2012, 2014,2016. Both plots show a shift in distribution towards the surface during warm years (2014, 2016). Colder years show a shift towards deeper waters.

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

US Arctic

Assessing alternative management strategies for eastern Bering Sea walleye pollock Fishery with climate change-REFM/ESSR

Chang Seung and James Ianelli*

**For further information, contact Chang.Seung@NOAA.gov*

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) 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.

Literature Cited

Ianelli, J., A. Hollowed, A. Haynie, F. Mueter, and N. Bond. 2011. Evaluating management strategies for eastern Bering Sea walleye pollock (*Theragra chalcogramma*) in a changing environment. ICES Journal of Marine Science 68(6): 1297–1304.

2. Stock Assessment

Gulf of Alaska – REFM

In 1998, the stock dropped below $B_{40\%}$ 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 increase again in 2018 as the strong 2012 year class continues to increase in body size. Survey data in 2017 are contradictory, with acoustic surveys indicating large or increasing biomass, and bottom trawl surveys indicating a steep decline in recent years. These divergent trends are likely due to changes in the availability of pollock to different surveying methods, though additional research is needed to confirm this hypothesis.

The stock assessment model estimate of female spawning biomass in 2018 is 342,683 t, which is 57.5% of unfished spawning biomass (based on average post-1977 recruitment) and above the $B_{40\%}$ estimate of 238,000 t. The 2017 pollock assessment features the following new data: 1) 2016 total catch and catch-at-age from the fishery, 2) 2017 biomass and age composition from the Shelikof Strait acoustic survey, 3) 2017 biomass and length composition from NMFS bottom trawl survey, 4) 2017 biomass and 2016 age composition from the ADFG crab/groundfish trawl survey, and 5) 2017 biomass and length composition from the summer GOA-wide acoustic survey.

The age-structured assessment model used for GOA W/C/WYAK pollock assessment was slightly modified from the 2016 assessment (Model 16.2). The 2017 assessment compared 4 models to the Model 16.2 with the new data:

Model 17.1—Age composition data reweighted using the Francis (2011) method.

Model 17.2—Same as model 17.1, but with random walks in survey catchability for the Shelikof Strait acoustic survey and the ADFG survey. This was the author’s preferred model.

Model 17.3—Same as 17.2, but a smaller penalty on variation in catchability.

Model 17.4—Same as 17.2, but with an offset for natural mortality for the 2012 year class.

Model 17.1 explored using the Francis (2011) method in place of the McAllister and Ianelli method (1997) used since 2014. While this change reduced the effective sample size of age composition data by 46-86%, the model results did not appear to be particularly sensitive to the weighting method used.

Models 17.2 and 17.3 implemented a random walk process to estimate year specific catchability for the Shelikof Strait and ADF&G trawl surveys, as the proportion of total stock observed by these surveys could be expected to not be constant. Model 17.3 differs from 17.2 in that the penalty term for annual variation was increased, allowing greater change in year-to-year catchability estimates. Model 17.2 was chosen as being less likely to overfit the data given a stronger constraint on change in catchability.
Model 17.4 implemented a cohort specific natural mortality for the 2012 year class, under the assumption that this may be lower given the dominance of this year class in the current surveys. A 26% reduction in M was estimated by the model, but the improvement in overall fit was negligible and therefore not recommended going forward.

Model 17.2 fits to biomass estimates follow general trends in survey time series. Fits to fishery age composition data were reasonable where the largest residuals tended to be at ages 1-2 in the NMFS bottom trawl survey due to inconsistencies between the initial estimates of abundance and subsequent information about year class size. Model fits to biomass estimates were like previous assessments, and general trends in survey time series were fit reasonably well. The model did not fit the most recent high Shelikof Strait acoustic survey biomass estimate, as this input was in contrast with the NMFS bottom trawl survey in 2017, which was substantially lower than previous years, and an age-structured pollock population cannot increase as rapidly as is indicated by this estimate. The model was unable to fit the extreme low value for the ADFG survey for 2015-2017, though otherwise the fit to this survey was quite good. The fit to the age-1 and age-2 Shelikof acoustic indices appeared adequate though variable. Therefore the assessment author chose to use Model 17.2.

Because the model projection of female spawning biomass in 2018 is above $B_{40\%}$, the W/C/WYAK Gulf of Alaska pollock stock is in Tier 3a. The projected 2018 age-3+ biomass estimate is 1,124,930 t (for the W/C/WYAK areas). Markov Chain Monte Carlo analysis indicated the probability of the stock dropping below $B_{20\%}$ is negligible (< 1 %) through 2022. For 2019, F_{ABC} was adjusted downward to $F_{47\%}$ based on the author's recommendation.

The 2018 ABC for pollock in the Gulf of Alaska west of 140° W longitude (W/C/WYAK) is 161,492 t which is a decrease of 21% from the 2017 ABC. The OFL is 187,059 t for 2018. The 2018 Prince William Sound (PWS) GHL is 4,037 t (2.5% of the ABC). For pollock in southeast Alaska (East Yakutat and Southeastern areas), the ABC for both 2018 and 2019 is 8,773 t and the OFL for both 2018 and 2019 is 11,697 t. 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.

The Gulf of Alaska pollock stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

The assessment was updated to include the most recent data available for area apportionments within each season (Appendix C of the GOA pollock chapter). The NMFS bottom trawl survey, typically extending from mid-May to mid-August, was considered the most appropriate survey time series for apportioning the TAC during the summer C and D seasons.

For more information contact Dr. Martin Dorn 526-6548.

Eastern Bering Sea - REFM

Spawning biomass in 2008 was at the lowest level since 1980, but has increased by 150% since then, although spawning biomass is projected to decline from the current high level in the near term. 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 (126%, 152%, and 68% above average for the post-1976 time series, respectively), along with spawning exploitation rates in 2009-2017 that averaged 11% below the post-1976 time series average. Spawning biomass is projected to be 80% above B_{MSY} in 2018.

New data in this year's assessment include the following:

The 2017 NMFS bottom-trawl survey (BTS) biomass and abundance at age estimates were included.·The 2016 NMFS acoustic-trawl survey (ATS) biomass and abundance at age estimates were updated based on age data collected from the ATS sampling (in 2016 the BTS age-length key was used).

The ATS age data from 1994-2016 that includes the bottom layer analysis (0.5-3m from bottom) was completed and used in the base/reference model (last year the accompanying biomass time series for these data were evaluated but the full set of age data was unavailable). This is new to the assessment.

Two additional years of opportunistic acoustic data from vessels transiting the EBS shelf region were processed and the time series now extends from 2006-2017.

Observer data for catch at age and average weight at age from the 2016 fishery were finalized and included.

Total catch as reported by NMFS Alaska Regional office was updated and included through the 2017 fishing season. There were no changes to assessment methodology this year.

The SSC has determined that EBS pollock qualifies for management under Tier 1 because there are reliable estimates of B_{MSY} and the probability density function for F_{MSY}. The updated estimate of B_{MSY} from the present assessment is 2.043 million t, down 6% from last year's estimate of 2.165 million t. Projected spawning biomass for 2018 is 3.679 million t, placing EBS walleye pollock in sub-tier "a" of Tier 1. 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 0.466, up 17% from last year's value of 0.398. The harvest ratio of 0.398 is multiplied by the geometric mean of the projected fishable biomass for 2018 (7.714 million t) to obtain the maximum permissible ABC for 2018, which is 3.598 million t, up 15% and down 4% from the maximum permissible ABCs for 2017 and 2018 projected in last year's assessment, respectively. However, as with other recent EBS pollock assessments, the authors recommend setting ABCs well below the maximum permissible levels. They list seven reasons for doing so in the SAFE chapter.

During the period 2010-2013, ABC harvest recommendations were based on the most recent 5-year average fishing mortality rate. Beginning in 2014, however, stock conditions had improved sufficiently that an increase in the ABC harvest rate was appropriate. Specifically, the Team and SSC recommended basing the ABCs on the harvest rate associated with Tier 3, the stock's Tier 1 classification notwithstanding. The Team recommends continuing this approach for setting the 2018 and 2019 ABCs, giving values of 2.592 million t and 2.467 million t, respectively.

The OFL harvest ratio under Tier 1a is 0.622, 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 2018 determines the OFL for 2018, which is 4.797 million t. The current projection for OFL in 2019 given a projected 2018 catch of 1.390 million t is 4.592 million t. The walleye pollock stock in the EBS is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

The 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, the 2018 "target" ABC values from CEATTLE are similar to the maximum permissible ABC value from the stock assessment (being 2% and 11% higher than the value from the stock assessment when CEATTLE is run in single-species mode and multi-species mode, respectively). Like the authors of the stock assessment, the authors of the CEATTLE appendix suggest setting the actual 2018 ABC at a significantly lower value (although based on a different harvest control rule than the Tier 3 rule).

Several of the concerns listed by the stock assessment authors in support of their ABC recommendation involve ecosystem considerations, specifically:

Because the environmental conditions in summer 2017 followed a warm period, precaution may be warranted, since warm conditions are thought to negatively affect the survival of larval and juvenile pollock. There is apparently a considerable amount of pollock showing up in the northern part of the shelf beyond the traditional EBS shelf survey area, approximately 1.3 million t in 2017. (The authors clarified during the Team meeting that this is a concern because, if it reflects a unidirectional migration and further such migrations occur in the future, this could reduce the biomass in the traditional EBS shelf survey area).

Pollock are an important prey species for the ecosystem and apparent changes in the distribution may shift their availability as prey. In particular, fur seal populations around the Pribilof Islands have had declines in pup production from 2014-2016. The extent that fishing intensity can allow for continued prey availability could be considered as a means to minimize further declines in the fur seal populations.

The CEATTLE model suggests that the B_{MSY} level is around 3.6 million t instead of the 2.3 million t estimated in the current assessment (noting that total natural mortality is higher in the multi-species model).

Aleutian Islands

This year's assessment estimates that spawning biomass reached a minimum level of about $B_{30\%}$ in 1999 and has since generally increased, with a projected value of $B_{38\%}$ for 2017. The increase in spawning biomass after 1999 has resulted more from a large decrease in harvest than from good recruitment, as there is no evidence that above-average year classes have been spawned since 1989. Spawning biomass for 2017 is projected to be 77,579 t.

The new data in the model consist of updated catch information, the 2016 AI bottom trawl survey biomass estimate and the 2014 AI bottom trawl survey age composition. There were no changes to the assessment model. The SSC has determined that this stock qualifies for management under Tier 3. The assessment features the continued use of last year's model for evaluating stock status and recommending ABC. The model estimates $B_{40\%}$ at a value of 81,240 t, placing the AI pollock stock in sub-tier "b" of Tier 3. The model estimates the values of $F_{35\%}$ as 0.42 and $F_{40\%}$ as 0.33. Under Tier 3b, with the adjusted $F_{40\%}$=0.30, the maximum permissible ABC is 36,061 t for 2017. The 2017 ABC was set at this level. Following the Tier 3b formula with the adjusted $F_{35\%}$=0.38, OFL for 2017 is 43,650 t. If the 2016 catch is 1,500 t and 1,157 for 2017 (i.e., equal to the five year average for 2011-2015), the 2018 maximum permissible ABC would be 40,788 t and the 2018 OFL would be 49,291 t.

The walleye pollock stock in the Aleutian Islands is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

Bogoslof Pollock

In accordance with the approved schedule, no assessment was conducted for Bogoslof this year, however, a full stock assessment will be conducted in 2018. Until then, the values generated from the previous stock assessment are rolled over for 2018 specifications. Additional information listed below summarizes the 2016 assessment. NMFS acoustic-trawl survey biomass estimates are the primary data source used in this assessment. Between 2000 and 2014, the values varied between 292,000 t and 67,000 t. The most recent acoustic-trawl survey of the Bogoslof spawning stock was conducted in March of 2016 and resulted in a biomass estimate of 506,228 t. The random-effects method of survey averaging resulted in 434,760 t, compared to the 2016 point estimate of 506,228 t. The degree of uncertainty in the estimate increases going forward and is fairly substantial. As an alternative method, the three-survey average approach gives an estimate of 228,000 t from which to make the Tier 5 calculations.

Estimated catches for 2015 and 2016 were updated and the 2016 acoustic-trawl survey biomass estimate and preliminary 2016 survey age data were included. Two methods for computing the survey average are provided: one using the random effects and the other using a simple 3-survey average. The SSC has determined that this stock qualifies for management under Tier 5. The assessment recommend that the maximum permissible ABC and OFL continue to be based on the random-effects survey averaging approach. Given the large degree of uncertainty in the 2016 survey estimate, and the fact that the next survey is scheduled for 2018, the assessment authors recommended using the biomass estimate based on the average of the three most recent surveys (228,000 t) for ABC.

The maximum permissible ABC value for 2017 is 97,428 t (assuming $M = 0.3$ and $F_{ABC} = 0.75 \times M = 0.225$ and the random effects survey estimate for biomass). The ABC for 2017 = 228,000 x M x 0.75 = 51,300 t. The recommended ABC for 2018 is the same. The recommended ABC for 2017 is close to what would be obtained from a two-year stair-step (60,800 t). The OFL was calculated using the random effects estimate for the survey biomass. Following the Tier 5 formula with M=0.3, OFL for 2017 is 130,428 t. The OFL for 2018 is the same. The walleye pollock stock in the Bogoslof district is not being subjected to overfishing. It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

For further information contact Dr. James Ianelli, (206) 526-6510

F. Pacific Whiting (hake)

G. Rockfish

1. Research

Pacific Ocean Perch Genomic Studies – ABL

DNA sequences are the result of the spatio-temporal dynamics in biological populations. With the advent of next generation sequencing techniques, we are now able to harness this information to test old hypothesis and pose new ones. We used Restriction Site Associated DNA sequencing (RAD-seq) technique to obtain 11,146 single nucleotide polymorphic (SNPs) sites from 401 POP young of the year collected during the 2014 (19 stations) and 2015 (4 stations) GOAIERP surveys in the

Eastern Gulf of Alaska. Our results show that the collections represented four to seven distinct populations confirming the DisMELS model predictions of populations from various parturition locations mixing during larval dispersal.

We are also beginning to explore new questions that can be addressed with the genomic data. For example, a genome-wide association study where all the loci are tested for correlation against physiological and environmental gradients, revealed signatures of natural selection. And although only few of the selected loci were found in the NCBI (National Center for Biotechnology Information) database we were still able to make limited inference on which specific gene coding protein variants were selected for or against. Based on the represented loci, we found that POP young of the year condition and growth was associated with gene variants coding for cellular growth, duplication and membrane trafficking, and interestingly a gene variant coding for TAAR13c-expressing olfactory sensory neurons. The TAAR13c receptor is activated by low concentrations of cadaverine, a diamine emanating from decaying flesh. In laboratory studies, it was found that zebrafish exhibit a powerful and innate avoidance behavior to cadaverine (Hussain, Ashiq, et al. "High-affinity olfactory receptor for the death-associated odor cadaverine." Proceedings of the National Academy of Sciences 110.48 (2013): 19579-19584.).

Latitudinal gradient was also found to be associated with a set of annotated gene variants. Interestingly, these genes code for proteins that are linked to stress, especially heat and muscle regeneration. These findings imply that POP young of the year are facing various selection forces during their first year at sea. Hence each adult cohort DNA signature is a result of the environmental conditions experienced during their first year at sea. These findings support the idea of a selective sieve hypothesis where the strongest selection occurs during the initial larval and YOY stages in response to environmental conditions, food availability and predator abundances. By examining the DNA sequences of older fish cohorts, we may be able to reconstruct environmental pressures they experienced as young of the year.

In 2017, we were able to obtain YOY and adult DNA samples from the Eastern and Western Gulf of Alaska. Pending further funding, we plan to analyze them and verify the findings to date as well as elucidate new insights into POP biology.

For more information, contact Jacek Maselko (Jacek.Maselko@noaa.gov).

Alaska rockfish environmental DNA (eDNA) - ABL

BACKGROUND

The Auke Bay Laboratory of the Alaska Fisheries Science Center (AFSC) is responsible for stock assessments of commercially valuable rockfish species in the Gulf of Alaska (GOA). The primary information used to assess rockfish in the GOA are catches from bottom trawl surveys. However, bottom trawl survey catches may not provide adequate information for assessing and understanding rockfish populations in Alaska. Many of these species are difficult to sample using bottom trawls because they reside in untrawlable habitat. Additionally, juvenile rockfish are rarely caught using traditional sampling methods so habitat utilization of the juvenile life stages is poorly understood. Alternative sampling tools are desirable to fully understand the distribution and habitat preferences of rockfish in Alaska.

Environmental DNA (eDNA) is a relatively new but rapidly growing field of research. eDNA can be used as a surveillance tool to monitor for the genetic presence of aquatic species. Several controlled studies have shown that the DNA can persist in seawater for several days and in sediment for thousands of years. The advantage of eDNA is that the presence or absence of an organism can be determined at various locations even if they are no longer visible or able to be sampled. Our work is a pilot study examining the efficacy of this method for identifying the presence of Alaska rockfish including, Pacific ocean perch (Sebastes alutus), rougheye rockfish (S. aleutianus), blackspotted rockfish (S. melanostictus) shortraker rockfish (S. borealis), dusky rockfish (S. variabilis) and northern rockfish (S. polyspinis). By collecting water samples in areas of untrawlable habitat, we hope to better understand rockfish habitat utilization by identifying the presence of rockfish in areas inaccessible to typical sampling procedures. Furthermore, this technique may eventually be used to roughly quantify rockfish populations and/or characterize their association with various habitats based on the strength of the eDNA signal.

METHODOLOGY

Water samples were collected with sterilized Niskin bottles in nearshore and offshore areas off southern Baranof Island, Southeast Alaska (Figure 1). Field operations began and ended at Little Port Walter (LPW) from 4-7 August, 2016. At each sampling location, water was collected at 10 m below the surface and at approximately 2-5 m above the seafloor. Replicate 1-liter water samples were immediately vacuum-filtered through 0.45 µm nitrocellulose membranes. Membranes were folded inward with sterilized forceps, placed in tubes with 200 proof ethanol, and stored at -20° C. In the laboratory, DNA was extracted from the membranes and stored in buffer solution. DNA concentration was determined within the water samples and next generation sequencing analyses identified individual taxa within a subset of 10 samples.

RESULTS

Twenty-eight paired samples (56 samples total) from surface (10 m) and bottom waters, as well as negative controls, were collected during the 4-day survey. Locations were chosen to ensure a diverse mix of habitats were sampled, including inside and outside fjords, as well as offshore pinnacles. Samples were obtained at bottom depths that ranged between 33-307 m over varied bottom substrates including rocky reefs and soft sediments. Additionally, in an effort to maximize the probability of sampling rockfish populations, samples were obtained in areas where dense echosounder sign was observed.

Laboratory processing of the filter membranes revealed that all contained DNA, except for the negative controls. A preliminary analysis of a subset of samples identified several broad categories of taxa present in the water samples including several fish (Figure 2). The semi-quantitative results demonstrated a distinct difference between the amount of DNA detected from surface and bottom samples, especially for groundfish species. Additional samples are currently being processed and further analyses may identify additional taxa, including crabs, shrimp, octopus, coral, sponge, otters, and whales. In subsequent analyses, we hope to further refine the results and relate DNA concentrations to habitat.

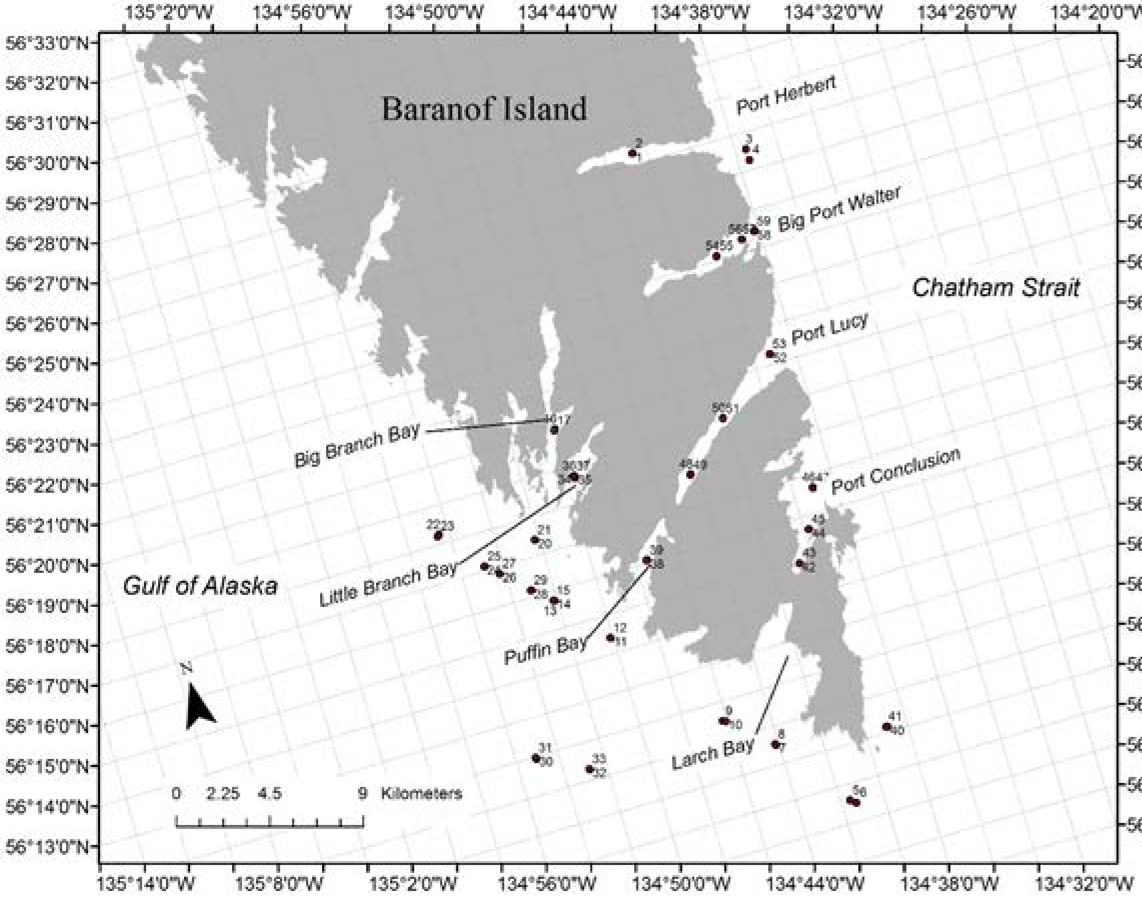

Figure 1. Map of eDNA sampling locations near southern Baranof Island.

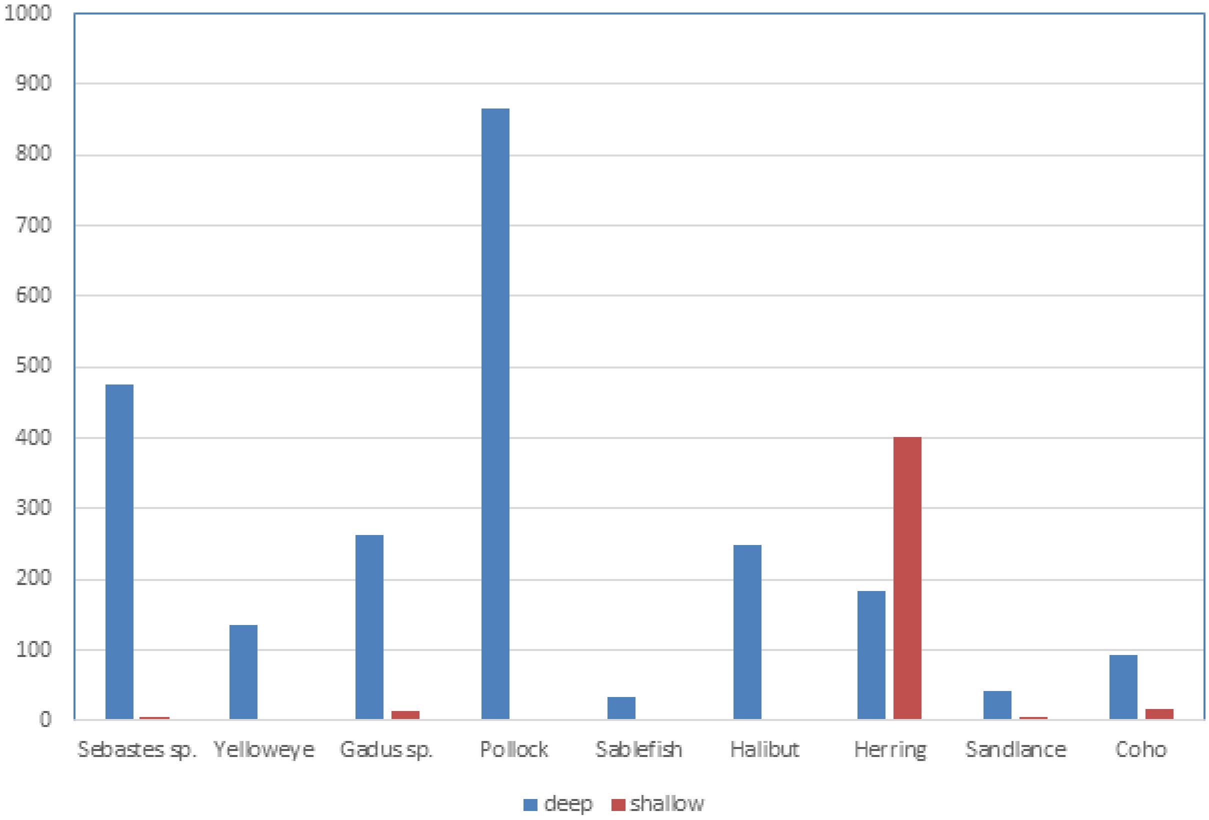

Figure 2. Number of eDNA fragments aligned with reference DNA sequences by species and sampling depth from a subset of water samples collected near southern Baranof Island, Southeast Alaska.

For more information, contact Patrick Malecha (pat.malecha@noaa.gov, 907-789-6415) or Chris Lunsford (chris.lunsford@noaa.gov, 907-789-6008).

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 preparation) Seasonal habitat use and community structure of rockfishes in the Gulf of Alaska.

Conrath, C. (in preparation) Reproduction potential of dusky and northern rockfish related to habitat within 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 2017 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 2021.

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

The Pacific Ocean perch assessment for 2017 was presented as a “partial assessment” format because it was a scheduled “off-year” assessment under the new Stock Assessment Prioritization guidelines. Therefore, only the projection model was run, with updated catches. New data in the 2017 assessment included updated 2016 catch and estimated 2017 and 2018 catches. No changes were made to the assessment model. A new feature included in the “off-year” assessments was a figure describing exploitation rate (i.e., catch/biomass).

The survey biomass estimates in the Aleutian Islands were high in 2016 and the female spawning biomass is estimated at 1.5 times the $B_{40\%}$ level. 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 305,804 t in 2018 and to decline to 295,593 t in 2019. Exploitation rates by area since 2004 appeared to be low in all areas.

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 214,685 t, 0.082, and 0.101, respectively. Spawning biomass for 2018 (305,804 t) is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier “a” of Tier 3. The 2018 and 2019 catches associated with the $F_{40\%}$ level of 0.082 are 42,509 t and 41,212 t, respectively, and are the recommended ABCs. The 2018 and 2019 OFLs are 51,675 t and 50,098 t.

ABCs be set regionally based on the proportions in combined survey biomass as follows (values are for 2018): EBS = 11,861 t, Eastern Aleutians (Area 541) = 10,021 t, Central Aleutians (Area 542) = 7,787 t, and Western Aleutians (Area 543) = 12,840 t. The recommended OFL for 2018 and 2019 is not regionally apportioned. Pacific ocean perch is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

Pacific Ocean Perch -- Gulf of Alaska - ABL

Pacific ocean perch total biomass has been increasing since the early 1980s (currently at 1.4 times the $B_{40\%}$ level). The stock assessment model estimates a 13% increase in spawning biomass from 2017 to 2018, and a 22% increase in ABC. The spawning stock biomass is projected to decrease by 1.4% from 2018 to 2019.

Changes to the input data include updated survey biomass estimates for 2017, survey age compositions for 2015, fishery age composition for 2014 and 2016, final catch for 2015 and 2016, and preliminary catch and projected catches for 2017-2019. The fishery length composition data was changed to 1 cm length bins with a plus group of 45 cm. The 1984 and 1987 bottom trawl survey biomass and age composition data were removed from the assessment.
Two changes to the 2015 assessment model were recommended for this year: 1) bottom trawl survey biomass is fit with a log-normal distribution; and 2) an additional fishery selectivity time

period (2007-present) was added to accommodate the Central GOA rockfish program and the availability of older fish to the fishery.

The GOA Pacific ocean perch stock is in Tier 3a. The recommended model resulted in an estimated maximum permissible ABC of 29,236 t ($F_{ABC} = F_{40\%}$ of 0.094). The F_{OFL} is specified to be equal to the $F_{35\%}$ (0.113) and results in an OFL of 34,762 t. The stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

The harvest apportionment for 2018 and 2019 is from the random effects model. Amendment 41 prohibited trawling in the Eastern GOA east of 140° W longitude. Trawling is allowed in the W. Yakutat (between 147° W and 140° W) portion of the Eastern GOA, and the proportion of Eastern GOA biomass is 0.58, smaller than the estimate of 0.61 from the 2015 assessment. The random effects model was not applied for the WYAK and EYAK/SEO split and the weighting method of using upper 95% confidence of the ratio in biomass between these two areas used in previous assessments was continued.

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

Dusky Rockfish-- Gulf of Alaska -- ABL

In 2017, the scheduled frequency for some stock assessments was changed in response to the National Stock Assessment Prioritization effort. Prior to 2017, Gulf of Alaska (GOA) rockfish were assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. The new schedule sets full assessments for dusky rockfish in the ‘off’ survey years (even years) and partial assessments for the ‘on’ survey years (odd years). In 2017 a partial assessment consisting of an executive summary including recent fishery catch and survey results was conducted, and harvest levels for the 2018 and 2019 were recommended. Estimates of spawning biomass for 2018 and 2019 from the current year (2017) projection model are 21,559 t and 20,151 t, respectively. Both estimates are above the $B_{40\%}$ estimate of 19,707 t. The exploitation rate has been less than 6% every year since 1991.

There were no changes in the assessment methods. New data added to the projection model included updated 2016 catch and new projected catches for 2017-2019. The dusky rockfish stock is in Tier 3a and the recommended maximum permissible 2018 ABC of 3,957 t was from the updated projection model. This ABC is 8% lower than the 2017 ABC of 4,278 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 for 2018 and 2019. The apportionment percentages are the same as in the last full assessment.

Area Apportionment	Western	Central	Eastern	Total
2018 Area ABC (t)	146	3,502	309	3,957
2019 Area ABC (t)	135	3,246	287	3,668

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

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 new Stock Assessment Prioritization guidelines. Therefore, only the projection model was run, with updated catches. New projections were slightly different from last year’s projections because observed catches were quite different from the estimated catches used last year. Spawning biomass is projected to be 106,486 t in 2018 (1.6 times the $B_{40\%}$ level) and to decline to 104,699 t in 2019. Exploitation rates by area since 2004 appeared to be low in all areas in most years.

New data in the 2017 assessment included updated 2016 catch and estimated 2017 and 2018 catches. No changes were made to the assessment model. A new feature included in the “off-year” assessments was a time series of exploitation rate (i.e., catch/biomass). It has been determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying northern rockfish for management under Tier 3. The current estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are 65,870 t, 0.065, and 0.80, respectively. Spawning biomass for 2018 (106,486 t) is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier “a” of Tier 3. The 2018 and 2019 catches associated with the $F_{40\%}$ level of 0.065 are 12,975 t and 12,710 t, respectively, and are the authors recommended ABCs. The 2018 and 2019 OFLs are 15,888 t and 15,563 t. Northern rockfish is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

Northern Rockfish – Gulf of Alaska-ABL

For Gulf of Alaska northern rockfish in 2017, a partial assessment was presented to recommend harvest levels for the next two years. The 2018 spawning biomass estimate (28,017 t) is just above $B_{40\%}$ (27,983 t) and projected to decrease to 26,512 t (below $B_{40\%}$) in 2019. Total biomass (2+) for 2018 is 74,748 t and is projected to decrease to 73,814 in 2019.

There were no changes in assessment methodology. New data added to the projection model included updated catch data from 2015 (3,944 t) and 2016 (3,437 t), and new estimated catches for 2017-2019. The 2018 spawning biomass estimate (28,017 t) is above $B_{40\%}$ (27,983 t) and projected to decrease to 26,512 t in 2019. Total biomass (2+) for 2018 is 74,748 t and is projected to decrease to 73,814 in 2019.

Northern rockfish are estimated to be in Tier 3a in 2018 and 3b in 2019. The assessment authors recommended to use the maximum permissible 2018 ABC and OFL values of 3,685 t and 4,380 t, respectively. This stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

Area apportionments of northern rockfish ABC’s for 2018 and 2019 are based on the random effects model applied to GOA bottom trawl survey biomass estimates through 2015 for the Western, Central, and Eastern Gulf of Alaska resulting in the following percentage area apportionments: Western 11.40%, Central 88.50% and Eastern 0.01%. Note that the small northern rockfish ABC apportionments from the Eastern Gulf are combined with other rockfish for management purposes. Northern rockfish is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

Shortraker Rockfish - - Bering Sea and Aleutian Islands - REFM

In accordance with the approved schedule, no assessment was conducted for shortraker this year, however, a full stock assessment will be conducted in 2018. Until then, the values generated from the previous stock assessment (below) will be rolled over for 2018 specifications. Additional information listed below summarizes the 2016 assessment.

2016 was a full assessment for this Tier 5 stock; there were no changes in the assessment methodology. Estimated shortraker rockfish biomass in the BSAI has been relatively stable since 2002. Biomass estimates have decreased slightly from 23,009 t in the 2014 assessment to 22,191 t in the current assessment. For the period 2002-2016, EBS slope survey biomass estimates ranged from a low of 2,570 t in 2004 to a high of 9,299 t in 2012 with CVs at 0.22 and 0.57, respectively. For the period 1991-2016, the AI survey biomass estimates ranged from a low of 12,961 t in 2006 to a high of 38,487 t in 1997 with CVs at 0.23 and 0.26, respectively. According to the random effects model, total biomass (AI and EBS slope combined) from 2002-2016 has been very stable, ranging from a low of 21,214 t in 2006 to a high of 23,990 t in 2002. 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.

New data included updated catch from 2015, estimated catch for 2016 and the biomass estimates from the 2016 Aleutian Islands and Eastern Bering Sea slope surveys were added to the model. The 2017 biomass estimate is based on the Aleutian Island survey data through 2016 as well as the 2002-2012, and 2016 eastern Bering Sea slope survey data. The 2014 eastern Bering Sea slope survey was cancelled. Prior to 2012, the EBS slope survey data had not been included in previous biomass estimates for this species.

The SSC has previously determined that reliable estimates of only biomass and natural mortality exist for shortraker rockfish, qualifying the species for management under Tier 5. The biomass estimate was based on the random effects model. The Team recommended setting F_{ABC} at the maximum permissible level under Tier 5, which is 75 percent of M. The accepted value of M for this stock is 0.03 for shortraker rockfish, resulting in a $maxF_{ABC}$ value of 0.0225. The ABC is 499 t for 2017 and 2018 and the OFL is 666 t for 2017 and 2018. Shortraker rockfish is not being subjected to overfishing. It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

Shortraker Rockfish – Gulf of Alaska – ABL

Rockfish in the Gulf of Alaska (GOA) are assessed on a biennial assessment schedule to coincide with new data from the AFSC biennial trawl surveys in the GOA. For 2018, the biomass estimate was updated with 2017 survey data. Estimated shortraker rockfish biomass is 38,361 t, which is a decrease of 33% from the previous estimate in the 2015 assessment. Catch data were updated as well.

Shortraker rockfish has always been classified into "tier 5" in the North Pacific Fishery Management Council's (NPFMC) definitions for ABC and overfishing level. Following the recommendation of the NPFMC for all Tier 5 stocks, we continue the use of a random effects model applied to the trawl survey data from 1984 – 2017 to estimate the exploitable biomass that is used to calculate the ABC and OFL values for the 2018 fishery. Estimated shortraker biomass is 38,361 mt, which is a decrease of 33% from the 2015 estimate. This is the first substantial decline in biomass since seeing a progressive increase in biomass since 1990. The NPFMC's "tier 5" ABC definitions state that FABC $\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 2018 fishery. Gulfwide catch of shortraker rockfish was 776 t in 2016 and estimated at 547 t in 2017. Shortraker rockfish in the GOA is not being subjected to overfishing. It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

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

Blackspotted/rougheye Rockfish Complex – Bering Sea and Aleutian Islands - REFM

This chapter is a partial assessment and update of the 2016 full assessment and used the Tier 3 age-structured model applied to the BSAI whereas previously the model was only used for the AI portion of the assessment. Spawning biomass for BSAI blackspotted/rougheye rockfish in 2018 is projected to be 8,208 t and is projected to increase. This increasing trend is supported by evidence of several large recruitments in the 2000s. The most recent survey in the AI (2016) increased substantially from the low estimate in 2014. New data included updated catch for 2016 and estimated catches for 2017 - 2019.

For the BSAI, this stock qualifies for management under Tier 3 due to the availability of reliable estimates for $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$. Because the projected female spawning biomass for 2018 of 8,208 t is less than $B_{40\%}$, (8,311 t) the stock qualifies as Tier 3b but is projected to be in Tier 3a in 2019 and the adjusted $F_{ABC} = F_{40\%}$ values for 2018 and 2019 are 0.044 and 0.045, respectively. The maximum permissible ABC for the Aleutian Islands is 501 t, which is the recommendation for the AI portion of the 2018 ABC. The apportionment of 2018 ABC to subareas is 239 t for the Western and Central Aleutian Islands and 374 t for the Eastern Aleutian Islands and Eastern Bering Sea. The recommended overall 2018 ABC of 613 t and a 2018 OFL of 749 t. It is unknown if the blackspotted and rougheye rockfish complex is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

Given on-going concerns about fishing pressure relative to biomass in the Western Aleutians, the SSC requested that the apportionment by sub-area be calculated and presented. The maximum subarea species catch (MSSC) levels within the WAI/CAI for 2018, based on the random effects model, are as follows: Western Aleutians = 35 t, Central Aleutians = 204 t.

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 full assessment was conducted for RE/BS in 2017.

RE/BS rockfish are assessed using a statistical age-structured model. 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.

A full assessment was completed for these species in 2017. Data input changes included the following: Updated catch estimates for 2016, new catch estimates for 2017-2019, new fishery ages for 2014 and 2016, new fishery lengths for 2015, a new trawl survey biomass estimate for 2017, new trawl survey ages for 2015, and new longline survey relative population numbers (RPN) and lengths for 2016 and 2017. There were no changes to the assessment methodology.

Model results indicate that the 2018 projected spawning biomass estimate (15,059 t) is 1.7 times the $B_{40\%}$ estimate (8,998 t) but is projected to slightly decrease to 14,972 t in 2019. The rougheye/blackspotted complex qualifies as a Tier 3a stock. For the 2018 fishery, the Plan Team accepts the authors' recommended maximum permissible ABC of 1,444 t ($F_{ABC} = F_{40\%} = 0.04$) and OFL of 1,735 t ($F_{OFL}=F_{35\%} = 0.048$).

This stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. The apportionment percentages have changed with the addition of the 2017 trawl survey biomass. In past assessments, apportionment was based on a 4:6:9 weighted average of the proportion of biomass in each area from the three most recent bottom trawl surveys. The Plan Team and SSC have requested that the random effects model be applied to the bottom trawl survey data. However, the RE/BS model includes the longline survey in the model. Rather than switching to another apportionment method, the authors continue to recommend status quo until the Survey Averaging Working Group can provide recommendations on what apportionment to use for stocks with multiple surveys and regional variability in the sampling error. Area apportionments based on the three-survey weighted average method are as follows for 2018: Western GOA = 176 t, Central GOA = 556 t, and Eastern GOA = 712 t.

Gulfwide catch of rougheye and blackspotted rockfish remains relatively stable in all areas, with some decrease in the central GOA and slight increase in the eastern GOA in 2017. The majority of the RE/BS rockfish catch remains in the rockfish and sablefish fisheries. The 2017 bottom trawl survey increased by 16% from the 2015 survey and is now near average for the time series. The 2017 longline survey abundance estimate (relative population number or RPN) increased about 50% from the 2016 estimate and well above the long-term mean. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

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

H. Thornyheads

1. Research

2. Stock Assessment

Gulf of Alaska - ABL

Rockfish have historically been assessed on a biennial stock assessment schedule to coincide with the availability of new trawl survey data (odd years). In 2017, the Alaska Fisheries Science Center participated in a stock assessment prioritization process. It was recommended that the Gulf of Alaska (GOA) thornyhead complex remain on a biennial stock assessment schedule with a full stock assessment produced in even years and no stock assessment produced in odd years. However, we performed a partial stock assessment for this year because the allowable biological catch (ABC) has been exceeded in the past in the western GOA, and because the biomass estimates provided by the GOA trawl surveys have at times displayed extreme variability between surveys. For 2018, the biomass estimate was updated with 2017 survey data. Estimated thornyhead rockfish biomass is 90,570 t, which is an increase of 4% from the previous estimate in the 2015 assessment. Catch data were updated as well.

Gulf of Alaska thornyheads (*Sebastolobus* species) 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 the use of a random effects model applied to the trawl survey data from 1984 – 2017 to estimate the exploitable biomass that is used to calculate the ABC and OFL values for the 2018 fishery. Estimated thornyhead biomass is 90,570 t, which is an increase of 4% from the 2015 estimate. Thornyhead biomass in the GOA has generally shown an increasing pattern since 2011. This follows a steady decline since 2003. The NPFMC's "tier 5" ABC definitions state that FABC ≤0.75M, where M is the natural mortality rate. Using an M of 0.03 and applying this definition to the exploitable biomass of thornyhead rockfish results in a recommended ABC of 2,038 t for the 2018 fishery. Gulfwide catch of thornyhead rockfish was 1,119 t in 2016 and estimated at 1,012 t in 2017. 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.

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

I. Sablefish

1. Research

Sablefish (*Anoplopoma fimbria*) reared in the laboratory to verify age, growth, and development for comparison to wild caught larvae from the western Gulf of Alaska - RPP

Annette Dougherty, Steven Porter, and Alison Deary

We conducted a pilot study of sablefish larvae rearing with the following objectives:

1. Validate daily increment formation in otoliths using alizarin complexone (ALC) staining to determine if field-collected larvae may be correctly aged for growth studies.

2. Document early-life development (when specific developmental traits appear, e.g., when the eyes

and mouth become functional, and determine the sizes of larvae at hatch and first feeding).

The Northwest Fisheries Science Center at Manchester, Washington provided eggs and milt. Gametes were transported to the Alaska Fisheries Science Center larval fish rearing laboratory in Seattle, Washington. Eggs and yolk-sac larvae were kept in the dark at 5.6°C until first feeding at which time the temperature was raised to 6.8°C and a light cycle started to emulate larvae rising into the surface water. A sub-set of eggs/larvae were kept isolated in a smaller rearing tank and immersed in a 25 mg/l alizarin complexone (ALC) solution to validate the periodicity of increment formation. Skeletal development was assessed using a clearing and staining technique modified from Taylor and Van Dyke (1985). In this technique, calcified elements stain red and un-calcified structures stain blue.

Results

Development at 5.6°C

Fertilization to hatch = 13 days. Approximate size at hatch = 5.00 mm.
Hatch to first feeding = 27 days. Approximate size at first feeding = 8.00 mm.

Developmental Observations

Figure 1. Hatch: large yolk, no body or eye pigment, mouth not formed, well defined hatch mark on otoliths

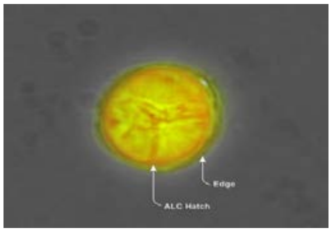

Figure 2. Result of 6 hour immersion of larva in 25 mg/l ALC solution. Sagitta otolith removed from a 5.2 mm larva preserved 3 days after hatch (ALC hatch mark, 1 increment, and edge).

8 days after hatch: eyes pigmentation begins, larvae reactive to touch and short bursts of swimming observed, gut apparent

15 days after hatch: cartilage of lower jaw forms

16 days after hatch: eyes fully pigmented (may be functional at this time)

17 days after hatch: first elements of gills form

19 days after hatch: first and second gill arch present, pectoral fin supported by a single element (cleithrum)

22 days after hatch: mouth apparent but not functional, cartilaginous elements that form muscle attachment points for functional mouth opening and closing first develop

27 days after hatch: first feeding, yolk still present

28 days after hatch: precursor to maxilla of the upper jaw formed

30 days after hatch: larvae attracted to light and swim to the surface

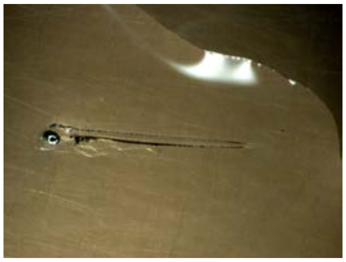

Figure 3. Sablefish larva (9.04 mm SL) 38 days after hatch. Yolk depleted.

43 days after hatch: all elements of ventral gills present but not ossified

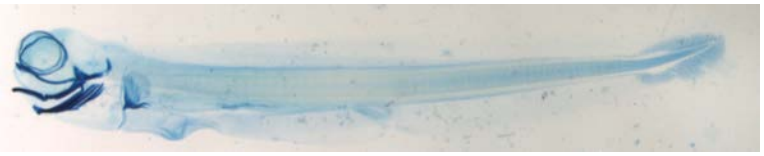

Figure 4. Lateral view of cleared and stained Sablefish larva (~8.59 mm notochord length (NL)) 43 days after hatch.

45 days after hatch: skeletal development begins in caudal region

49 days after hatch: ossification of cleithrum

59 days after hatch: hemal arches begin to form in caudal region; caudal fin supports develop

Figure 5. Lateral view of cleared and stained Sablefish larva (9.31 mm NL) 59 days after hatch.

Sablefish have a prolonged period of yolk-sac retention after hatching of approximately 5 weeks in comparison to walleye pollock (*Gadus chalcogrammus*), which reach yolk depletion about 2 weeks after hatching. Since sablefish spawning may begin as early as January in the Gulf of Alaska, this prolonged yolk-sac retention may prevent starvation in wild sablefish since the peak in zooplankton production does not occur until spring. ALC staining validated that a well-defined increment is deposited on the otoliths at hatch (defines day 1 for fish ageing), but otoliths from older larvae that had been marked several times throughout the rearing experiments suggest that daily increment deposition does not continue or is beyond the resolution of a the microscope at 1000X (<1 µ). Further samples will be analyzed to determine if daily or non-daily increment deposition continues throughout larval development. The laboratory reared fish will serve as validation specimens to aid in the interpretation of otolith increments and condition of the larvae from the field.

During this study, we also conducted the first examination of the internal anatomy of sablefish and have identified some potential bottlenecks related to the developmental state of feeding and swimming structures. First feeding was observed at 27 days post-hatch after several cartilaginous structures developed that provided muscle attachment and necessary leverage to open and close the lower jaw. Although the maxilla was present in the upper jaw, it remains rudimentary throughout the sizes examined, suggesting that only elements of the lower jaw were involved in feeding by the end of the study (59 dph). Feeding is likely accomplished by a combination of suction and ram feeding, where pre-flexion sablefish overtake prey in the water column while using some suction pressure to overcome the viscosity of the water. Ossification is delayed in sablefish, relative to other species such as walleye pollock, with only a single element in the pectoral fin being ossified by the end of the study period (59 days after hatch). By examining development at a fixed temperature in laboratory-reared specimens, we have assembled an early developmental series that can be used to assess the developmental state and functional abilities of field-collected specimens.

For more information please contact Annette Dougherty at: Annette.Dougherty@noaa.gov

Sablefish 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 2017. Total sablefish tag recoveries for the year were around 715. Twenty three percent of the recovered tags in 2017 were at liberty for over 10 years. About 36 percent of the total 2017 recoveries were recovered within 100 nautical miles (nm; great circle distance) from their release location, 37 percent within 100 – 500 nm, 21 percent within 500 – 1,000 nm, and 7 percent over 1,000 nm from their release location. The tag at liberty the longest was for approximately 39 years, and the greatest distance traveled of a 2017 recovered sablefish tag was 1,544 nm. Six adult sablefish and five juvenile sablefish tagged with archival tags were recovered in 2016. First reports describing the vertical movement (using collected depth data) of adult sablefish from these electronic tags are currently in review.

Tags from shortspine thornyheads, Greenland turbot, Pacific sleeper sharks, lingcod, spiny dogfish, and rougheye rockfish are also maintained in the Groundfish Tag Database. Eighteen thornyhead (17 conventional and 1 electronic) and 1 Greenland turbot were recovered in 2017.

Releases in 2017 on the groundfish longline survey totaled 3,322 adult sablefish, 877 shortspine thornyheads, and 9 Greenland turbot. Pop-up satellite tags (PSAT) were implanted on 3 spiny dogfish. An additional 164 juvenile sablefish were tagged during a juvenile sablefish tagging cruise in 2017.

For more information contact Katy Echave at (907) 789-6006, 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 2017. A total of 164 juvenile sablefish were caught and tagged and released in St. John Baptist Bay and Silver Bay near Sitka, AK over 4 days (July 9 – July 12) with 91 rod hrs. A biologist from the Alaska Department of Fish and Game participated for one of the days. Total catch-per-unit-effort (CPUE) equaled 1.96 sablefish per rod hour fished. This was down significantly from 2016 (9.72), and the lowest since 2014 (1.04). Overall CPUE had been increasing since around 2006, but 2017 did not follow that trend. The mean length of sablefish was slightly higher than in 2016 but still lower than the recent average for the same time of year. Notably, the sablefish near the hatchery were much larger than last year and larger than the fish in SJBB, probably as a result of the much lower density encountered this year.

For more information contact Dana Hanselman at dana.hanselman@noaa.gov

Sablefish Archival Tagging Study - ABL

Archival tags were implanted into 599 adult sablefish (*Anoplopoma fimbria*) to study their diel vertical migration (DVM). Of these tags, 98 were recovered with usable depth data that we used to identify DVM and to classify DVM into 1 of 2 types, Type 1 DVM (rise from bottom during nighttime) and Type 2 DVM (rise from bottom during daytime). Our study demonstrates 3 important attributes of DVM for sablefish. First, DVM occurred widely. Nearly all tagged sablefish (97%) exhibited DVM. Although widespread, the occurrence of DVM was intermittent (12% of days). Second, bottom depth for Type 1 DVM was about 130 m shallower than for Type 2 DVM. Third, for both DVM types, one high and one low in the occurrences of both DVM types were observed each year, but their timing was mismatched.The occurrence of Type 1 DVM was highest in fall and lowest in spring, whereas the occurrence of Type 2 DVM was observed about 3 months later. The most probable explanation for Type 1 DVM by sablefish is that they move to follow vertically migrating prey. Type 2 DVM more commonly occurs during winter, likely representing an increase in foraging during the daytime to compensate for decreased pelagic resources in winter.

For more information, contact Mike Sigler at mike.sigler@noaa.gov.

A comparison of methods for classifying female sablefish maturity– ABL

For sablefish, the spawning season is estimated to peak in February. Typically, sampling platforms, such as the NMFS longline survey in Alaska, occur from June through August (Figure 1). This encompasses the time in the reproductive cycle when fish are either resting or beginning to develop. The goal of this study was to determine if maturity classifications collected during summer surveys in Alaska could be used to accurately predict if fish would spawn in the coming winter and whether histology was required to accurately classify ovarian development. The maturity classification methods included 1) macroscopic classification at-sea by scientists that varied throughout the survey period, 2) macroscopic classification after the survey from photographs by a single experienced scientist (standardized macroscopic), and 3) a microscopic evaluation of ovarian structures from histological slides by the same scientist as in 2.

On the latter two legs of the survey in August, particularly leg 7, there were a greater proportion of fish in later stages of vitellogenesis than earlier legs of the survey (Figure 2). This indicates that observations on later legs of the survey will provide more accurate predictions of whether a fish will spawn. Overall, the at-sea macroscopic method resulted in earlier estimates of age or length at maturity. The magnitude of the effect varied by survey leg. The standardized macroscopic and microscopic methods yielded very similar results. Because sampling ovaries, processing histological slides, and analyzing ovarian structures is a more expensive and time consuming method of classifying ovarian development than macroscopic methods, our results demonstrate that the standardized macroscopic method may be practical to use in place of microscopy when there are time and fiscal constraints.

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

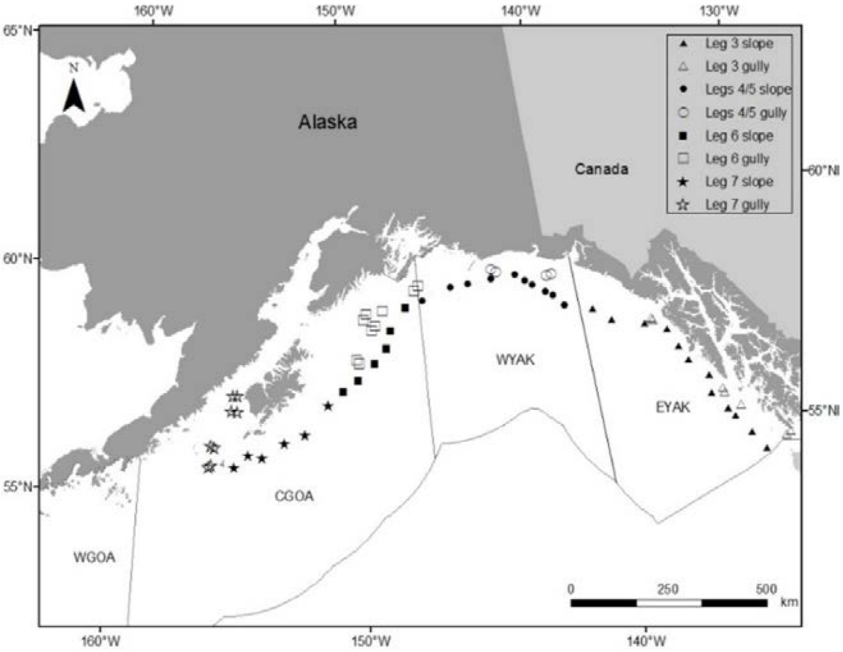

Figure 1. Map of AFSC longline survey stations sampled on survey legs 3-7. Leg 3 is sampled in early July and the vessel heads westward, ending at the western side of the central Gulf of Alaska at the end of August.

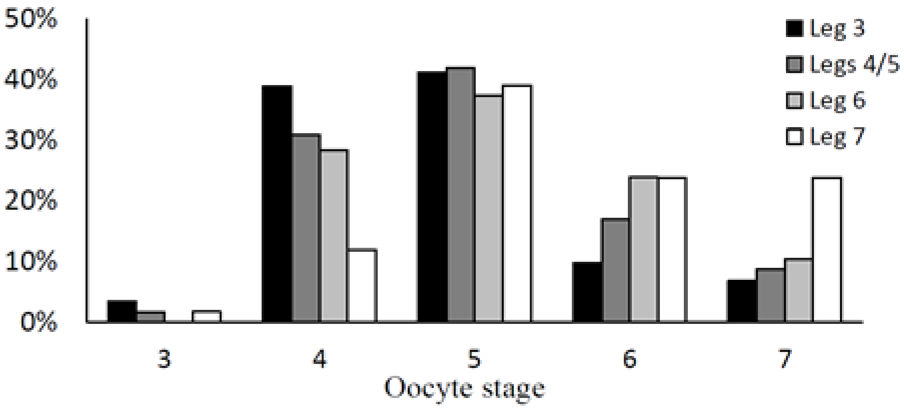

Figure 2. Frequency of each oocyte development stage by leg of the Alaska Fisheries Science Center longline survey in July and August, where the developmental stage is the most advanced oocyte stage in the ovary. Stages 3 through 7 are progressively later stages of vitellogenesis.

The utility of relative liver size and body condition for predicting maturity and fecundity of sablefish

– ABL

Female sablefish were sampled on four survey legs during a summer longline survey in July (legs 3 through 5) and August (legs 6 through 7) 2015 and during a winter survey in December 2015, which is 1 to 3 months prior to spawning in the Gulf of Alaska. The body condition and liver size relative to body size (hepatosomatic index, HSI) increased throughout the summer and by the end of the summer were similar to winter measurements (for HSI see Figure 1). There were significant differences between immature and mature fish HSI and body condition during most sampling periods. Fecundity and relative fecundity were significantly related to body condition and HSI. Increasing or decreasing these measures of condition by 1 standard deviation in a model of fecundity, which also included length, resulted in an estimated decrease in fecundity of 32% or an increase or 47%. This indicates that incorporating condition into measures of productivity may give a more accurate measurement of total egg production than solely spawning biomass. In models that utilized summer condition and liver weight, as well as length and age, to predict whether a fish was immature or would spawn, predictions later in the summer (on legs 6 and 7) produced maturity at age models that were similar to those that used the maturity designations from histology slides (Figure 2).

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

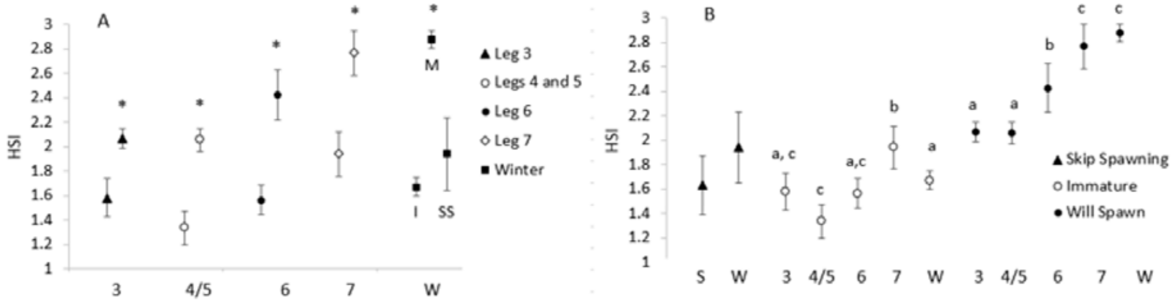

Figure 1. Hepatosomatic index (HSI) for sablefish collected on legs 3 through 7 of the summer longline survey or in winter. Immature (I), mature (M), and skip spawning (SS) fish are labeled for the winter because skip spawning must be differentiated from the other two groups. In Panel A, on every survey leg the mean for immature fish is lower than the mean for fish that will spawn. 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 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).

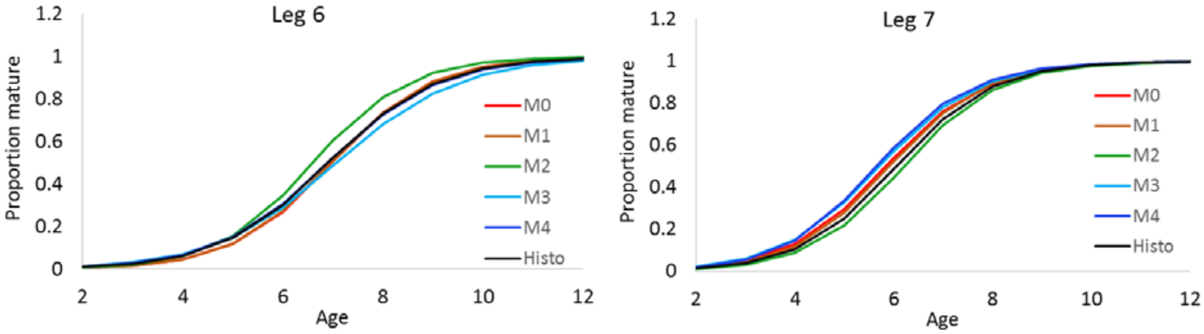

Figure 2. Logistic curves of maturity at age when maturity was determined using histology slides (Histo) or predicted with models (M0 through M4) for legs 6 and 7 of the NMFS Alaska summer longline survey.

Southeast Coastal Monitoring Survey Indices and the Recruitment of Gulf of Alaska Sablefish - ABL

Description of indicator: Biophysical indices from surveys in 2016 and salmon returns in 2017 were used to predict the recruitment of sablefish to age-2 in 2017 and 2018 (Yasumiishi et al. 2015a). Biophysical indices were collected during the southeast coastal monitoring (SECM) survey. The SECM survey has an annual survey of oceanography and fish in inside and outside waters of northern southeast Alaska since 1997 (Orsi et al. 2012). Oceanographic sampling included, but was not limited to, sea temperature and chlorophyll *a*. These data are available from documents published through the North Pacific Anadromous Fish Commission website from 1999 to 2012 (www.npafc.org) and from Emily Fergusson at the Alaska Fisheries Science Center in Juneau, Alaska. An index for pink salmon survival was based on adult returns of pink salmon to southeast Alaska (Piston and Heinl, 2014). These oceanographic metrics may index sablefish recruitment, because sablefish use these waters as rearing habitat early in life (late age-0 to age-2).

Status and trends: We modeled age-2 sablefish recruitment estimates from 2001 to 2016 (Hanselman et al. 2016) as a function of sea temperatures during 1999-2014, chlorophyll a during 1999-2014, and adult pink salmon returns in 2000-2015. The model with the lowest Bayesian information criterion (108) described the stock assessment estimates of age-2 sablefish abundance as a function of late August maximum chlorophyll *a* during the age-0 stage, late August maximum sea temperature during the age-0 stage, and pink salmon returns during the age-1 life stage of these sablefish (Figure 1; Table 1). A regression model indicated positive coefficient for the predictor variables chlorophyll a, sea temperature, and pink salmon returns were positively in the sablefish model ($R^2 = 0.7667$, Adjusted $R^2 = 0.7084$, F-statistic: 13.15 on 3 and 12 DF, p-value: 0.0004224).

Based on 2016 environmental data, the high levels of 10.83 chlorophyll a (10.83), warm waters (13.4 °C) and good forecast for pink salmon returns (43 million) in 2017, we predict above average abundance of age-2 sablefish (68 million) in 2018 (2016 year class). Based on 2017 environmental data, low chlorophyll a (1.12) in 2015, average sea temperatures (12 °C), and low pink salmon returns in 2016 (17,820,985), we predict below average abundance of age-2 sablefish in 2017 for the 2015 year class.

Factors influencing observed trends: Warmer sea temperatures were associated with high recruitment events in sablefish (Sigler and Zenger, 1989). Higher chlorophyll *a* content in sea water during late summer indicate higher primary productivity and a possible late summer phytoplankton bloom. Higher pink salmon productivity, a co-occurring species in near-shore waters, was a positive predictor for sablefish recruitment to age-2. These conditions are assumed more favorable for age-0 sablefish, overwintering survival from age-0 to age-1, and overall survival to age-2.

Implications: Our 2017 model indicates that we should expect a weak 2015 year class and a strong 2016 year class of sablefish.

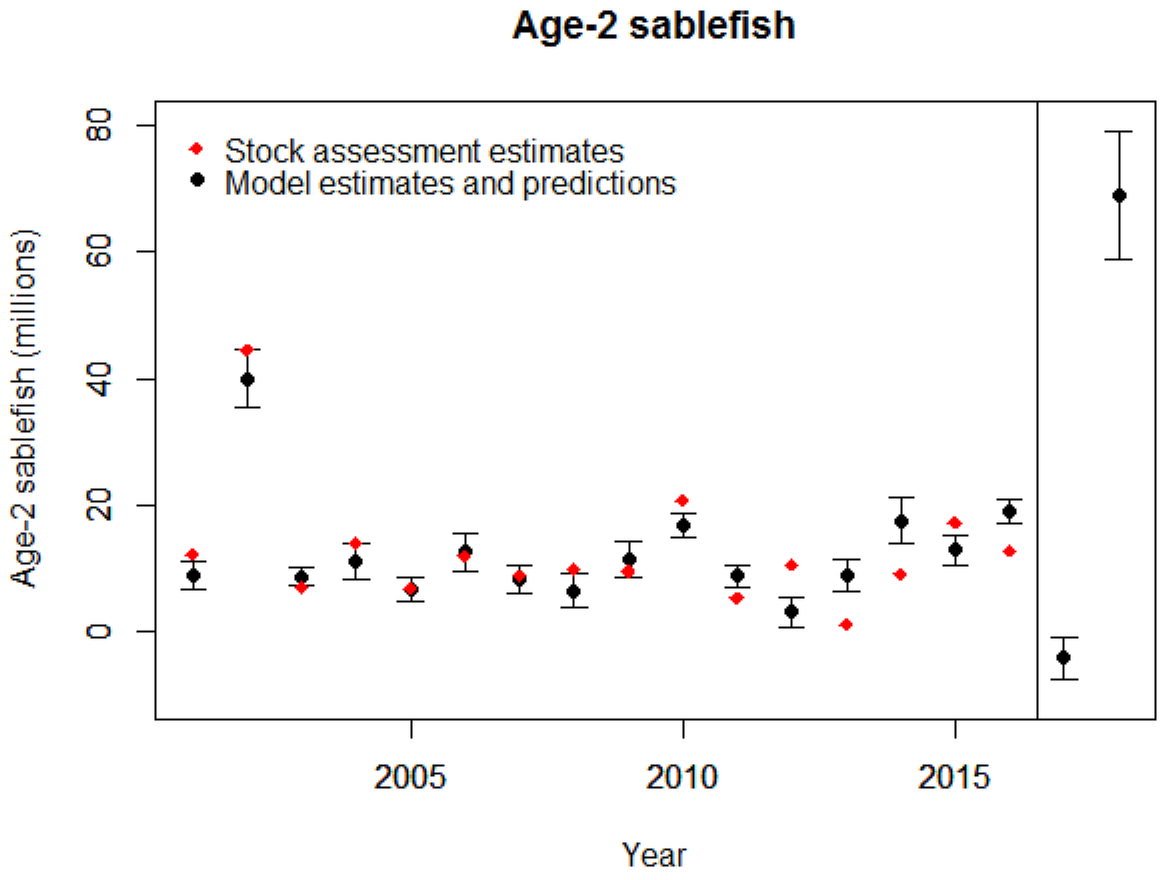

Figure 1. Stock assessment estatimes, model estimates, and the 2017 and 2018 prediction for age-2 Alaska sablefish. Stock assessment estimates of age-2 sablefish were modeled as a function of late August chlorophyll *a* levels and late August sea temperatures in the waters of Icy Strait in northern southeast Alaska during the age-0 stage (*t*-2), and the returns of age-1 pink salmon (*t*-1). These predictors are indicators for the conditions experiences by age-0 sablefish. Stock assessment estimates of age-2 sablefish abundances are from Table 3.14 in Hanselman et al. 2016.

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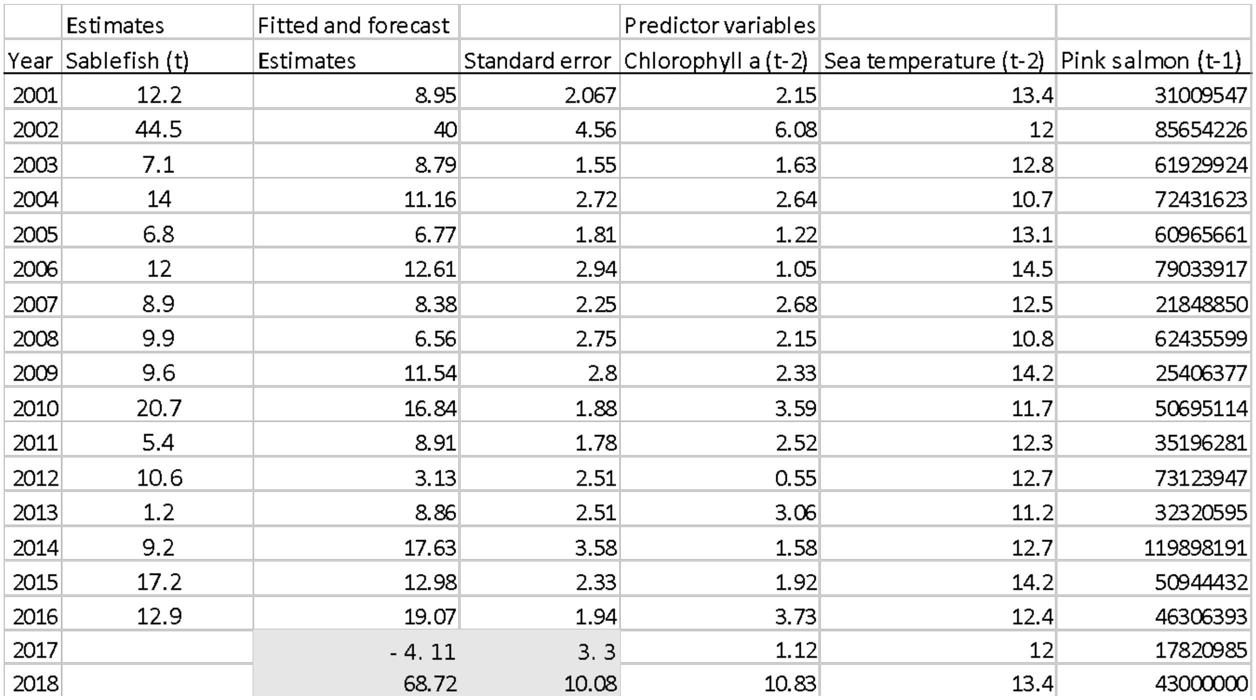
Yasumiishi, E., K. Shotwell, D. Hanselman, J. Orsi, and E. Fergusson. 2015a. Using salmon survey and commercial fishery data to index nearshore rearing conditions and recruitment of Alaska sablefish. Marine and Coastal Fisheries: Dynamics, Management, and Ecosystem Science. 7(1): 316-324. DOI: 10.1080/19425120.2015.1047070

Yasumiishi, E.M., K. Shotwell, D. Hanselman, J. Orsi, and E. Fergusson. 2015b. Southeast coastal monitoring survey indices and the recruitment of Gulf of Alaska sablefish. In: S. Zador (Ed.), Ecosystem Considerations for 2014. Appendix C of the BSAI/GOA Stock Assessment and Fishery Evaluation Report. Technical report, North Pacific Fishery Management Council, 605W. 4th Ave., Suite 306, Anchorage, AK 99501.

Table 1. Nearshore survey data fit to the stock assessment estimates of age-2 sablefish (millions of fish) from Hanselman et al. (2016). Table shows the 2017 model fitted (2001-2016) and forecast (2017, 2018) estimates and standard errors for age-2 sablefish, and the predictor variable from 1999-2015 used to estimate (2001-2016) and predict (2017, 2018) the stock assessment estimates of age-2 sablefish. Gray shaded cells indicate predicted values based on the 2017 Model and environmental indices from 2016 and 2017.



	Estimates	Fitted and forecast		Predictor variables		
Year	Sablefish (t)	Estimates	Standard error	Chlorophyll a (t-2)	Sea temperature (t-2)	Pink salmon (t-1)
2001	12.2	8.95	2.067	2.15	13.4	31009547
2002	44.5	40	4.56	6.08	12	85654226
2003	7.1	8.79	1.55	1.63	12.8	61929924
2004	14	11.16	2.72	2.64	10.7	72431623
2005	6.8	6.77	1.81	1.22	13.1	60965661
2006	12	12.61	2.94	1.05	14.5	79033917
2007	8.9	8.38	2.25	2.68	12.5	21848850
2008	9.9	6.56	2.75	2.15	10.8	62435599
2009	9.6	11.54	2.8	2.33	14.2	25406377
2010	20.7	16.84	1.88	3.59	11.7	50695114
2011	5.4	8.91	1.78	2.52	12.3	35196281
2012	10.6	3.13	2.51	0.55	12.7	73123947
2013	1.2	8.86	2.51	3.06	11.2	32320595
2014	9.2	17.63	3.58	1.58	12.7	119898191
2015	17.2	12.98	2.33	1.92	14.2	50944432
2016	12.9	19.07	1.94	3.73	12.4	46306393
2017		- 4. 11	3. 3	1.12	12	17820985
2018		68.72	10.08	10.83	13.4	43000000

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

YOY Sablefish Growth and Consumption Study - ABL

Effects of temperature on growth and consumption rates of YOY Sablefish (218 – 289 mm TL) were measured in laboratory trials with fish held over 5 temperature treatments (5°C, 8°C, 12°C, 16°C and 20°C) and maintained on *ad libitum* ration for 3 weeks. Growth, consumption, and body condition of fish were compared between treatments. Specific growth rate (SGR; % wet weight gain (g) d^{-1}) was used to derive a temperature-dependent growth model, and consumption rates were used to calculate species specific parameters for the consumption function of a Wisconsin-type bioenergetics model. Daily growth in length varied from 0.13 mm d^{-1} to 1.74 mm d^{-1} and SGR ranged from 0.52 to 2.31. SGR peaked at 15.4°C, remained high at 12°C and 16°C, and steadily declined as temperatures shifted outside this range. Residuals of length-weight regressions showed YOY Sablefish condition was positive at 12°C and 16°C, and negative at 5°C, 8°C, and 20°C. Consumption rose sharply with temperature, peaking at 18.6°C. The narrow thermal range of positive condition and optimal SGR indicates YOY Sablefish growth and development may be dramatically influenced by relatively small shifts in water temperatures. Further, when compared to similar studies of smaller sized Sablefish, we observed a shift with size in thermal performance with larger fish performing better at colder temperatures compared to smaller fish. A secondary growth study was conducted to test the reliability of the growth and consumption models from our main study. Observed growth and consumption rates matched well with model estimates and provide important information linking temperature-dependent physiological response through early development. The shift in thermal performance with size is an important consideration for future management initiatives. While traditional recruitment models rely heavily on information from a single life-stage, resource use and physiological requirements often change with development. Given the widespread occurrence of anomalous thermal events in the GOA, a life-stage specific understanding of the effects of varying temperatures is crucial.

Analysis of body composition revealed an energy allocation strategy across all temperature treatments strongly emphasizing protein synthesis relative to lipid storage, i.e. somatic growth over energy storage. Fish across all treatments had ~8% total-body lipid, while protein linearly increased with temperature. Conversion efficiency of fish (a measure of food consumed relative to instantaneous growth rate) showed highest conversion efficiencies between 12°C and 16°C. RNA/DNA ratios (an instantaneous cellular growth index) were lowest at 16°C, and was coupled with highest growth, suggesting the presence of an optimal growth efficiency window between 12°C and 16°C, further emphasizing that growth/condition of these fish could be affected by even small variations in temperature. The emphasis on heightened somatic growth in YOY sablefish relative to energy storage suggests that the benefit of growth outweighs the potential costs, i.e., risk of starvation. The benefits could include predator avoidance and/or prey capture in a new benthic environment. While YOY sablefish were able to survive the relatively wide range of temperature treatments in our study, the reduced growth at temperatures outside the growth efficiency window could have implications for survival of these fish once they settle to the benthic habitat.

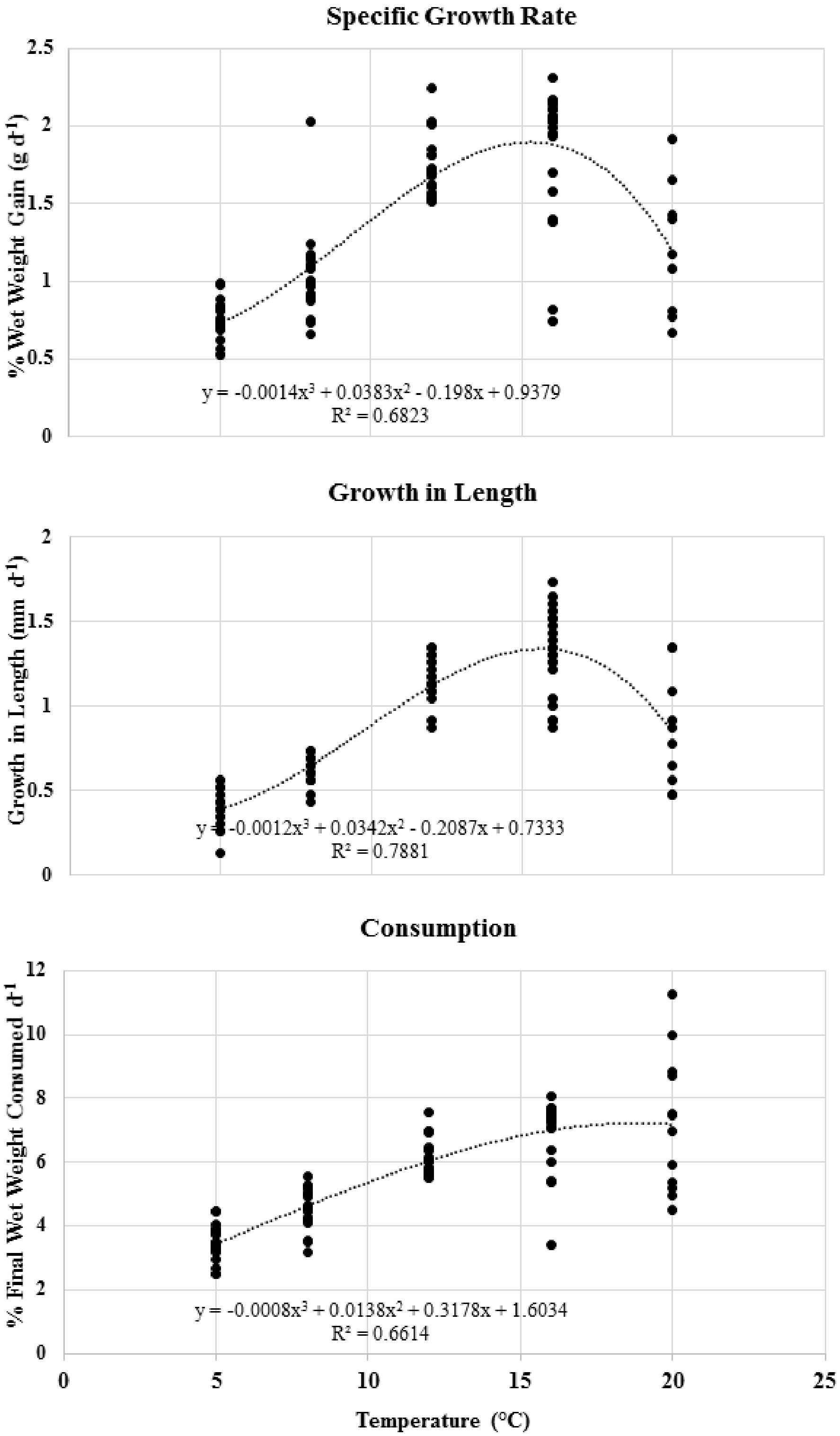


Fig. 1. Temperature-dependent specific growth rate (SGR), growth in length, and consumption, for YOY Sablefish (218 - 289 mm TL). Values are based on individual values of fish from each temperature treatment following 3 weeks of growth at each temperature. A third-order polynomial function describing the temperature-dependent physiological response of each parameter is given.

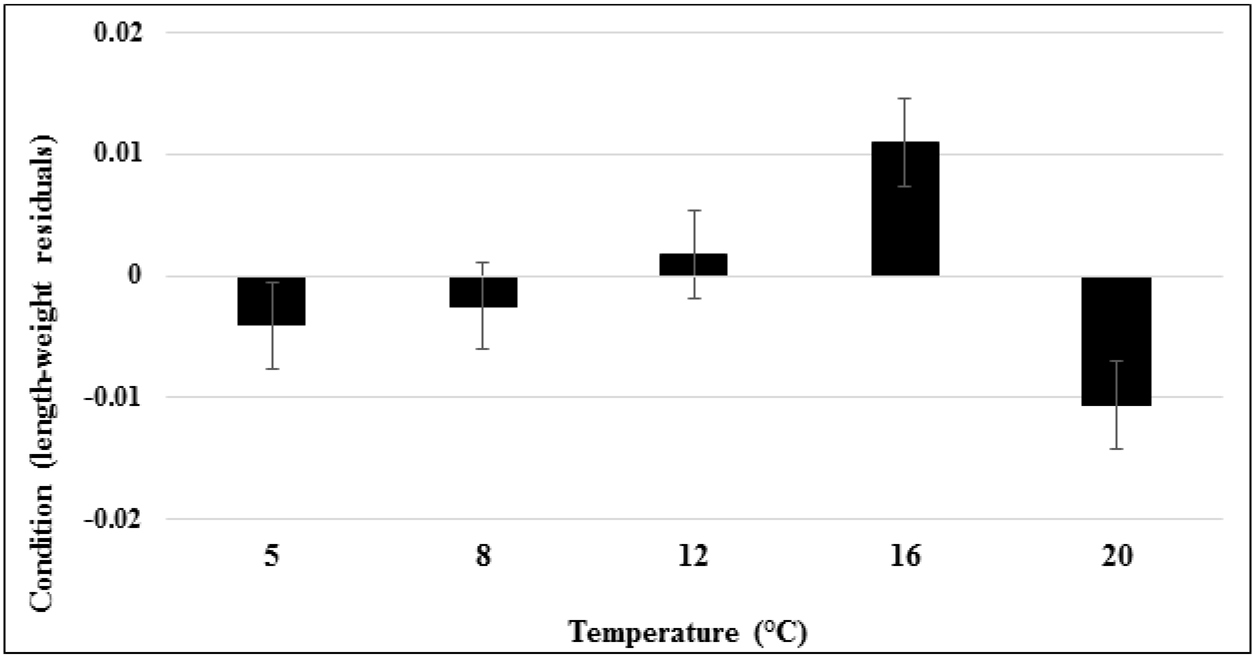


Fig. 2. Temperature-dependent condition factor of YOY Sablefish (218 – 289 mm TL). Condition is based on the length-weight residuals of fish following 3 weeks of growth at each temperature. Mean (± SD) values are based on individuals from duplicate tanks at each temperature.

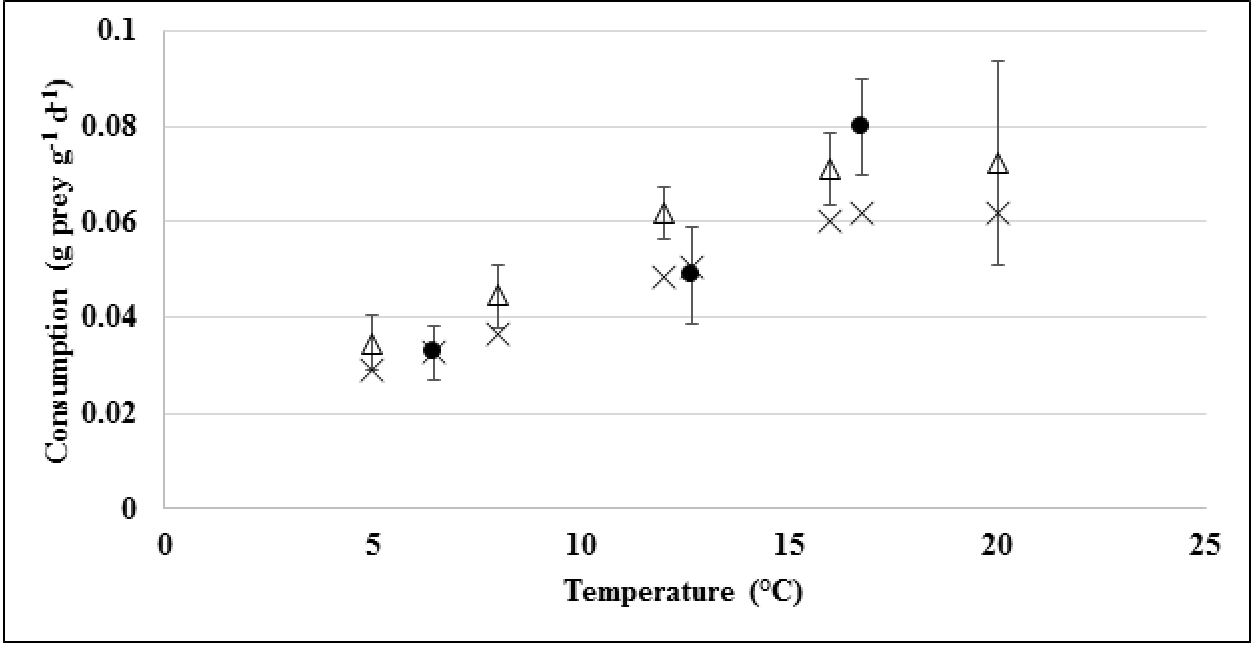


Fig. 3. Mean (± SD) prey consumption rates from 2016 (hollow triangles) and 2017 (black dots) trials for YOY Sablefish during laboratory experiments and estimates of consumption rates calculated using the consumption function of the bioenergetics model (X).

For more information contact Joe Krieger at (907) 789- 6058 or Joeseph.Krieger@noaa.gov

2. Stock Assessment

Bering Sea, Aleutian Islands, and Gulf of Alaska - ABL

A full sablefish stock assessment was produced for the 2018 fishery. New data included in the assessment model were relative abundance and length data from the 2017 longline survey, relative abundance and length data from the 2016 fixed gear fishery, length data from the 2016 trawl fisheries, age data from the 2016 longline survey and 2016 fixed gear fishery, updated catch for 2016, and projected 2017 - 2019 catches. Estimates of killer and sperm whale depredation in the fishery were updated and projected for 2017 - 2019.

The longline survey abundance index increased 14% from 2016 to 2017 following a 28% increase in 2016 from 2015. The lowest point of the time series was 2015. The fishery abundance index decreased 23% from 2015 to 2016 and is the time series low (the 2017 data are not available yet). There was a new Gulf of Alaska (GOA) trawl survey in 2017 which increased 89% from 2015 to 2017. Spawning biomass is projected to increase rapidly from 2018 to 2022, and then stabilize. Sablefish are currently right at the spawning biomass limit reference point and still well below the target, which automatically lowers the potential harvest rate, but the recent 2014 year class should rapidly move the stock above it's target.

The maximum permissible ABC for 2017 is 15% higher than the 2016 ABC of 11,795 t. The 2015 assessment projected a 9% decrease in ABC for 2017 from 2016. We recommended a lower ABC than maximum permissible based on newly available estimates of whale depredation occurring in the fishery. Because we are including inflated survey abundance indices as a result of correcting for sperm whale depredation, this decrement is needed in conjunction to appropriately account for depredation on both the survey and in the fishery. This ABC is still 11% higher than the 2016 ABC. This relatively large increase is supported by a substantial increase in the domestic longline survey index time series that offset the small decrease in the fishery abundance index seen in 2015. The fishery abundance index has been trending down since 2007. The International Pacific Halibut Commission (IPHC) GOA sablefish index was not used in the model, but was similar to the longline survey, hitting its time series low in 2015, down 36% from 2014. The 2008 year class showed potential to be large in previous assessments based on patterns in the age and length compositions. This year class is now estimated to be about 30% above average. There are preliminary indications of a large incoming 2014 year class, which was evident in the 2016 longline survey length compositions. Spawning biomass is projected to decline through 2019, and then is expected to increase assuming average recruitment is achieved in the future. ABCs are projected to slowly increase to 13,688 t in 2018 and 14,361 t in 2019.

Instead of maximum permissible ABC, we recommended a 2018 ABC of 14,957 t, which is 14% higher than the 2017 ABC. The maximum permissible ABC for 2018 is 89% higher than the 2017 ABC of 13,809 t. The 2016 assessment projected a 1% increase in ABC for 2018 from 2017. The author recommended ABCs for 2018 and 2019 are lower than maximum permissible ABC for two important reasons.

First, the 2014 year class is estimated to be 2.5 times higher than any other year class observed in the current recruitment regime. Tier 3 stocks have no explicit method to incorporate the uncertainty of this new 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. These concerns warrant additional caution when recommending the 2018 and 2019 ABCs. It is unlikely that the 2014 year class will be average or below average, but projecting catches under the assumption that it is 10x average introduces risk knowing the uncertainty associated with this estimate. Only one large year class since 1999 has been observed, and there is only one observation of age compositions to support the magnitude of the 2014 year class. Future surveys will help determine the magnitude of the 2014 year class and will help detect if there are additional incoming large year classes other than the 2014 year class.

Projections that consider harvesting at the maximum ABC for the next two years, if the 2014 year class is actually average, results in future spawning biomass projections that are very low, where depensation (reduced productivity at low stock sizes) could occur. Recommending an ABC lower than the maximum should result in more of the 2014 year class reaching spawning biomass and achieving higher economic value. Because of these additional considerations, we assume that the recent recruitment is equal to the previous highest recruitment event in the current regime for projections (1977, which is still 4x average.) This results in more precautionary ABC recommendations to buffer 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 compositions in 2018 and adjust our strategy accordingly.

Second, we also recommend a lower ABC than maximum permissible based on estimates of whale depredation occurring in the fishery in the same way that as recommended and accepted in 2017. 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. This ABC is still 14% higher than the 2017 ABC.

Survey trends support this moderate increase in ABC relative to last year. There was a substantial increase in the domestic longline survey index time series, and a large increase in the GOA bottom trawl survey. These increases offset the continued decline of the fishery abundance index seen in 2016. The fishery abundance index has been trending down since 2007. The International Pacific Halibut Commission (IPHC) GOA sablefish index was not used in the model, but was similar to the 2015 estimate in 2016, up 5% from 2015. 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 13% above average. There were preliminary indications of a large incoming 2014 year class, which were evident in the 2016 longline survey length compositions and now are extremely dominant in the 2016 age compositions. This year class appears to be very strong, but year classes have sometimes failed to materialize later and the estimate of this year class is extremely uncertain.

For more information contact Dana Hanselman at (907) 789-6626, dana.hanselman@noaa.gov

Whale Depredation Estimation - ABL

A challenge that few fisheries and assessments face is depredation of fish off of longline gear by both killer whales and sperm whales. Depredation is when whales strip or pluck fish from the gear as it is being hauled back to the boat. For sablefish catch on the AFSC longline survey, killer whale affected sets have always been removed from catch rate calculations because of their obvious impact on catch rates, while the sperm whale depredation is more difficult to detect and had not previously been considered when calculating catch rates. Presence and evidence of depredation by sperm whales on the AFSC longline survey have increased significantly over time. We developed models that estimated that sablefish catch rate reductions caused by sperm whale depredation ranged from 12%-18% at affected longline sets under various model assumptions. Correcting for sperm whale depredation in the assessment resulted in a 3% increase in estimated female spawning biomass in the terminal year and a 6% higher quota recommendation (Hanselman et al. 2018).

When recommending a larger quota because of whale depredation on the survey, it was necessary to account for the additional mortality from whale depredation during the fishery (Peterson and Hanselman 2017). We used data collected by fishery observers, comparing “good performance” sets with those with “considerable whale depredation.” A generalized additive mixed modeling approach was used to estimate the whale effect on commercial sablefish fishery catch rates; killer whale depredation was more severe (catch rates declined by 45%-70%) than sperm whale depredation (24%-29%). Annual estimated sablefish catch removals during 1995-2016 ranged widely from 69 t – 683 t by killer whales in western Alaska and 48 t – 328 t by sperm whales in the Gulf of Alaska from 2001-2016. We included this as additional catch in the stock assessment model and used a 3-year average of this estimated whale induced sablefish mortality to decrement from the larger ABC caused by survey corrections. These new models and changes were reviewed and approved by the Center for Independent Experts in a sablefish assessment review in 2016. These assessment changes were accepted by the North Pacific Fishery Management Council (NPFMC) and are in place for the 2017 fishery. In addition, the NPFMC and Alaska Regional Office have recently opened up the Gulf of Alaska to the use of pot, or trap, gear to the fixed gear fishery as an option to avoid whale depredation.

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For more information contact Dana Hanselman at dana.hanselman@noaa.gov

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 will meet to discuss ongoing sablefish research, sablefish assessment models, and opportunities for collaboration. It is hoped that this review will help form a more complete picture of the population dynamics of sablefish at a coastwide scale, and potentially lead to further analyses on coastwide abundance trends via simulation studies or enhanced assessment methods. 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.

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

J. Lingcod

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-GAP

Groundfish stocks in Alaska are managed at large scales, however commercial fishing is an activity with potential for localized effects. This NPRB Project (No. 1305) addresses concerns that local fishery effects could impact foraging success of the endangered Steller sea lion. Our project assesses the small-scale abundance and movement of Atka mackerel in the Western Aleutian Islands where sea lion populations continue to decline and where in 2011 protection measures closed the directed commercial fishery for Atka mackerel and Pacific cod to mitigate against potential competition between sea lions and the commercial fishery. We are comparing these with data collected in the Eastern Aleutian Islands where sea lion populations are stable and a fishery occurs. Information on the local abundance and movement of sea lion prey is essential to evaluate the effect of these closures and gather baseline information on prey fields around sea lion rookeries and haulouts. This is being accomplished through tagging, releasing and recovering Atka mackerel at several Atka mackerel population centers in the Western and Eastern Aleutian Islands and conducting opportunistic sampling in areas of preferred Steller sea lion foraging. Our project also assesses the relative abundance of major groundfish prey of sea lions in the summer and winter such as Pacific Cod, Pollock, and rockfish using catch-per-unit-effort abundance indices. The winter data are being compared with Steller sea lion diet samples collected by National Marine Mammal Laboratory and will thus describe the prey utilization patterns by sea lions. This project is conducted in collaboration with the North Pacific Fisheries Foundation (NPFF).

For more information, contact Susanne McDermott at Susanne.McDermott@noaa.gov.

2. Stock Assessment

Spawning biomass reached an all-time high in 2005, then decreased continuously through 2017 (the spawning biomass is estimated to be roughly 50% of what it was in 2005). It is projected to decrease further, at least through 2018. The 1998-2001 year classes were all very strong, and the 2006 and 2007 year classes were above average. The addition of the 2016 fishery and survey age compositions information impacted the estimated magnitude of the 2011 year class which increased 14%, relative to last year's assessment, and the magnitude of the 2012 year class which increased 32% relative to last year assessment. The 2012 year class is now estimated to be slightly above average. The projected female spawning biomass for 2018 (139,300 t) is still above $B_{40\%}$ (122,860 t), and the stock is projected to remain above $B_{40\%}$ through the next several years.

The following new data were included in this year's assessment:

- Total 2016 year-end catch was updated, and the projected total catch for 2017 was set equal to the 2017 TAC.
- The 2016 fishery age composition data were added.
- The 2016 Aleutian Islands survey age composition estimates were added.

Methodological changes included the following:

- Refinements to the time-varying fishery selectivity inputs were made using the same statistical weighting ("Francis") method for the time-varying fishery selectivity variance term that was used for the survey age composition data.
- In the projection model:
    - Catches for 2018 and 2019 were assumed to equal 75% of the BSAI-wide ABC, based on the effect of the revised Steller Sea Lion Reasonable and Prudent Alternatives that were implemented in 2015 (it was 62% in last year's assessment).

The projected female spawning biomass under the recommended harvest strategy is estimated to be above $B_{40\%}$, thereby placing BSAI Atka mackerel in Tier 3a. The projected 2018 yield (ABC) at $F_{40\%}$ = 0.38 is 92,000 t, up 5% from the 2017 ABC and up 8% from last year's projected ABC for 2018. The projected 2018 overfishing level at $F_{35\%}$ = 0.46 is 108,600 t, up 5% from the 2017 OFL and up 8% from last year's projected OFL for 2018.

As in last year's assessment, the standard Tier 5 random effects model was used to apportion the ABC among areas. The recommended ABC apportionments by subarea for 2018 are 36,820 t for Area 541 and the Bering Sea region (a 5% increase from 2017), 32,000 t for Area 542 (a 5% increase from 2017), and 23,180 t for Area 543 (a 5% increase from 2017). Atka mackerel is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition. As requested, this section was significantly expanded and updated. Temperature anomaly profiles from the 2016 Aleutian Island survey data appear to be some of the warmest on record. Temperature may affect recruitment of Atka mackerel and availability to the bottom trawl survey. Atka mackerel is the most common prey item of the endangered western Steller sea lion throughout the year in the Aleutian Islands. 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 (but with a maximum TAC of 65% of the area ABC), removed the TAC reduction in area 542, and re-opened areas in 541 and 542 that had been closed to directed Atka mackerel fishing. Prior to 2011, a "platoon" system was in place that restricted the timing of fishing effort in the AI.

Atka mackerel is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

L. Flatfish

1. Research

Availability of yellowfin sole to the eastern Bering Sea trawl survey and its effect on survey biomass--GAP

Availability of yellowfin sole *Limanda aspera* to the eastern Bering Sea trawl survey, rather than trawl sampling efficiency, is proposed as the primary reason for relatively high annual variability of biomass estimates in this region, including most recently, a 48% increase from 2015 to 2016. The main hypothesis presented here is that temperature-mediated differences in the timing of spring-summer spawning migrations to unavailable nearshore spawning grounds, affect survey biomass estimates. Colder bottom temperatures delay both migrations and spawning, causing higher proportions of mature individuals to reside in the unavailable nearshore grounds at the time of annual survey (June-July). Indicators of this scenario include decreases of mature fish proportions and decreases in mean overall fish lengths during colder years when biomass was less than expected. Further evidence includes differences in spatial distribution between warm and cold years, and spatial shifts away from nearshore areas between early June and July-August sampling during which catch per unit effort (CPUE) increased and proportion of females increased. That neither of these spatial shifts nor temperature-CPUE relationships occurred for northern rock sole *Lepidopsetta polyxystra*, a species of similar morphology and abundance, and overlapping spatial distribution, suggests that temperature-mediated trawl sampling efficiency was not a major contributing factor for yellowfin sole. We have also found a positive relationship between survey biomass estimates and survey start times, reinforcing that availability is a function of timing. The addition of survey start time to the catchability (*q*) parameter within the current stock assessment model significantly improved model fits to survey biomass.

For further information, contact Dan Nichol, dan.nichol@noaa.gov

Connectivity, cross-shelf transport, and the delivery of larval arrowtooth flounder (*Atheresthes stomias*) to suitable nursery habitats in the Gulf of Alaska - RPP

Esther D. Goldstein, Janet T. Duffy-Anderson, Jodi L. Pirtle, William T. Stockhausen, Matthew T. Wilson, Mark Zimmermann, and Calvin W. Mordy

Arrowtooth flounder (ATF: *Atheresthes stomias*) is an ecologically important predator and the most abundant groundfish species in the Gulf of Alaska (GOA) throughout the past few decades (Spies and Turnock, 2013). The shift toward high abundance and biomass of arrowtooth flounder in recent years in the GOA has led to concern regarding potential predation pressure on the juvenile stages of commercially important species such as walleye pollock (*Gadus chalcogrammus;* Gaichas et al., 2011; Hollowed, 2000) and highlighted the need for increased understanding of the processes and that influence arrowtooth flounder survival and recruitment.

Arrowtooth flounder spawn along the continental slope in water depths of ~300-600 meters, and after a pelagic larval duration that spans multiple months, late-stage larvae settle to obligate juvenile nursery habitats in shallower water on the continental shelf (Stockhausen et al. *in revision*). Like many marine fish with ontogenetic habitat requirements, arrowtooth flounder recruitment is dependent upon spatial and temporal coupling between life-stage transitions and access to suitable habitats. The successful transition between the pelagic larval stage and benthic-associated juvenile stage is substantially influenced by two processes: 1) along-shelf and cross-shelf transport of larvae that is driven by oceanography and hydrology, and 2) delivery of larvae to high quality nursery habitats. We hypothesize that inter-annual oceanographic variability will influence the degree to which larvae are successfully transported from offshore environments to suitable nursery habitats, and that successful recruitment of arrowtooth flounder may be enhanced by submarine canyons that act as conduits of cross-shelf transport for larvae.

We utilized an Individual-Based Biophysical Model (IBM) developed using the DisMELS modeling framework (Stockhausen et al. *in revision*) in combination with a juvenile habitat suitability model using a Maximum Entropy modeling approach to identify coupling between transport and delivery to suitable nursery habitats for the years 2000-2011 in the GOA. Based on habitat suitability models and coupled IBM results habitat requirements restrict the amount of nursery habitat available for settlement-stage arrowtooth flounder, and subsequently, decrease expected survivorship and recruitment. The majority of suitable habitat is located in the western GOA, and accordingly, successful delivery to suitable habitats is associated with particle trajectories that extend to the western GOA and primarily along the continental shelf in comparison to trajectories that deliver larvae to low quality habitats (Fig. 1a, b). Inter-annual oceanographic variability influences the degree to which settlement-stage arrowtooth flounder are successfully delivered to suitable habitats, by up to a two-fold increase in recruitment in some years. Particularly, recruitment success was enhanced by transient, retentive, oceanographic features such as eddies. For larvae that are advected offshore, cross-shelf transport to and delivery to suitable nursery habitats via canyons was lower than non-canyon routes of transport. However, routes of cross-shelf transport and the efficacy of submarine canyons as conduits of shelf-ward movement is substantially influenced by the presence and location of eddies (Fig. 2). These findings suggest that in the heterogeneous GOA, connectivity, survival, and recruitment of arrowtooth flounder is enhanced by eddies that promote retention, and mediated by the interaction between persistent topographic features and transient oceanographic processes.

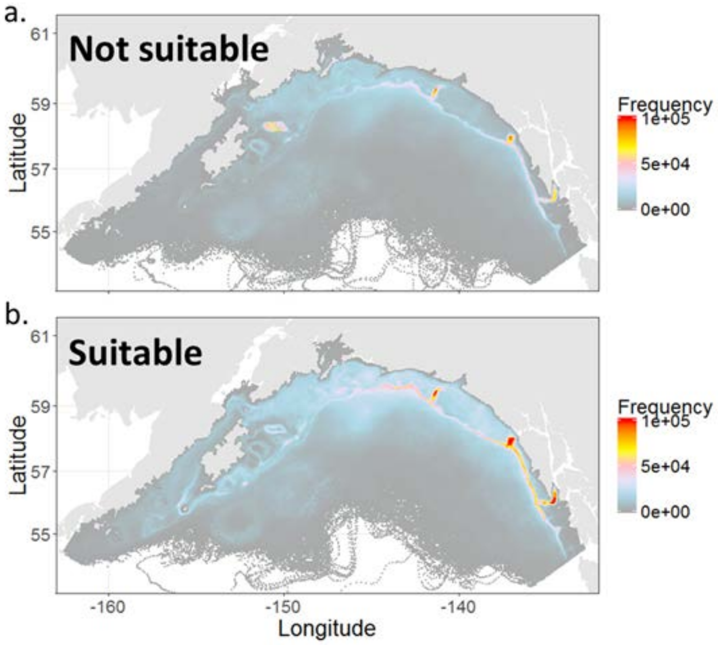

Figure 1. Arrowtooth flounder Individual-based Biophysical Model (IBM) output paired with the habitat suitability model from 2000-2011. The color scale shows the number of modeled larval particles that traversed a 3 km x 3 km grid cell and the values were averaged across the 12 year study period. The panels show the transport trajectories of individuals that were delivered as settlement-stage larvae to a) nursery habitats that are not suitable and b) suitable nursery habitats.

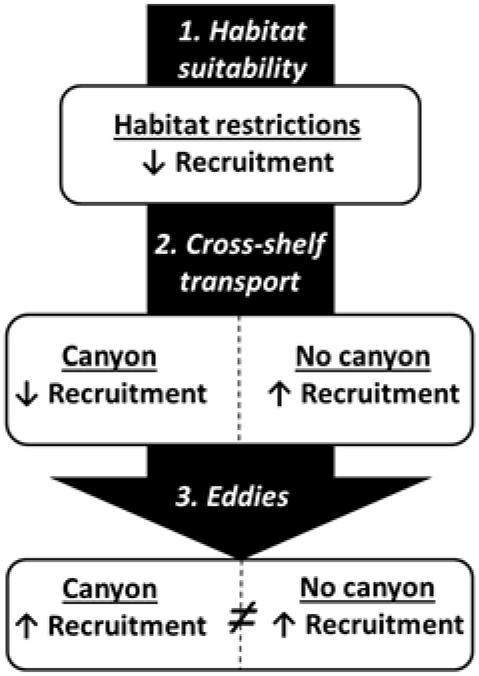

Figure 2. Schematic representation of the processes that influence recruitment for arrowtooth flounder in the Gulf of Alaska focusing on 1) habitat suitability, 2) cross-shelf transport, and 3) eddies. 1) Habitat suitability requirements enhance habitat restrictions and decrease recruitment. 2) Successful recruitment associated with cross-shelf transport through canyons is lower than non-canyon routes. 3) Transient eddy feature enhance recruitment regardless of the route of cross-shelf transport but the timing and location of eddies influences the relative importance of cross-shelf transport via canyons and other routes.

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For more information contact Esther Goldstein at: Esther.Goldstein@noaa.gov

Bering Sea benthic prey availability and juvenile flatfish habitat quality--GAP

Research continues in characterizing and assessing the productivity of flatfish habitat in the eastern Bering Sea (EBS) under the Essential Fish Habitat provision of the fishery management plan. Field sampling has been conducted intermittently since 2011 as special projects of the EBS annual bottom trawl survey. The current focus is on the habitats of juvenile yellowfin sole (*Limanda aspera*; YFS) and northern rock sole (*Lepidopsetta polyxystra*; NRS), particularly on how habitat may be impacted by the multi-year warm-cold thermal shifts and the long-term warming trend in the EBS.

Recent studies suggested that the latitudinal shift in the distribution of NRS juveniles was linked to the thermal regime: 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). Whether YFS juveniles also followed a similar pattern is currently being investigated. Larval transport is most likely the key determinant of the distribution of juveniles over the habitat range.

Results from this research so far showed that the north and south habitats both had high prey abundance and similarly high summer bottom temperature during the latest warm thermal phase, which began circa late 2013. It appeared that both habitat areas were comparable in critical habitat qualities. However, the body condition of juveniles was higher in the south. 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, In review). Diets may also be different between the north and the south areas for both NRS and YFS. Juveniles of both species may consume more polychaetes on average in percentage weight in the south than in the north, and more clams in the north than in the south. A difference in diets could contribute to difference in condition and growth. Otolith analysis showed that NRS in the south were much larger than those in the north at the same age, as was first annulus size. Overall, the results indicate that juvenile NRS grows faster in the south than in the north.

In 2017, juvenile flatfish habitat investigations were extended into the northern Bering Sea (NBS) with the extension of the bottom trawl survey. Juveniles (≤15 cm total length) were collected along the coast in waters mostly ≤ 25 m deep from Bristol Bay in the south to Norton Sound in the north to examine the spatial variation in their body condition. Fish specimens are collected at 15 stations in the NBS, and 6 stations in the EBS (the working definition of the NBS and EBS divide being 60oN). Specimens are being analyzed for stomach contents, lipids biochemistry, and otolith age. As in 2016, very high abundances of juvenile NRS and YFS were observed in the bottom-trawl survey. Colder bottom water temperatures have returned to the EBS in 2017 following a record high in 2016. The continuation of this research will enable the comparison of juvenile condition between a cold and a warm thermal phase.

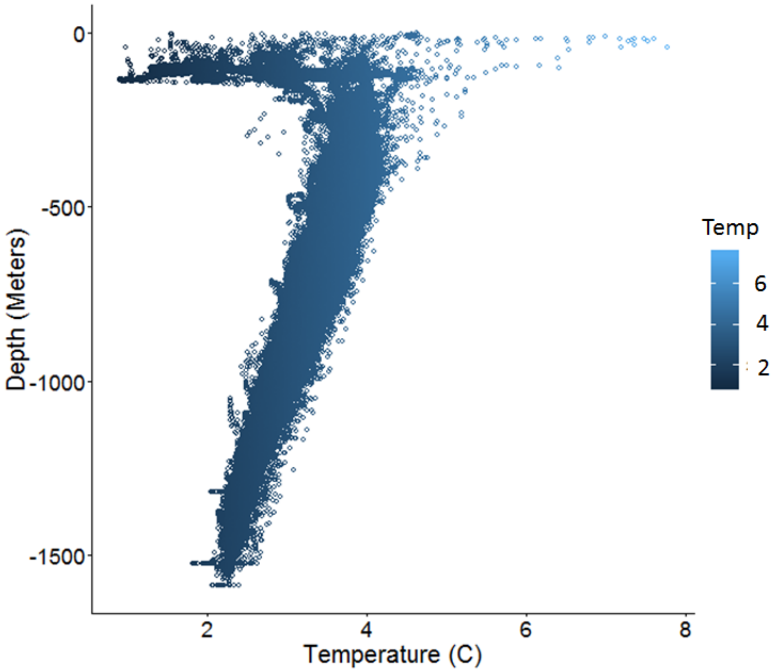
For further information, contact Cynthia Yeung, (206)526-6530, cynthia.yeung@noaa.gov.

Yeung, C., Yang, M.S., In review. Spatial variation in habitat quality for juvenile flatfish in the southeastern Bering Sea. Journal of Sea Research.

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 turbot vertical movement and temperatures experienced in the Bering Sea. Archival tag data were recovered from 12 Greenland turbot, spanning 35-1100 days, with mean depths and temperatures for individual fish ranging from 450 – 725 meters (m) and 3.2 – 3.7 °C. The average distance between fish release and recapture location was 64 nautical miles with a maximum of 306 nautical miles and the majority of releases and recaptures occurred near or on the shelf break. All of the tagged fish that were at liberty for 1+ years (n=8) exhibited seasonal differences in depth and vertical movement with a general trend of shallower depths in the summer, suggesting movement on or towards the continental shelf. In winter months there were more occurrences of deep dives. For example, one fish descended from 850 to 1500 m within a span of 15 hours. The temperature range at depth sharply increased in depths < 200 m and there is evidence that some tagged turbot were on the continental shelf experiencing Bering Sea cold pool conditions in the summer months. Future work will investigate the relationship between vertical activity (change in depth over 15 min) and variables such as day/night, fish length, sex, temperature, and season.

Plot showing temperatures at depths experienced for combined detections of tagged Greenland turbot that recorded for 1+ years with depth on the y-axis (depicted as negative for intuitive interpretation, 0 represents the surface) and temperature on the x-axis.



For more information, contact Karson Coutré at (907) 789-6020 or Karson.coutre@noaa.gov

Flatfish biology in the Bering Sea: examining spatial and temporal effects on maturity and growth across the eastern and northern Bering Sea continental shelves

Funded by NPRB, the overarching goal of this project is to provide life history information for flatfishes that is essential for their management and conservation. This study has the following main objectives:

1) Identify maturity schedules for flatfishes in the NBS (yellowfin sole and Alaska plaice) and

update maturity schedules in the EBS (Greenland turbot and Bering flounder);
2) Incorporate new maturity-at-age estimates for the above species into their respective age-structured models for estimation of spawning stock biomass;
3) Analyze spatial and temporal variation in maturity for yellowfin sole and Alaska plaice under environmental conditions by examining the utility of linear and non-linear modeling;
4) Estimate the relationship of NBS yellowfin sole and Alaska plaice growth to environmental conditions.

Field collections for yellowfin sole and Alaska plaice were conducted during the annual eastern Bering Sea (EBS) and an extension to the survey area into the northern Bering Sea (NBS). Ovaries from female specimens were collected as part of the standard otolith collection on these surveys. Processing of ovary samples and age determination of otoliths is being finalized for histological review and subsequent maturity-at-age estimates, and potential for spatial and temporal variation. An effort will be made to collect additional females from the 2018 EBS survey for yellowfin sole.

Non-linear Modeling with Aspects of Reproduction and Covariates

We've begun to explore the use of non-linear techniques through generalized additive models, with maturity data used in this project for the final models that involve examining spatial and temporal components of flatfish reproduction. Once all the maturity collections are processed and analyzed histologically, final models will be constructed on the full suite of samples, both spatially and temporally. The 1993 EBS yellowfin sole maturity collections was initially explored because of its large spatial coverage and sample size. GAM construction may involve testing the fit for multiple error distribution types (e.g. Poisson, Negative Binomial, Tweedie, Binomial), depending on the type of model used. Results from a single output, with setting gamma=1.4 with a quasi-Poisson error distribution using the *mgcv* package in R, show significance of smooth terms from selected variables used. For this model, maturity code was used as a proxy for oocyte development stages, based on five assigned stages: Maturity development stage ~ s(Latitude, Longitude) + s(Bottom temperature) + s(Depth) + s(Fish Length). The plots show that fish at a more advanced level of oocyte development (vitellogenesis or have spawned, exhibiting post-ovulatory follicles) are larger and occur shallower on average during the spawning season where the bottom temperature is warmer.

For further information contact Todd TenBrink (206) 526-4697.

2. Assessment

Yellowfin sole Stock Assessment - Bering Sea - REFM

The 2017 EBS bottom trawl survey resulted in a biomass estimate of 2.78 million t, compared to the 2016 survey biomass of 2.859 million t (a 3% decrease). The stock assessment model indicates that yellowfin sole have slowly declined over the past twenty years, although they are still at a fairly high level (1.9 times B_{MSY}), due to recruitment levels which are less than those which built the stock to high levels in the late 1960s and early 1970s. The time-series of survey age compositions indicate that only 8 of the past 27 year classes have been at or above the long term average. However, the 2003 year class appears to be the second strongest as any observed since 1983 and the 2006-2009 year-classes also are estimated to be a bit above average as future contributors to the reservoir of female spawners. The 2017 catch of 132,300 t represents the largest flatfish fishery in the US and the five-year average exploitation rate has been 6% for this stock (consistently less than the ABC).

Changes to the input data include: 1) 2016 fishery and survey age compositions, 2) 2017 trawl survey biomass and point estimate and standard error, 3) estimate of the discarded and retained portions of the 2016 catch composition, 4) estimate of total 2017 catch, 5) and updated weight at age for survey and fishery. No changes were made to the assessment model. The projected female spawning biomass estimate for 2018 is 895,000 t, which is 1.9´B_{MSY}. This is a 15% increase from last year’s 2017 estimate (778,600 t). Although there has been a general decline that has prevailed since 1993, there is now some indication of a slow increase over the past three years.

This stock is in the Tier 1 management category since reliable estimates of B_{MSY} and the probability density function for F_{MSY} exist for this stock. The estimate of B_{MSY} from the present assessment is 456,000 t, and projected spawning biomass for 2018 is 895,000 t, meaning that yellowfin sole qualify for management under Tier 1a. Corresponding to the approach used in recent years, the 1978-2010 age 1 recruitments (and corresponding spawning biomass estimates) were used this year to determine the Tier 1 harvest recommendation. This provided a maximum permissible ABC harvest ratio (the harmonic mean of the F_{MSY} harvest ratio) of 0.109. The current value of the OFL harvest ratio (the arithmetic mean of the F_{MSY} ratio) is 0.12. The product of the maximum permissible ABC harvest ratio and the geometric mean of the 2018 biomass estimate produced the 2018 ABC of 277,500 t, and the corresponding product using the OFL harvest ratio produces the 2018 OFL of 306,700 t. For 2019, the corresponding quantities are 267,500 t and 295,600 t, respectively. Yellowfin sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

For further information, contact Thomas Wilderbuer (206) 526-4224, tom.wilderbuer@noaa.gov

Northern Rock Sole – Bering Sea - REFM

The northern rock sole stock is currently at a high level due to strong recruitment from the 2001, 2002, 2003 and 2005 year classes that are now contributing to the mature population biomass. The 2017 bottom trawl survey resulted in a biomass estimate of 1.33 million t, a 9% decrease from the 2016 point estimate. The northern rock sole harvest primarily comes from a high value roe fishery conducted in February and March which usually takes only a small portion (25%) of the ABC because it is constrained by prohibited species catch limits and market conditions. The catch has averaged 40,000 t from 1975 – 2017.

The 2017 assessment was presented in a “partial assessment” format because it was a scheduled “off-year” assessment under the new Stock Assessment Prioritization guidelines. Due to unforeseen technical complications involved with extending the projection range in the Tier 1 assessment model from 2 to 3 years, the authors retained last year's 2018 projection values and computed the 2019 projection values by assuming that the percentage change from 2018 to 2019 would equal the percentage change from 2017 to 2018. The authors anticipate that the technical complications will be overcome before the next partial assessment is conducted. New data in the 2017 assessment included updated 2016 catch and estimated 2017 catch. No changes were made to the assessment model. A new feature included in the “off-year” assessments was a time series of exploitation rate (i.e., catch/biomass).

Spawning biomass was at a low in 2008, but until recently has continuously increased since then. The 2001-2005 year classes are all estimated to be above average; however, the spawning biomass has peaked and is now projected to be declining. The stock assessment model projects a 2018 spawning biomass of 472,200 t. The projected spawning biomass for 2019 is 413,300 t. Northern rock sole qualifies for management under Tier 1 due to reliable estimates of B_{MSY} and the pdf of F_{MSY}. Spawning biomass for 2018 is projected to be well above the B_{MSY} estimate of 257,000, placing northern rock sole in sub-tier "a" of Tier 1. The Tier 1 2018 ABC harvest recommendation is 143,100 t ($F_{ABC} = 0.155$) and the 2018 OFL is 147,300 t ($F_{OFL} = 0.160$). The 2019 ABC and OFL values are 132,000 t and 136,000 t, respectively. Recommended ABCs correspond to the maximum permissible levels. This is a stable fishery that lightly exploits the stock. Usually the average catch/biomass ratio is about 3-4 percent of the northern rock sole stock. Northern rock sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

For further information, contact Thomas Wilderbuer (206) 526-4224, tom.wilderbuer@noaa.gov

Northern Rock Sole – Gulf of Alaska Shallow Water Complex - REFM

A full assessment for shallow water flatfish was completed for 2017. The complex total biomass estimate for 2018 is 339,152 t, a 13% increase from the 2017 value of 299,858 t. This increase is due primarily to a higher model estimate for both northern and southern rock sole and 2017 survey estimates that were higher than 2015 for yellowfin sole, starry flounder, sand sole, and Alaska plaice (estimated from the random effects model). The random effects model estimates for 2017 biomass of butter sole and English sole were smaller than estimated in 2017. On the whole, the random effects model estimated an increase in biomass in 2017 compared to 2015 for the complex combined.

Age structured assessment models are used for northern and southern rock sole, and the random effects model is used for the remaining tier 5 species in the shallow water flatfish complex (as well as for apportionment). The northern and southern rock sole assessment model was updated with data through 2017, including updated 2016 catch and estimated 2017 catch, 2017 trawl survey biomass, 2017 fishery length composition, 2017 trawl survey length composition, and 2015 trawl survey conditional-age-at-length (CAAL). The random effects model was updated with 2017 trawl survey biomass.

The author's recommended change to the rock sole assessment models for 2017 incorporated the time series of trawl survey length compositions and removed the age compositions. The age data from the trawl survey is employed within the CAAL framework.

Northern and southern rock sole are in Tier 3a while the other species in the complex are in Tier 5. The GOA Plan Team agrees with authors' recommended ABC for the shallow water flatfish complex which was equivalent to maximum permissible ABC. For the shallow water flatfish complex, ABC and OFL for southern and northern rock sole are combined with the ABC and OFL values for the rest of the shallow water flatfish complex. This yields a combined ABC of 54,688 t and OFL of 67,240 t for 2018.

Information is insufficient to determine stock status relative to overfished criteria for the complex as a whole. For the rock sole species, the assessment model indicates they are not overfished nor are they approaching an overfished condition. Catch levels for this complex remain below the TAC and below levels where overfishing would be a concern.

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

Flathead Sole – Bering Sea - REFM

The flathead sole assessment also includes Bering flounder, a smaller, less abundant species with a more northern distribution relative to flathead sole. The 2017 shelf trawl biomass estimate increased 22% from 2016 for flathead sole. Survey estimates indicate high abundance for both stocks for the past 30 years, with the last nine years being very stable at a lower level than the peak years. Strong, above-average recruitment was observed from 2001-2003 followed by 7 consecutive years (2004-2010) of below average recruitment. The 2011 year class is estimated to be above average.

The assessment employs an age-structured stock assessment model. Model results indicate the Age 3+ biomass has declined slowly since the mid 1990's (20% overall), but show a steady increase since 2016. Estimates for 2019 show continued increases are likely.
The 2017 assessment was presented as a "partial assessment" format because it was a scheduled "off-year" assessment under the new Stock Assessment Prioritization guidelines. Therefore, only the projection model was run, with updated catches. New data in the 2017 assessment included updated 2016 catch and estimated 2017 and 2018 catches. No changes were made to the assessment model. A new feature included in the "off-year" assessments was a time series of exploitation rate (i.e., catch/biomass). Changes to the input data in this analysis include:

- 2017 catch biomass was added to the model
- 2016 catch biomass was updated to reflect October – December 2015 catches

Flathead sole are designated in Tier 3 since reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying flathead sole for management under Tier 3. The current values of these reference points are $B_{40\%}$=129,175 t, $F_{40\%}$=0.34, and $F_{35\%}$=0.41. Because projected spawning biomass for 2018 (214,124 t) is above $B_{40\%}$, flathead sole is in Tier 3a. ABCs for 2018 and 2019 was set at the maximum permissible values under Tier 3a, which are 66,773 t and 65,227 t, respectively. The 2018 and 2019 OFLs under Tier 3a are 79,862 t and 78,036 t, respectively. Flathead sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

Gulf of Alaska

The 2018 spawning biomass estimate (85,765 t) is 2.3 times $B_{40\%}$ (36,620 t) and is projected to be stable through 2019. Total biomass (3+) for 2018 is 281,635 t and is projected to slightly increase in 2019. Flathead sole are assessed on a biennial schedule and for 2017 a full assessment was conducted without any new changes to the assessment methodology. The 2015 assessment model was updated with the most recent fishery catch and length data (2015-2017), 2017 bottom trawl survey biomass and length compositions, and 2015 bottom trawl survey conditional age-at-length data.

Flathead sole are determined to be in Tier 3a. For 2018 the author recommended to use the maximum permissible ABC of 35,266 t, a level nearly identical to the 2017 ABC of 35,243 t. The F_{OFL} is set at $F_{35\%}$ (0.40) which corresponds to an OFL of 43,011 t. The Gulf of Alaska flathead sole stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. Catches are well below TACs and below levels where overfishing would be a concern. Area apportionments of flathead sole ABC's for 2018 and 2019 are based on the random effects model applied to GOA bottom trawl survey biomass in each area. Flathead sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

Greenland Halibut (Turbot)

The projected 2018 female spawning biomass is 58,035 t, which is a 15% increase from last year's 2017 estimate of 50,461 t. Female spawning biomass is projected to increase to 61,878 t in 2019. The effects of the incoming 2007-2009 year classes are creating a steep increase 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. Projections for 2018 predict an increase in spawning biomass as these year classes grow and mature.

This chapter was presented in a "partial assessment" format because it was a scheduled "off-year" assessment under the new Stock Assessment Prioritization guidelines. Therefore, only the projection model was run, with updated catches. New data in the 2017 assessment included updated 2016 catch and estimated 2017 and 2018 catches. No changes were made to the assessment model. A new feature included in the "off-year" assessments was a time series of exploitation rate (i.e., catch/biomass).

Changes to the input data include: 1) Updated 2016 and projected 2017 catch data, 2) 2017 EBS shelf trawl survey estimates, 3) 2017 ABL longline survey estimates, and 4) 2017 EBS shelf survey and ABL longline survey length composition estimates.

The $B_{40\%}$ value using the mean recruitment estimated for the period 1978-2014 gives a long-term average female spawning biomass of 41,239 t. The projected 2018 female spawning biomass was at 58,035 t, well above the estimate of $B_{40\%}$ (41,239 t). Because the projected spawning biomass in year 2018 is above $B_{40\%}$, Greenland turbot ABC and OFL levels are determined at Tier 3a of Amendment 56. The maximum permissible value of F_{ABC} under this tier translates into an OFL of 13,148 t for 2018 and 13,540 t for 2019 and a maximum permissible ABC of 11,132 t for 2018 and 11,473 t for 2019.

As in previous assessments, apportionment recommendations are based on unweighted averages of EBS slope and AI survey biomass estimates from the four most recent years in which both areas were surveyed. The Team's recommended 2018 and 2019 ABCs in the EBS are 9,718 and 10,016 t. The 2018 and 2019 ABCs for the AI are 1,414 and 1,457 t. Area apportionment of OFL is not recommended. Greenland turbot is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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

Arrowtooth Flounder – Bering Sea and Aleutian Islands- REFM

The projected age 1+ total biomass for 2018 is 785,131 t, a 2% increase from the value of 772,153 t projected for 2018 in last year's assessment. The projected female spawning biomass for 2018 is 490,663 t which is an increase from last year's 2018 estimate of 464,066 t and is over twice the $B_{40\%}$ level. The stock has remained at a high level for the past 20 years and is subject to light exploitation.

The 2017 assessment was presented in a "partial assessment" format because it was a scheduled "off-year" assessment under the new Stock Assessment Prioritization guidelines. Therefore, only the projection model

was run, with updated catches. New data in the 2017 assessment included updated 2016 catch and estimated 2017 and 2018 catches. No changes were made to the assessment model. A new feature included in the "off-year" assessments was a time series of exploitation rate (i.e., catch/biomass).
The total catch for 2017 estimated by calculating the proportion of catch between January 1st and September 21st from the previous five years (2012-2016), 90.2%. The total year's catch was extrapolated from the catch through September 21, 2017, for an estimated total of 5,698 t. We note that the actual catch is slightly higher as of November 9, 2017. The 2018 catch was estimated as the average catch over the past four years, with the average catch from 2014-2016 from AKFIN, and the full year's catch estimate for 2017, for a 2018 estimate of 11,797 t. There has been a decreasing trend in ATF catch and the years selected for the 2018 catch estimate capture that trend.

Since reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock. Arrowtooth flounder qualifies for management under Tier 3. The point estimates of $B_{40\%}$ and $F_{40\%}$ from this year's assessment are 212,054 t and 0.129. The projected 2017 spawning biomass is well-above $B_{40\%}$, so ABC and OFL recommendations for 2018 were calculated under sub-tier "a" of Tier 3. F_{ABC} was set at the $F_{40\%}$ level, which is the maximum permissible level under Tier 3a, resulting in 2018 and 2019 ABCs of 65,932 t and 64,494 t, respectively, and 2018 and 2019 OFLs of 76,757 t and 75,084 t. Arrowtooth flounder is a lightly exploited stock in the BSAI. Arrowtooth flounder is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

In contrast to the Gulf of Alaska, arrowtooth flounder is not at the top of the food chain on the EBS shelf. Arrowtooth flounder in the EBS are an occasional prey in the diets of groundfish, being eaten by Pacific cod, walleye pollock, Alaska skates, and sleeper sharks. However, given the large biomass of most of the predator species in the EBS, these occasionally recorded events translate into considerable total mortality for the arrowtooth flounder population in the EBS ecosystem.

Arrowtooth Flounder – Gulf of Alaska - REFM

Arrowtooth flounder biomass estimates in the current model have decreased relative to the projection model estimates in 2016, but are still at a high level. The projected spawning biomass for 2018, assuming fishing mortality equal to the recent 5-year average, was 873,789 t. This was 24% lower than the projected 2018 biomass from the 2016 assessment of 1,154,310 t. The projected estimate of total biomass for 2018 of 1,421,306 t was 32% lower than the estimate from the 2016 projection model.

There were several changes from the previous assessment. The length-age conversion matrix was estimated from length at age data from 1984-2013, and the weight at age was re-estimated. An ageing error matrix was added, and the age and length and age composition information was weighted with the Francis (2011) method.

The 2018 ABC of 150,945 t was 11% lower than estimate from the 2016 projection model. Arrowtooth flounder is estimated to be in Tier 3a, and assessment recommended ABC and OFL were adopted. This stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

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

Other Flatfish – Bering Sea - REFM

The “other flatfish” complex currently consists of Dover sole, rex sole, longhead dab, Sakhalin sole, starry flounder, and butter sole in the EBS and Dover sole, rex sole, starry flounder, butter sole, and English sole in the AI. Starry flounder, rex sole, and butter sole comprise the vast majority of the species landed. Starry flounder, rex sole and butter sole comprise the majority of the fishery catch with a negligible amount of other species caught in recent years. In 2016 Starry flounder continued to dominate the shelf survey biomass in the EBS and rex sole was the most abundant “other” flatfish in the Aleutian Islands.

EBS shelf survey biomass estimates for this complex were all below 100,000 t from 1983-2003, and reached a high of 150,480 t in 2006. The EBS and AI survey estimate for 2016 was 113,450 t, about 10% above that of last year. Starry flounder, rex sole, and butter sole comprise the majority of the fishery catch with a negligible amount of other species caught in recent years. Sakhalin sole are primarily found north of the standard survey area. Distributional changes, onshore-offshore or north-south, might affect the survey biomass estimates of other flatfish.

The assessment incorporates 2015 and 2016 total and discarded catch and 2016 EBS shelf trawl survey biomass, 2016 AI trawl survey biomass, and 2016 EBS slope trawl survey biomass. There were no changes to the assessment methodology. The random effects model was used to estimate biomass as in previous years.

The SSC has classified “other flatfish” as a Tier 5 species complex with harvest recommendations calculated from estimates of biomass and natural mortality. Natural mortality rates for rex (0.17) and Dover sole (0.085) borrowed from the Gulf of Alaska are used, along with a value of 0.15 for all other species in the complex. Projected harvesting at the 0.75 *M* level (biomass-weighted) average $F_{ABC} = 0.117$) gives a 2016 ABC of 16,395 t for the “other flatfish” complex. The corresponding 2016 OFL (average $F_{OFL} = 0.155$) is 21,860 t.

Deep-water flatfish - REFM GULF OF ALASKA

The deepwater flatfish complex is comprised of Dover sole, Greenland turbot, and deepsea sole. This complex is assessed every fourth year and was last assessed in 2015 and will be assessed again in 2019. In non-assessment years, such as 2017, an executive summary is completed to recommend harvest levels for the next two years.

For Dover sole, a single species projection model was run using parameter values from the accepted 2015 assessment model and using updated catch information for 2015-2017. Greenland turbot and deepsea sole are Tier 6 stocks, and accordingly, ABCs and OFLs are based on historical catch levels and these quantities were not updated. ABCs and OFLs for the individual species in the deepwater flatfish complex are determined and then summed for calculating complex-level OFLs and ABCs.

Dover sole is a Tier 3 stock and is assessed using an age-structured model. The single species projection model was run using parameter values from the accepted 2015 Dover sole assessment model. The 2018 and 2019 Dover sole ABCs are 9,202 t and 9,316 t, respectively, and 2018 and 2019 OFLs of 11,050 t and 11,187 t, respectively.

For the Tier 6 species in the complex, 2018 and 2019 OFL (average catch from 1978–1995) is 244 t, and ABC (75%OFL) is 183 t. The combined ABC and OFL for the deepwater flatfish complex for 2018 and 2019 gives the maximum permissible ABC of 9,385 t and OFL of 11,294 t for the deepwater flatfish complex, and a 2019 maximum permissible ABC of 9,499 t and OFL of 11,431 t. Gulf of Alaska Dover sole is not being subjected to overfishing, and is neither overfished nor approaching an overfished condition. Information is insufficient to determine stock status relative to overfished criteria for Greenland turbot and deepsea sole. 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 random effects model is used to determine area apportionment for Dover since 2016. The Greenland turbot and deepsea sole portion of the apportionment is based on the relative proportion of survey biomass of these species found in each area, averaged over the years 2005-2015. The ABC by area for the deepwater flatfish complex is then the sum of the species-specific portions of the ABC.

M. Pacific halibut

1. Research

N. Other Groundfish Species

CONSERVATION ENGINEERING (CE)

Evaluation of salmon behaviour to reduce bycatch in the Bering Sea pollock fishery--CE
The Conservation Engineering (CE) group 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. In 2017, 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 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 (Ed Richardson, At-sea Processors Association, personal communication). 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 2017 CE conducted projects (1) to evaluate salmon behavior in response to artificial lights in the trawl; and (2) to collaborate on an industry driven project evaluating salmon behavior around excluders.

Salmon Response to Artificial Light--CE

Between 24 August and 11 September 2017, CE conducted a research cruise to evaluate salmon behavior in a commercial pollock trawl net in the presence and absence of artificial light, and with a barrier to water flow. The chartered cruise was aboard the F/V Pacific Explorer, a 155 ft catcher vessel trawler in the Bering Sea pollock fishery. The net used was made by Hampidjan, had headrope and footrope lengths of 140 m and 314.4 m (respectively), and steel trawl doors. The intermediate section was untapered, 30 meshes long, with 114 mm (4.5 in) stretch mesh (measured between knots). The trawl was towed in a way to mimic commercial fishing operations. The one exception was that, in over half of the tows, the codend was opened so that no fish would be captured. A 4’ x 4’ reinforced vinyl square (a ‘parachute’) was attached in the front of the codend to simulate it being closed and filling with fish. This was done to avoid retaining fish and, therefore, the need to either discard at sea or offload. For all tows, fishing location was determined by the captain, with guidance from the ‘rolling hot spot’ locations, with the goal of ‘catching’ a mix of pollock and salmon (targeting 30-100 salmon per approximately two hour tow). This was done to ensure that, during a tow, sufficient numbers of salmon would experience the experimental lights, and that conditions were representative of commercial fishing operations.

During the charter, the behavior trials were conducted in the straight, intermediate section of the trawl (i.e., between the net and codend, or ‘stuffing tube’). On the port and starboard sides of the net, halfway between the top and bottom riblines, lights were attached facing towards the net opening. The lights, housed in pressurized acrylic tubes, were synced so that they would turn on for 15 minutes, then off for 15 minutes, in repeating, alternate cycles until the lights were manually turned off at the end of the tow. White LED lights were used, both strobing and not (at different times). The light was covered with a ‘sconce’ to direct the illumination up the net rather than bleeding across to the other side. We also tested a green Wesmar light (one that is currently being applied by some fishermen and scientists to guide salmon towards an escape portal) at full intensity, and without strobe. During separate trials, this green light was placed only on one side of the net at a time. Wildlife Computer TDR-MK9 archival tags were used to record light quantity (i.e., photosynthetically active radiation, PAR) in 30 s intervals. During six of the tows, a 4’ x 4’ ‘parachute’ was attached to the four riblines in the intermediate, opening 8 ft behind the experimental area to observe salmon and pollock behavior near the lights with the addition of something that slowed the water flow down near the experimental area. An acoustic sounder (DIDSON by Sound Metrics), and low light cameras with infrared illumination were used to observe the behavior of pollock and salmon as they passed by the lights.

Analysis of the video footage and DIDSON data collected during this research cruise is currently underway (winter 2018). This includes (1) scanning the footage to select clips when salmon are present in the field of view, (2) quantifying presence of salmon in each side of the net and linking that to when the experimental lights were on or off, and (3) analyzing behavior of the salmon in the presence of the illuminated and non-illuminated lights with respect to intentional movements in any direction.

Collaboration on Industry Led Excluder Research--CE

In August 2017, John Gauvin (North Pacific Fisheries Research Foundation, NPFRF) proposed an Exempted Fishing Permit (EFP) research project to iteratively, over 3 years, develop and test salmon excluder designs for the different trawl vessel size classes fishing for Bering Sea pollock. 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 group. 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 selected for sea trials that are currently taking place (winter 2018). 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. 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. CE has also provided 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. CE continues to support the research by being involved in the on-going sea trials, and will be involved in data evaluation, and planning next steps.

Support of Industry Innovation--CE

In addition to the research, in 2017 CE continued efforts to support innovation and collaboration with the fishing industry and conservation engineering community. To do this, CE hosted a workshop, in collaboration with industry and scientific partners, held in Seattle, WA to (1) present research being done by CE and other scientists focusing on Alaska fisheries; (2) provide an opportunity for industry members to present on ways they are innovating; (3) provide information that supports industry innovation; (4) facilitate a discussion about industry bycatch concerns and potential solutions; and (5) get feedback from industry members, NGOs, managers, and other scientists about needed research for Alaskan fisheries with respect to bycatch and habitat impacts, and how CE can support industry led innovation. There were ~40 people in attendance and 10 presentations. At the completion of the workshop, there was a brief discussion about steps moving forward. It was agreed that an annual workshop would be beneficial.

In addition to the CE annual workshop, in 2017, CE continued to provide underwater video systems to be used by the fishing industry to allow them to directly evaluate their own modifications to fishing gear. Beyond their direct use, exposure to NMFS systems has motivated many companies to procure similar systems for dedicated use on their vessels. These cameras support better understanding of fishing gear operation and facilitate timely improvements. The current systems have been in use for over 5 years now, and have seen some changes and improvements over the years. In 2017, CE continued to maintain, upgrade, and expand the loaner pool of underwater cameras to further facilitate and encourage industry-driven innovation.

Technology to Observe Fish Behavior--CE

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 underwater cameras that illuminate the field of view with white light, we imaged with low light cameras and near infrared (NIR) light. We used a Stanford Photonics intensified charge-coupled device (ICCD) camera with a Gen III intensifier, which was sensitive to both infrared (IR) and visible light. The camera was connected to a titanium underwater housing that contained a digital video recorder (DVR), battery, and depth activated power control. The camera was illuminated by off-the-shelf security infrared light emitting diode (LED) arrays in pressure tolerant potting epoxy. Additional, low-light charge coupled device (CCD) cameras, with the infrared light cut out filter removed, were used. These were housed in pressurized acrylic tubes. Next to each camera were independent infrared LED arrays housed in aluminum pressure housings with clear acrylic ports, and connected to a titanium underwater housing that contained a battery and depth activated power control. These lights provided a minimum of 100 degree angle wide illumination. The wavelength distribution of the infrared LEDs used for both camera set ups was centered at 840 nm, and had a range of approximately 1 meter in situ. In addition to the cameras, during the 2017 field work, a DIDSON acoustic sonar was used to determine its efficacy in visualizing fish behavior compared to cameras, given the greater range of the sonar, but limited resolution.

Evaluating Trawl Footrope-Seafloor contact in the Bering Sea Pollock Fishery--CE

In 2017, CE collaborated on a study with Alaska Pacific University professor Dr. Brad Harris and his master’s student Brianna King to develop technology and discern best practices for quantifying and evaluating seafloor contact of a pelagic trawl footrope during commercial fishing operations. This work is being done in response to ambiguity that surrounds rate of contact for the Bering Sea pollock fishery. Currently, a range of 20% - 90% is used for the North Pacific Fishery Management Council fishing effects model. These rates of contact are based on conversations with the industry and expert opinions rather than empirically derived data. During the 2017 research charter to evaluate salmon behavior (described above), Brianna’s objective was to determine reliable methods for collecting data on footrope-seafloor contact. Various bottom contact sensors were attached along different parts of the footrope to determine an effective way to measure contact. These sensors are accelerometers placed in a housing with a steel rod extending downward. As the net approaches the seafloor, the steel rod begins to tilt as it lays down on the bottom, and the accelerometer records these angles (e.g., 90 degrees is off the bottom, whereas 0 degrees is on the bottom), which can then be trigonometrically translated into a height off bottom. Brianna is currently (winter 2018) analyzing these data.

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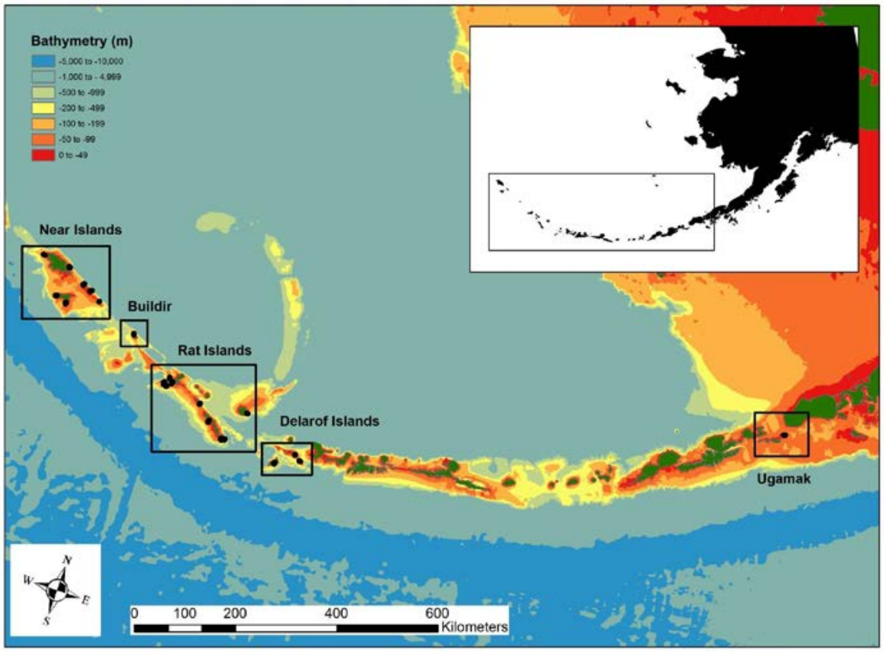
For more information, contact MACE Program Manager, Chris Wilson, (206) 526-6435.

GROUNDFISH ASSESSMENT PROGRAM

Opportunistic nearshore underwater camera survey in the Aleutian Islands-GAP

The availability of fish resources in nearshore shallow areas in the Aleutian Islands remains poorly understood because traditional bottom trawl surveys conducted by NOAA’s Alaska Fisheries Science Center (AFSC) cannot sample the prevalent rocky, nearshore habitats and lack precision for specific localized areas. 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 20-100m. Transects were analyzed using software developed at the AFSC which allowed for fish and associated habitat to be identified, quantified, and measured. Camera transects encompassed substrates ranging from sand to high-relief boulder fields, and we found that higher fish abundance was associated with rocky 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.

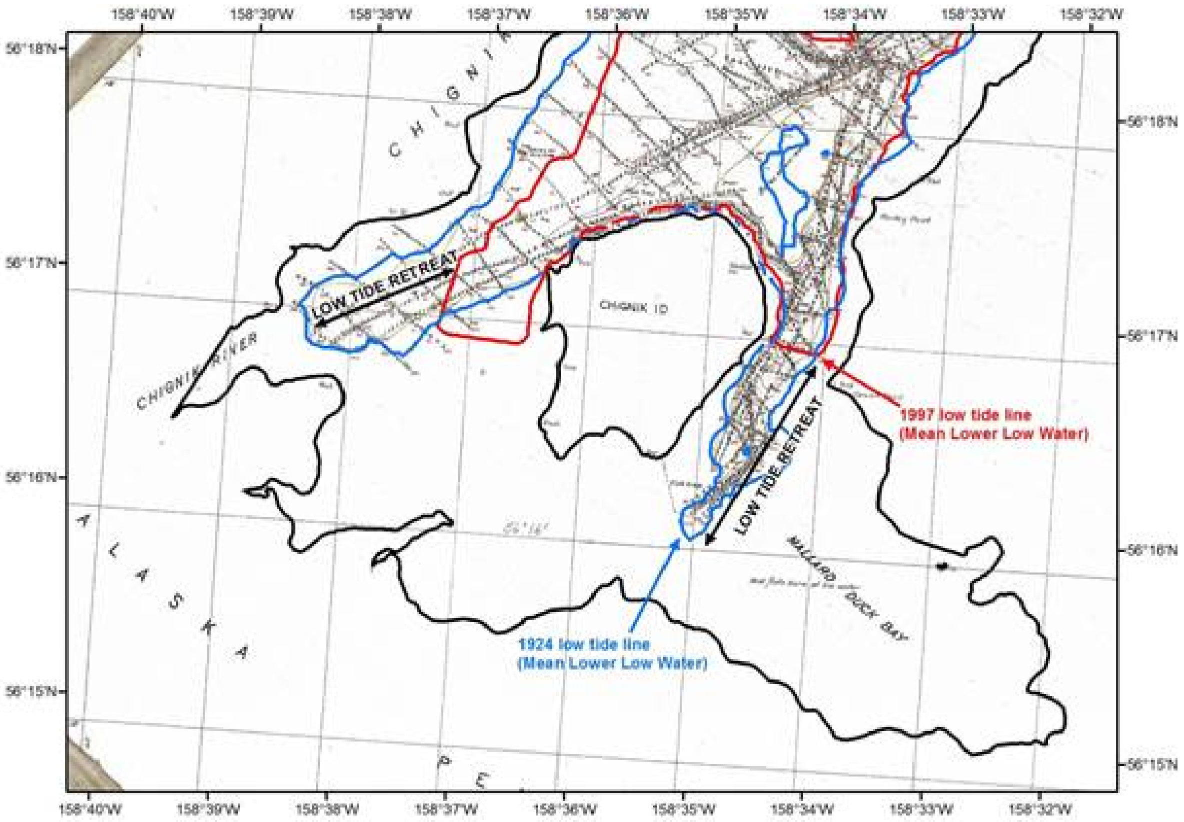
For more information, contact Susanne McDermott at Susanne.McDermott@noaa.gov.



Camera tow locations during the opportunistic underwater camera survey in the Aleutian Islands.

Inshore shallowing at Chignik, in the western Gulf of Alaska - RACE GAP

We quantified the shallowing of the seafloor in five of six bays examined in the Chignik region of the Alaska Peninsula, confirming National Ocean Service observations that 1990s hydrographic surveys were shallower than previous surveys from the 1920s. Castle Bay, Chignik Lagoon, Hook Bay, Kujulik Bay and Mud Bay lost volume as calculated from Mean Lower Low Water (Chart Datum) to the deepest depths and four of these sites lost volume from Mean High Water to the deepest depths. Calculations relative to each datum were made because tidal datum records exhibited an increase in tidal range in this region from the 1920s to the 1990s. Our analysis showed that Mud Bay is quickly disappearing while Chignik Lagoon is being reduced to narrow channels.



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

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Contact Mark.Zimmermann@noaa.gov

Research on surveying untrawlable habitats-RACE MACE & GAP

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

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

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

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

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

For more information contact: Kresimir Williams or Chris Rooper

Multispecies Acoustic Dead-zone Correction and Bias Ratio Estimates Between Acoustic and Bottom-trawl Data--GAP

In this study, we extended the original work of Kotwicki et al. (2013) to jointly estimate the acoustic dead-zone correction, the bias ratio, and the gear efficiency for multiple species by using simultaneously collected acoustic and bottom-trawl data. The model was applied to cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) in the Barents Sea and demonstrated a better or similar performance compared with a single species approach. The vertical distribution of cod and haddock was highly variable and was influenced by light level, water temperature, salinity, and depth. Temperature and sunlight were the most influential factors in this study. Increase in temperature resulted in decreasing catch and fish density in the acoustic dead zone (ADZ), while increasing sun altitude (surrogate for light level) increased the catch and fish density in the ADZ. The catch and density of haddock in the ADZ also increased at the lowest sun altitude level (shortly after midnight). Generally, the density of cod and haddock changed more rapidly in the ADZ than in the catch (from bottom to the effective fishing height) indicating the importance of modelling fish density in the ADZ. Finally, the uncorrelated variability in the annual residual variance of cod and haddock further strengthen the conclusion that species vertical distribution changes frequently and that there are probably many other unobserved environmental variables that affect them independently.

For further information, contact Stan Kotwicki, (206)526-6614, Stan.Kotwicki@noaa.gov.

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Using the ME70 Multibeam to map untrawlable habitat in the Gulf of Alaska

Stienessen, S, Jones, D, Rooper, C, Pirtle, J, Wilson, C, Weber, T

Fisheries independent biomass estimates used in rockfish (Sebastes sp.) stock assessments in the Gulf of Alaska (GOA) are generated from data collected during multi-species biennial groundfish bottom trawl surveys. Some rockfish species prefer rugged bottom habitat, which makes them difficult to sample with bottom trawl survey nets. Therefore, only those rockfish found in trawlable habitat are fully sampled by the biennial bottom trawl surveys and this non-random sampling can lead to disproportionate allocation of species composition and introduce biases to the biomass estimates. To improve estimates of habitat-specific groundfish biomass, Pirtle et al. (2015) developed a model that used multibeam-derived seafloor metrics to predict seafloor trawlability. The model was correct for 69% of the haul locations examined. We have expanded upon this work to re-evaluate the trawlability designation of the seafloor in areas historically designated as trawlable or untrawlable by the bottom trawl survey. Simrad ME70 multibeam echosounder data and associated video imagery of seafloor substrates were collected in the GOA during the summers of 2013 and 2015 by NOAA scientists from the Alaska Fisheries Science Center. Multibeam data were collected along parallel transects spaced approximately 1 nmi apart at fine-scale survey sites, and video data were collected at up to 3 camera stations within these sites. Seafloor metrics were extracted from the multibeam data, and video imagery was used to determine seafloor trawlability. The data collected in 2013 and 2015 were combined with historical data and a Generalized Linear Model was parameterized to extract new model coefficients. The updated model was used to derive probabilities of trawlable and untrawlable habitat. This new information will be used to assess the proportion of the GOA that is sampled by the bottom trawl survey. In combination with habitat specific fish densities, the data can also be used to estimate the quantity of each rockfish species that is unavailable to the GOA bottom trawl survey.

Defining EFH for Alaska Groundfish Species using Species Distribution Modeling-RACE

Principal Investigators: Chris Rooper, Ned Laman, Dan Cooper (RACE Division, AFSC)

Defining essential fish habitat for commercially important species is an important step for managing marine ecosystems in U.S. waters. Using species distribution modeling techniques (SDM), data from fishery-independent groundfish and ichthyoplankton surveys, and commercial fisheries observer data, we developed habitat-based descriptions of essential fish habitat (EFH) for all federally managed species in Alaska. We used maximum entropy (MaxEnt) and generalized additive modeling (GAM) to describe distribution and abundance of early (i.e., egg, larval, and pelagic juvenile) and later (settled juvenile and adult) life history stages of groundfish and crab species across multiple seasons in three large marine ecosystems in Alaska (Gulf of Alaska, eastern Bering Sea, and Aleutian Islands) and the northern Bering Sea. To demonstrate our methods and techniques, we present a case study of Kamchatka flounder (Atheresthes evermanni) from the eastern and northern Bering Sea as an example of over 400 SDMs we generated for > 80 unique species-region-season combinations. The resulting models and maps will be used in Alaska for marine spatial planning, and to support current and future stock assessments. The North Pacific Fishery Management Council has approved the EFH descriptions provided by the SDMs and the results have been used in conjunction with a fishing effects model to evaluate the impacts of fishing on EFH.

Determination of Parameters for an Underwater Camera System that Maximizes Available Light for Analysis While Minimizing Visual Detection by Demersal Fishes Associated With Untrawlable Habitats--GAP

One of the primary challenges facing researchers in developing optical sampling technologies for assessing demersal fish populations over untrawlable habitat is the need for supplemental light for species identification and assessment of species distributed to depths where the ambient light environment is too dim for optical systems. This is derived from two issues, reduced ambient light due to the depth of the habitat areas of interest and the morphological similarity of species of interest (e.g. rockfishes, groupers, or other mesophotic fishes) necessitating the addition of a color component to aid in species identification. To develop an underwater camera and lighting system for assessing deepwater fish populations that limits behavioral avoidance or attraction to the optical sampling gear while maintaining enough image information to quantitatively assess and identify species, three visual questions is being addressed by: (1) what is the spectral sensitivity of the visual system of the species to be identified, (2) what are the relative optical properties of the habitat where they are encountered, and (3) what are the spectral properties of the targets that the camera must be able to identify, i.e. the body of the fish?

So far, this need has addressed for deep-water rockfishes in Southern California, where microspectrophotometry (MSP) was used to describe the spectral sensitivity of 18 species of southern California rockfishes that were sampled offshore of Santa Barbara, California in April 2016. All of the rockfish sampled were found to possess a duplex retina containing rods and cones (see table). Rod visual pigments had lamda max values ranging from 486 nm to 505 nm with the lower values typically being encountered in deeper dwelling species. All of the species examined possessed a dichromatic photopic visual system consisting of short- and long-wavelength sensitive visual pigments. Generally, the lamda max for the visual pigments was shifted towards the blue region of the spectrum for deeper dwelling species. As such, a greater proportion of the spectra is available for lighting that would have limited detectability by rockfishes at longer wavelengths. A manuscript describing the visual pigments of rockfishes is nearing completion.

The optical properties of deep water reefs near Santa Barbara, CA, where the specimens for this study were collected are being modelled using a customized software package that we created for determining target contrast ratios at depth. This work is being combined with the third objective of this study whereby the spectral reflectance of the coloration patterns of rockfishes are being analyzed to determine the illumination characterization needed by artificial lights and camera systems to aid in species identification at depth (see figure). The manuscript describing these results is in review. Currently, similar studies are being proposed for Alaskan rockfishes, nearshore rockfishes along the west coast, groupers in the Gulf of Mexico, and for mesophotic fishes in the Pacific Islands region.

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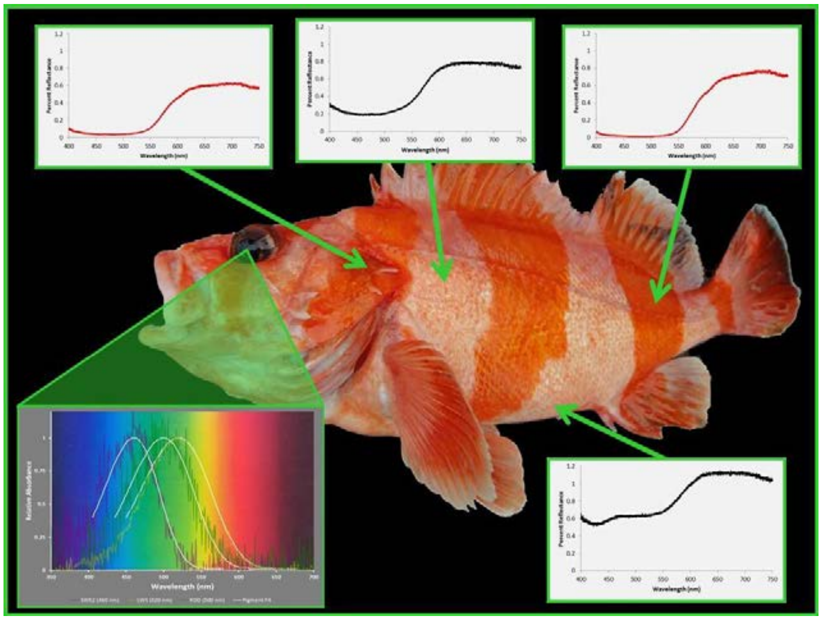
Species	**Common Name**	**Max Depth***	**ROD†**	**LWS†**	**SWS2/RH2†**
S. chlorostictus	Greenspotted Rockfish	363	486	493	442
S. goodei	Chilipepper Rockfish	325	486	488	454
S. rosenblatti	Greenblotched Rockfish	491	489	493	438
S. elongatus	Greenstriped Rockfish	250	490	497	446
S. emphaeus‡	Puget Sound Rockfish	366	490	524	437
S. ensifer	Swordspine Rockfish	433	491	490	437
S. rubrivinctus	Flag Rockfish	200	493	516	456
S. rosaceus	Rosy Rockfish	262	495	514	446
S. constellatus	Starry Rockfish	274	496	512	453
S. caurinus	Copper Rockfish	183	496	520	460
S. mystinus	Blue Rockfish	90	497	516	449
S. flavidus‡	Yellowtail Rockfish	180	497	521	437
S. carnatus	Gopher Rockfish	80	499	519	456
S. dalli	Calico Rockfish	120	500	519	457
S. miniatus	Vermillion Rockfish	150	500	520	460
S. paucispinus	Bocaccio	250	501	519	450
S. entomelas	Widow Rockfish	210	502	518	453
S. crocotulus	Sunset Rockfish	150	503	518	452
S. serranoides	Olive Rockfish	120	503	521	455
S. auriculatus	Brown Rockfish	120	505	520	450

*Listed typical maximum depth for region where collected. Taken from Love et al 2002.

†Mean λ_{max} values collected from individual photoreceptor cells. Standard deviation was < ± 2 nm for all cell types and species.

‡Specimens collected near San Juan Island, WA. All other specimens collected near Santa Barbara, CA.



For further information, contact Lyle Britt, (206)526-4501, Lyle.Britt@noaa.gov.

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.

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

Systematics Program - RACE GAP

Several projects on the systematics of fishes of the North Pacific have been completed or were underway during 2017. 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. An additional study testing the hypothesis of cryptic speciation in northern populations of the eelpout genus *Lycodes* (Stevenson) is underway. Continuing progress has been made in examining identifications of rockfishes (*Sebastes aleutianus* and *S. melanostictus*) off the West Coast (Orr, with NWFSC); morphological variation related to recently revealed genetic heterogeneity in rockfishes (*Sebastes crameri*; Orr, with NWFSC) and flatfishes (*Hippoglossoides*; Orr, Paquin, Raring, and Kai); a study of the developmental osteology of the bathymasterid *Ronquilus jordani* (Stevenson, with Hilton and Matarese); and a partial revision of the agonid genus *Pallasina* (Stevenson). Work on the molecular phylogenetics and morphology of the pectoral girdle of snailfishes (Orr, Stevenson, Spies, with UW) was completed, as well as a partial systematic revision of the lumpsucker genus *Eumicrotremus* (Stevenson et al., 2017). Descriptions of new species, based on morphology and genetics, from Alaska and Canada continues.

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. 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. Molecular and morphological studies on *Bathyraja interrupta* (Stevenson, Orr, Hoff, and Spies), *Bathyraja spinosissima* (Orr, Hanke, Stevenson, Hoff, and Spies), *Eumicrotremus* (Kai and Stevenson), *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) now in press. Stevenson recently completed a study documenting the reliability of species identifications in the North Pacific Observer Program (Stevenson, 2018), co-authored the data report from the 2014 eastern Bering Sea shelf survey (Conner et al., 2017), and is working on a comparison of fish distributions in the northern Bering Sea (Stevenson and Lauth, in prep) as well as a study documenting fishery interactions with skate nursery areas in the Bering Sea (Stevenson et al., in prep).

Orr and Stevenson have also conducted work with invertebrates. On-deck guides have been 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).

Publications for 2017:

Stevenson, D. E. 2018. Documenting the reliability of species identifications in the North Pacific Observer Program. Fisheries Research 201:26–31.

Stevenson, D. E., C. W. Mecklenburg, and Y. Kai. 2017. Taxonomic clarification of the *Eumicrotremus asperrimus* species complex (Teleostei: Cyclopteridae) in the eastern North Pacific. Zootaxa 4294(4):419–435.

Conner, J., D. E. Stevenson, and R. R. Lauth. 2017. Results of the 2014 eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate resources. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-350, 154 p.

Orr, J. W. In press. Pleuronectidae: Righteye Flounders, 30 ms pages. In: North American Freshwater Fishes: Evolution, Ecology, and Behavior. B. Burr and M. Warren (eds.), Johns Hopkins University Press.

Orr, J. W. In press. Paralichthyidae: Sand Flounders, 20 ms pages. In: North American Freshwater Fishes: Evolution, Ecology, and Behavior. B. Burr and M. Warren (eds.), Johns Hopkins University Press.

Orr, J. W. In press. Achiridae: American Soles, 20 ms pages. In: North American Freshwater Fishes: Evolution, Ecology, and Behavior. B. Burr and M. Warren (eds.), Johns Hopkins University Press.

Pietsch, T. W., and J. W. Orr. In press. Fishes of the Salish Sea: Puget Sound and the Strait of Georgia and Juan de Fuca. University of Washington Press, Seattle, 1505 MS pp + 350 figs.

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 for operationalizing the integration of ecosystem and socioeconomic factors within the NOAA Fisheries' stock assessment system (Shotwell et al. 2017). These ecosystem and socioeconomic profiles (ESPs) serve as a corollary stock-specific process to the large-scale ecosystem considerations report, effectively creating a two-pronged system for ecosystem based fisheries management at the AFSC. We use Alaska groundfish as a case study and data collected from a large variety of national initiatives was first synthesized for all stocks. A four-step process was then used to generate a set of standardized products that culminate in a focused, succinct, and meaningful communication of potential drivers on a given stock. We combine a priority-based data gap analysis with a graded metric panel and a Bayesian model selection process to test potential indicators on data-limited to data-rich stocks. The resulting ESP report is effectively a synthesis of ecosystem and socioeconomic factors that can be distilled into several different formats to communicate with the scientific community, stakeholders, and the public. The standardized process/product framework allows for comparison across stocks and provides the necessary building blocks to move toward an ecosystem-based approach to fisheries management.

These baseline ESPs can then be enhanced with new information from process studies (e.g. IERPs, FATE) continued ecosystem monitoring (e.g. standard surveys, remote sensing), laboratory experiments (e.g. early life history development, energetics studies), or integrated modeling (e.g. habitat suitability models, individual based models, multi-species models). The ESPs initiate the active integration of ecosystem and socioeconomic data within the stock assessment process and take a giant leap toward implementing the next generation of stock assessments.

Please refer to the following report for more details:

Shotwell, S.K., B. Fissel, and D. Hanselman. 2017. Ecosystem-Socioeconomic Profile of the Sablefish stock in Alaska. Appendix 3C *In* Hanselman, D., C. Rodgveller, C. Lunsford, and K. Fenske. 2017. Assessment of Sablefish stock in Alaska. Stock assessment and fishery evaluation report for the groundfish resources of the Bering Sea Aleutian Islands and Gulf of Alaska. North Pacific Fishery Management Council, 605 W 4th Ave, Suite 306 Anchorage, AK 99501.

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

A pilot study for assessing deep-sea corals and sponges as nurseries for fish larvae in the western Gulf of Alaska-RACE GAP

Principal Investigators: Rachel Wilborn, Chris Rooper, Pam Goddard

A recent study in eastern Canada found evidence that deep-sea corals (specifically a fan-type sea pen) were consistently associated with Sebastes larvae (Ballion et al. 2012). This study found larval Sebastes inside the withdrawn polyps and branches of pennatulaceans. The prevalence of this association was widespread with 11.5 to 100% of sea pens captured with Sebastes larvae. The finding has provided one of the most direct lines of evidence for the importance of deep-sea corals as essential fish habitat for Sebastes. However, there are some questions regarding the methodology of the study, as the samples were all trawl caught and in some cases sea pens were caught in the same hauls as mature female Sebastes. This suggests that the larvae could have been extruded as a response to being captured, resulting in the observed association.

In 2016, a cursory examination of specimens of trawl caught coral (Fanellia sp.) that were retained for a genetics study yielded the finding of a fish larva, preliminarily identified as a walleye pollock (Figure 1). This anecdotal evidence raises questions about the potential role of deep-sea corals as larval habitat for commercially important fish species in Alaska. This proposal is to directly examine whether deep-sea corals serve as spawning habitat for rockfish and other species in the Gulf of Alaska.

The objective of this study was to collect plankton samples inside and outside of coral habitat to determine whether these habitats were preferentially chosen for spawning by rockfish species. The study was carried out over 2 days in conjunction with Leg 1 of the 2017 bottom trawl survey of the Gulf of Alaska. Only a single tow during Leg 1 of the survey captured rockfish that were close to extruding larvae. So an alternative study design that focused on known areas of coral habitat was employed. Thus, stations were chosen within GOA slope closed areas (HAPC closures) at Sanak Bank and in previously studied juvenile Pacific Ocean perch nursery habitat near Samalga Pass. Stations included coral, sponge and bare habitats that were previously surveyed (with a couple exceptions).

This study implemented a new design that had not been tested before, so there was a unique opportunity for proof of concept in addition to collecting larval fish. As a pilot project, there were several opportunities for modifying and improving the larval fish pump design in situ. Improvements were immediately made to the deployment gear after the first deployment to prevent the pump from opening during ascent and emptying its contents. In addition, initial flow rates were set using a programmed thruster and based on tank studies that didn’t take into account a swift benthic current. Therefore, Plankton Pump Deployments (PD) #2 - #11 had thruster speeds that were potentially inadequate for collecting more active zooplankton, such as larval fish and chaetognaths. Battery problems, as well as a few camera and door activation issues also occurred, but ultimately, the pump worked autonomously at depths where coral and sponge occurred and in regions where rockfish were spawning. The final four samples were collected with appropriate thruster speeds and no malfunctions, and resulted in an abundant and diverse array of zooplankton, including a larval rockfish. The autonomous pump design used for this project to sample larval fish may be useful for other important data collection such as examining benthic prey fields and energetics of near-bottom fishes in a variety of deep-water habitats.

Data are still in the process of being summarized for analysis. Some of the habitat classifications of study sites have not been matched with existing camera survey data (listed as NA in Table 1). The zooplankton community was dominated by copepods in all habitat types (Figure 1). Barnacle nauplii, amphipods and euphausiids were also important components of the zooplankton communities. It is of interest to note that the one larval rockfish was found in rocky, coral habitat, which was also the station with the highest count of zooplankton.

Table 1. Station identification of 15 plankton pump deployments (PD), habitat type (sponge, coral, bare rock), substrate type (unconsolidated or rocky), depth, surface current, invertebrate counts, and diversity.

Station ID	*Habitat Type*	*Substrate Type (Unconsolidated=U, Rocky=R)*	*Depth (m)*	*Surface Current (cm s^{-1})*	*Total Invertebrate Count*
PD1	*NA*	*NA*	*123.1*	*1.5*	*NA*
PD2	*Sponge*	*U*	*122.8*	*1.2*	*12*
PD3	*NA*	*NA*			*NA*
PD4	*Bare*	*U*	*120*	*1.7*	*36*
PD5	*NA*	*NA*	*120*	*1.5*	*170*
PD6	*NA*	*NA*			*NA*
PD7	*Bare*	*R*	*88*	*0.0*	*146*
PD8	*Coral*	*U*	*80*	*0.5*	*3*
PD9	*NA*	*NA*	*98*	*0.5*	*127*
PD10	*Sponge*	*U*	*92*	*0.75*	*70*
PD11	*Sponge*	*U*	*94*	*0.5*	*31*
PD12	*Sponge*	*U*	*105*	*0.5*	*157*
PD13	*Sponge*	*U*	*105*	*0.5*	*137*
PD14	*Coral*	*R*	*93*	*0.5*	*531*
PD15	*Sponge*	*U*	*90*	*0.5*	*278*

Figure 1. Percent composition of invertebrates identified at 3 different habitat types (sponge, coral, and bare rock).

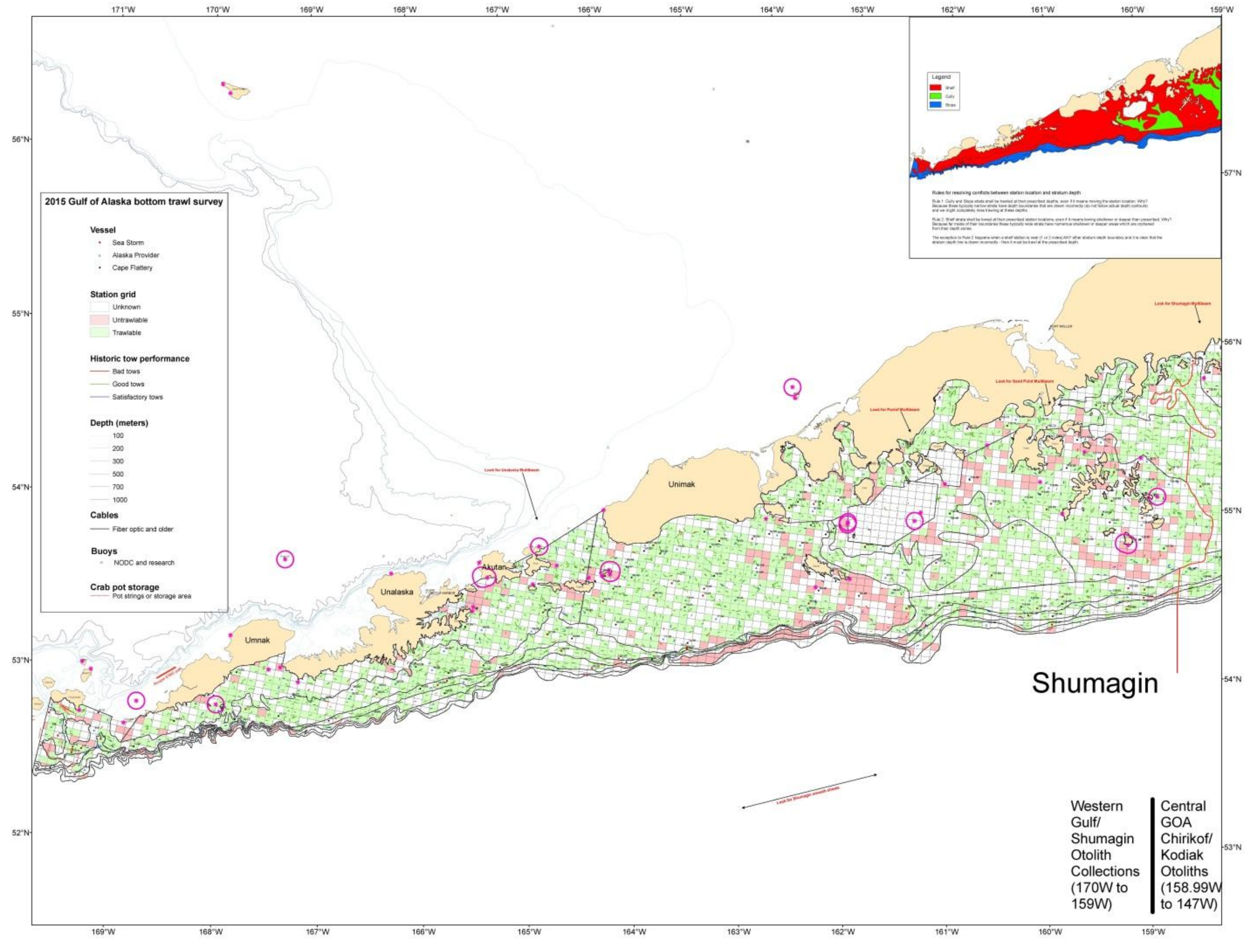


Figure 2. Map of 2015 western Gulf of Alaska bottom trawl survey stations from the Islands of Four Mountains to the Shumagin Islands as an example of the station pattern for the study. One of the survey vessels will conduct the study at its assigned stations.

Figure 3. Plankton pump and deployment system with camera and lights. Images courtesy of ShelfReCover

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

In the fall of 2014, researchers projected a continuation of anomalously warm ocean conditions in the northeast Pacific Ocean, aka. The Blob, using a new seasonal forecasting capability. Based on the results of these forecasts, the North Pacific Research Board funded a coordinated research project to examine the impacts of the unusual warming event in the northeast Pacific. This project (NPRB #1033) evaluates a unique dataset of acoustic and bottom trawl survey data that spans from the southern California Bight to the western Gulf of Alaska. An interdisciplinary multi-national research team has been assembled to conduct this research. The NPRB provided funds to supplement existing surveys with additional oceanographic measurements to enhance our ability to describe the mechanisms underlying observed shifts in spatial distributions. This paper will present the initial observations from the 2015 acoustic and bottom trawl surveys in the Gulf of Alaska and contrast them with previous years when NMFS conducted comprehensive surveys simultaneously in both the GOA and CCS (2003, 2005, 2011 and 2013). Preliminary results suggest that the sea surface temperatures in late July along the northeast Pacific were among the warmest on record and similar to 2005. The heat content was significantly warmer. Distributional responses of Pacific hake, walleye pollock, selected flatfish and rockfish to the observed warming will be presented by length category.

One of the deliverables from this project will be the development and testing of methods to stitch together the bottom trawl survey data from three sources (AFSC, US west coast, and DFO) to provide biennial updates on the impact of climate change or climate variability on the spatial distribution of groundfish. If successful this could be a useful product for the TSC.

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

Using ichthyoplankton time series data form California to Alaska to identify ecosystem changes - RPP

Jens M. Nielsen, Lauren A. Rogers, J. Anthony Koslow, Richard D. Brodeur, Andrew Thompson, and Janet T. Duffy-Anderson

Ecological indicators can be used to track ecosystem change and assess impacts from natural and human mediated pressures. Ichthyoplankton data are particularly useful for assessing temporal ecosystem changes as they respond quickly to environmental variability and furthermore may provide a link to fish recruitment dynamics. However, what has so far only been tentatively explored is the use of multispecies larval indices as ecological indicators of ecosystem dynamics. We combine ichthyoplankton time-series from long-term monitoring programs ranging from California to Alaska, to identify if ichthyoplankton data can be used as ecological indicators for tracking and predicting marine ecosystem dynamics. Specifically, we analyzed ichthyoplankton time series data from the Gulf of Alaska (33 years) and the northern and southern California Current (Vancouver 16 years, Oregon 20 years, California 63 years). Dynamic factor analysis (DFA) and chronological clustering analysis were used to assess common trends in the ichthyoplankton time series data. First, we assessed if there are shared or divergent responses to environmental changes among ichthyoplankton assemblages from different regions. Second, we explored the relationship between trends in fish larvae dynamics and recruitment of commercially important species. Because early life stages of single species often exhibit high variability, we focus on multispecies analyses to assess how fish larvae can be used as a leading indicator of future recruitment dynamics of fishes of economic importance.

Preliminary analyses using the multi species approach show that the common trend of 40 ichthyoplankton species (estimated using DFA) corresponds closely to the common trend of recruitment estimates from 12 species in the Gulf of Alaska (Fig. 1). Similarly, there seem to be some co-variation between the winter PDO, used as a proxy for climatic perturbations, and the common trend of the ichthyoplankton data. Similar analysis will be conducted with data from the Vancouver, Oregon and California regions.

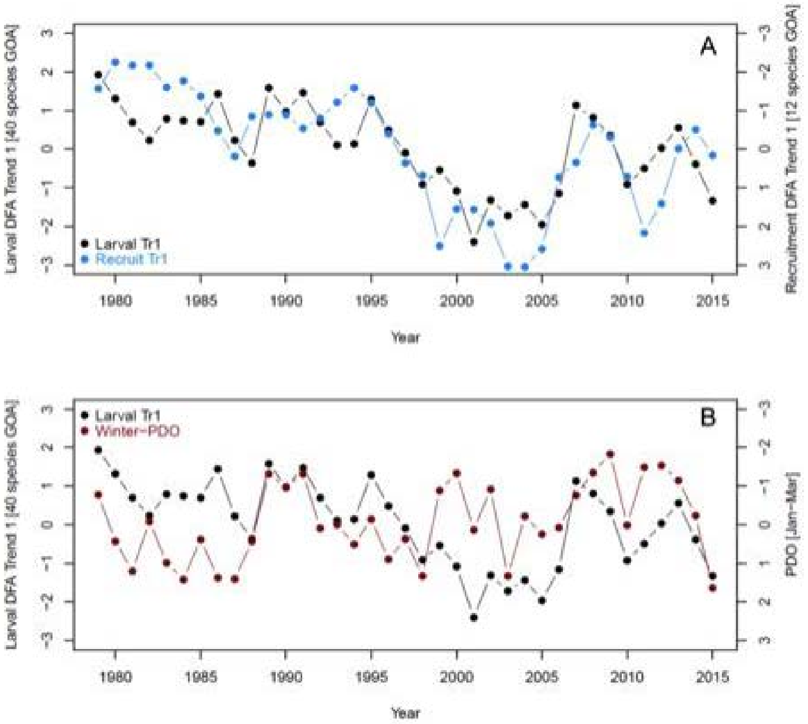


Fig 1: Temporal dynamics of **A**) the common DFA trend 1 of 40 ichthyoplankton species (black) and the DFA trend 1 of recruitment estimates of 12 adult species (blue), and **B**) the common DFA trend 1 of 40 ichthyoplankton species (black) and the winter PDO index (Jan-Mar, red) from the Gulf of Alaska. Note that the second y-axes were inverted.

By combining extensive time-series data from multiple regions the complementary multispecies approaches can help categorize species synchronies within sub-regions and between large marine ecosystems along the US west coast.

For more information contact: jens.nielsen@noaa.gov & lauren.rogers@noaa.gov

Chukchi Sea Integrated Ecosystem Survey Beam Trawl Sampling - RPP

Libby Logerwell and Dan Cooper

The goal of NPRB's Arctic Integrated Ecosystem Research Program (IERP) (https://www.nprb.org/arctic-program/about-the-program/) is to better understand the mechanisms and processes that structure the Arctic marine ecosystem and influence the distribution, life history, and interactions of biological communities in the Chukchi Sea. A major field component of the Program is the Arctic Integrated Ecosystem Survey (IES), a multi-disciplinary survey that covered the US Chukchi Shelf in August – September 2017. A second survey is planned for 2019. Benthic fish and invertebrates were sampled with a 3-m plumb staff beam trawl at 60 grid stations from the Chukchi slope south to Bering Strait (Fig. 1).

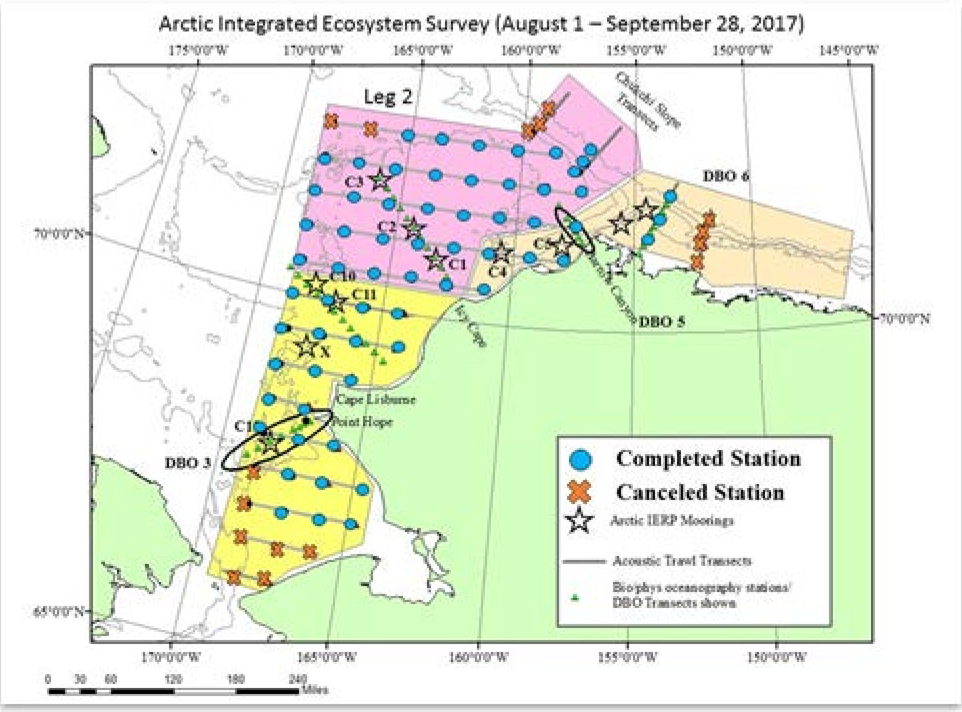


Figure 1. Stations sampled during the 2017 Arctic Integrated Ecosystem Research Program (IERP) Integrated Ecosystem Survey (IES) in the Chukchi Sea

Epibenthic invertebrates dominated the beam trawl catch, making up 94% of the total catch weight. The top 10 invertebrate taxa caught (by biomass) were brittlestars, Psolus sp. (Holothuroidea), snow crab, starfish, clams, sponges, and tubeworms. The most abundant fish taxa were Arctic cod, sculpin, eelblennies, eelpout and flatfish (Table 1). Pacific cod and walleye pollock were also caught, but were much smaller than the size caught in the commercial fishery, and were likely immature (mean 7.5 and 12.5 cm length, respectively). Similarly, snow crab were smaller than the legal limit for commercial harvest (mean 25 cm carapace width), although ovigerous females were caught.

Table 1. Total catch of snow crab and fish from beam trawl sampling during the 2017 Arctic Integrated Ecosystem Research Program (IERP) Integrated Ecosystem Survey (IES) in the Chukchi Sea. CPUE = catch-per-unit effort

Scientific name	Common name	CPUE kg/ha	CPUE No./ha
Chionoecetes opilio	Snow crab	296.17	33,621.35
Boreogadus saida	Arctic cod	22.269	22,575.12
Gymnocanthus tricuspis	Arctic staghorn sculpin	16.551	4,605.90
Myoxocephalus scorpius	Shorthorn (Warty) sculpin	16.197	5937.89
Lumpenus fabricii	Slender eelblenny	12.910	3,761.39
Lycodes turneri	Polar eelpout	10.014	1,998.42
Lumpenus medius	Stout eelblenny	8.172	2,754.45
Ammodytes sp.	sand lance unid.	5.836	1,645.61
Lumpenus sagitta	Snake prickleback	5.670	2,391.45
Hippoglossoides robustus	Bering flounder	4.514	429.05
Artediellus scaber	Hamecon	3.650	1,564.53
Limanda aspera	Yellowfin sole	2.417	193.41
Gadus chalcogrammus	Walleye pollock	1.893	132.59
Eleginus gracilis	Saffron cod	1.852	690.90
Stichaeus punctatus	Arctic shanny	1.613	472.31
Lumpenus sp.	Lumpenus sp.	1.237	1,879.34
Gadus macrocephalus	Pacific cod	1.083	362.71
Icelus spatula	Spatulate sculpin	1.062	295.64
Lycodes polaris	Canadian eelpout	0.941	552.52
Ulcina olrikii	Arctic alligatorfish	0.694	829.79
Lycodes sp.	Lycodes sp.	0.616	49.05
Lumpenus maculatus	Daubed shanny	0.518	128.64
Lycodes mucosus	Saddled eelpout	0.509	83.95
Liparis sp.	Liparis sp.	0.486	818.61

Gymnelus sp.	Gymnelus sp.	0.474	143.57
Triglops pingeli	Ribbed sculpin	0.429	191.80
Pleuronectiformes	Flatfish unident.	0.405	65.59
Liparis tunicatus	Liparis tunicatus	0.399	57.04
Mallotus villosus	Capelin	0.372	173.72
Lycodes palearis	Wattled eelpout	0.317	195.27
Nautichthys pribilovius	Eyeshade sculpin	0.309	130.63
Limanda proboscidea	Longhead dab	0.295	133.81
Lycodes raridens	Marbled eelpout	0.280	330.62
Hexagrammos stelleri	Whitespotted greenling	0.140	18.90
Gymnelus hemifasciatus	Gymnelus hemifasciatus	0.131	56.32
Podothecus sp.	Podothecus sp.	0.130	60.05
Liparidinae	Snailfish unident.	0.111	110.43
Gymnocanthus galeatus	Armorhead sculpin	0.093	6.64
Clupea pallasi	Pacific herring	0.093	11.61
Chirolophis snyderi	Bearded warbonnet	0.086	6.64
Eumesogrammus praecisus	Fourline snakeblenny	0.082	10.37
Gymnelus viridis	Fish doctor	0.073	5.61
Myoxocephalus polyacanthocephalus	Great sculpin	0.072	48.43
Enophrys sp.	Enophrys sp.	0.066	6.64
Limanda sakhalinensis	Sakhalin sole	0.062	5.13
Cottidae	Sculpin unident.	0.053	160.16
Myoxocephalus sp.	Myoxocephalus sp.	0.039	22.86
Aspidophoroides bartoni	Aleutian alligatorfish	0.031	34.76
Hypsagonus quadricornis	Fourhorn poacher	0.029	28.85
Trichocottus brashnikovi	Bullhorn sculpin	0.015	30.51
Ammodytes hexapterus	Arctic Sand Lance	0.015	7.29
Podothecus veternus	Vetrans poacher	0.013	13.04

Pleuronectiformes larvae	Flatfish larvae unident.	0.006	6.43
Liparis gibbus	Variegated snailfish	0.006	11.96
Icelus sp.	Icelus sp.	0.006	5.84
Gadus chalcogrammus Age 0	Walleye pollock age 0	0.005	10.49

Arctic cod were caught at nearly all stations over a range of water temperatures (Fig. 2). In contrast, saffron cod were found only in the southern half of the survey area, in relatively warm waters (Fig. 2). Walleye pollock were found over a fairly wide range of latitudes in the survey area, whereas Pacific cod were found only in warmer waters in the southern portion of the survey (Fig. 3). Snow crab were caught at nearly all stations. Female snow crab with eggs (ovigerous) were found in the northwestern area of the survey (Fig. 4). Bering flounder were most abundant in relatively cool waters at stations furthest from shore and associated with muddy substrates (Fig. 5).

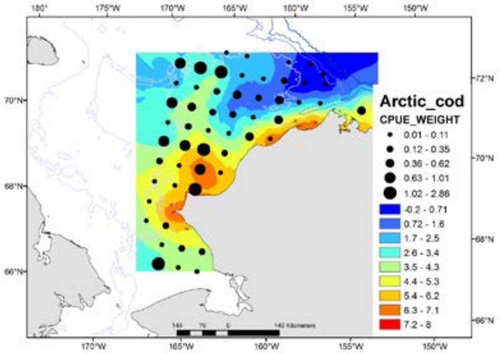


Figure 2. The distribution of Arctic cod and saffron cod overlaid on near-bottom water temperature (temperature data from CTD casts conducted at each station, courtesy of Ryan McCabe, Pacific Marine Environmental Laboratory).

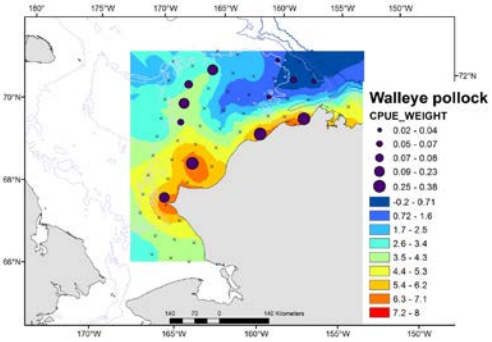


Figure 3. The distribution of walleye pollock and Pacific cod overlaid on near-bottom water temperature (temperature data from CTD casts conducted at each station, courtesy of Ryan McCabe, Pacific Marine Environmental Laboratory).

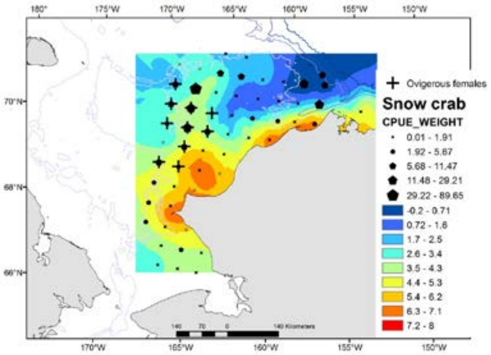


Figure 4. The distribution of snow crab overlaid on near-bottom water temperature (temperature data from CTD casts conducted at each station, courtesy of Ryan McCabe, Pacific Marine Environmental Laboratory). The presence of ovigerous females is indicated by a cross.

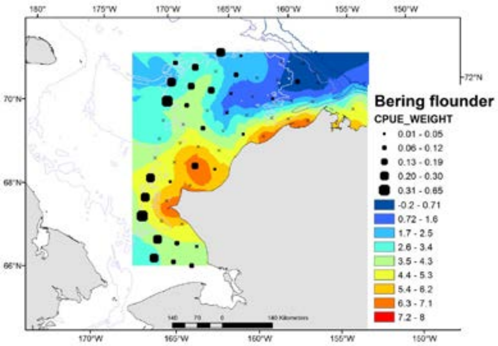


Figure 5. The distribution of Bering flounder overlaid on near-bottom water temperature (temperature data from CTD casts conducted at each station, courtesy of Ryan McCabe, Pacific Marine Environmental Laboratory).

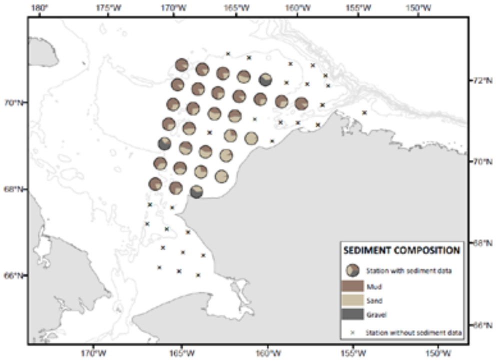


Figure 5. Sediment composition at each station is from benthic grab samples collected during the IES survey (data courtesy of Staci McMahon, University of Washington).

For more information please contact Libby Logerwell at: Libby.Logerwell@noaa.gov

AUKE BAY LABORATORIES

Spatial and temporal trends in the abundance and distribution of Pacific herring (*Clupea pallasii*) in the eastern Bering Sea during late summer, 2002-2015 - ABL

Description of index: Pacific herring (*Clupea pallasii*) were captured using surface trawls in the eastern Bering Sea during the late summer (September) from 2002-2015 in the Bering Arctic Subarctic Integrated Surveys (BASIS) surveys. Abundance and distribution were estimated using a standardized geostatistical index developed for stock assessments and management by Thorson et al. (2015). Survey stations were approximately 30 nautical miles apart. A trawl net was towed in the upper 20 m of the water column for approximately 30 minutes. Fish catch was estimated in kilograms at each station. Area swept was calculated as the product of the haversine distance of the tow and the horizontal spread of the net. Geostatistical analysis were conducted using R statistical software version 0.99.896 and the SpatialDeltaGLMM package version 3l (Thorson et al. 2015) to estimate abundance and distribution. We used a lognormal distribution and estimated spatial and spatio-temporal variation for both encounter probability and positive catch rate components, and a spatial resolution with 100 knots.

Status and trends: Pacific herring had a northern and nearshore distribution in the eastern Bering Sea during late summer (Figure 1). Field densities were generally higher in warm years. North-south elongation of the anisotropy ellipse indicated that densities are correlated over a longer distance in the north-south direction than in the east-west direction (Figure 2). The distribution of herring was more nearshore and north in 2010-2012 (Figure 3) and also more contracted over a smaller area in 2010-2012 (Figure 4). Estimated abundance of Pacific herring ranged from 15,616 metric tonnes in 2002 to 145,853 metric tonnes in 2014 (Figure 5; Table 1). The general trend was of higher abundances in warm years and lower abundances in cold years.

Factors causing trends: The eastern Bering Sea has recently undergone a series of warm (2002-2006), cold (2008-2012), and warm (2014) stanzas. The estimated abundance of Pacific herring was higher in warm years and lower in cold years. Climate may influence abundance through the impact of prey quality for herring nearshore in the eastern Bering Sea (Andrews et al. 2015). This model however does not account for the age of herring so estimates of abundance likely include multiple year classes.

Implications: Possible implications for increases in abundance of herring include increase prey availability for piscivores. The herring in our survey are likely mostly from Norton Sound. Pacific herring spawn in shallow subtidal and intertidal area along the coast during spring. In the summer, Bering Sea herring move west crossing the continental shelf where they feed (Mecklenburg et al. 2002). The distribution of the late summer herring indicate that they are in feeding grounds and likely migrating offshore.

For more information contact Ellen Yasumiishi at (907) 789-6604 or (ellen.yasumiishi@noaa.gov), Kristin Cieciel, Ed Farley.

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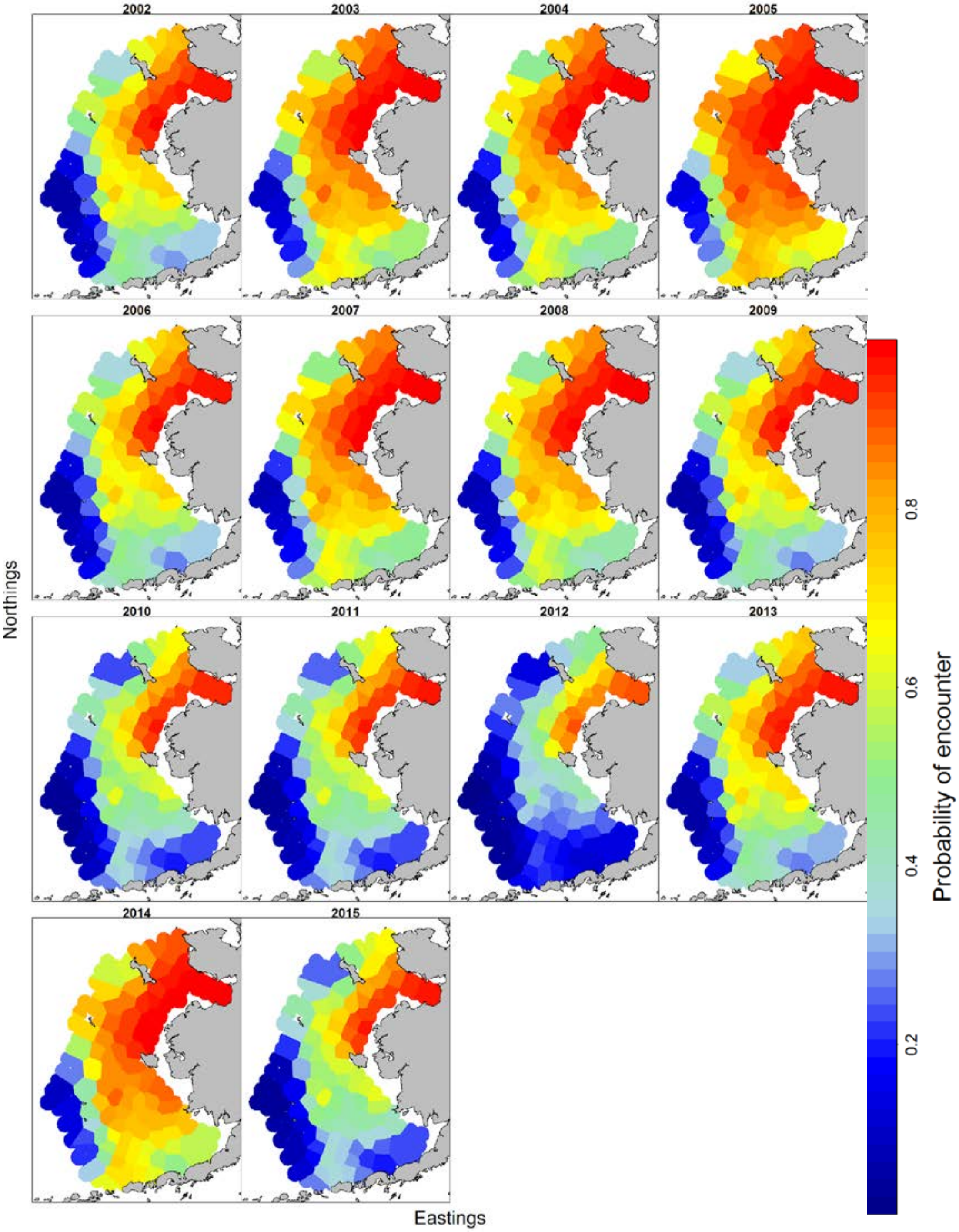


Figure 1. Density of Pacific herring in the eastern Bering Sea during late summer, 2002-2015. Densities were estimated using the geostatistical delta-generalized linear mixed model from Thorson et al. (2015).

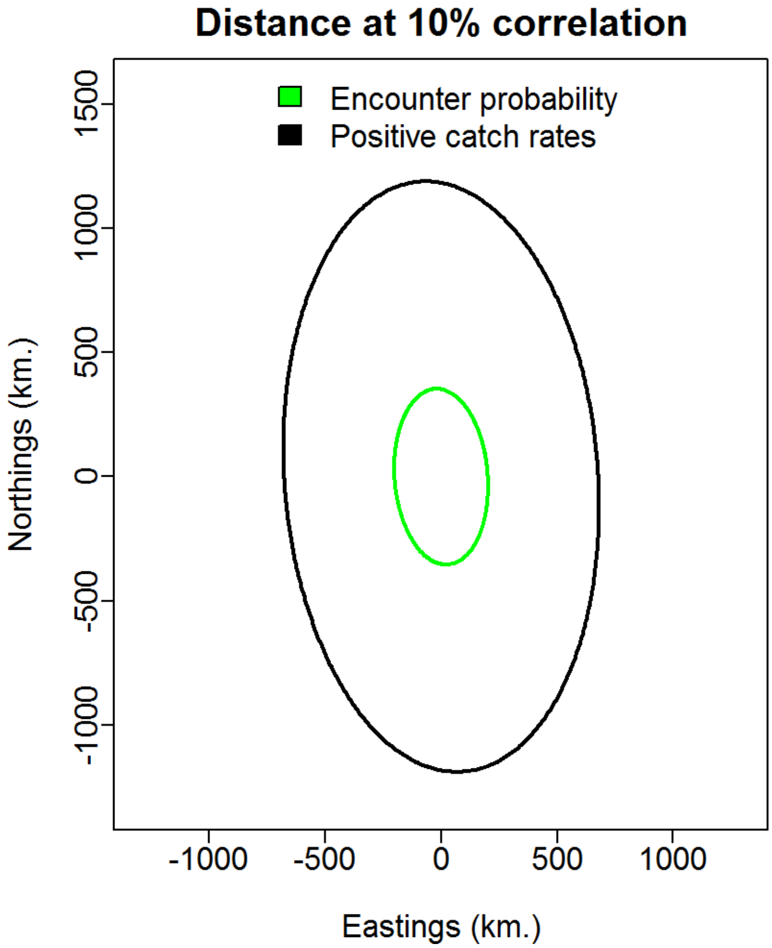


Figure 2. Geometric anisotropy plots for encounter probability of Pacific herring on the eastern Bering Sea shelf during late summer, 2002-2015.

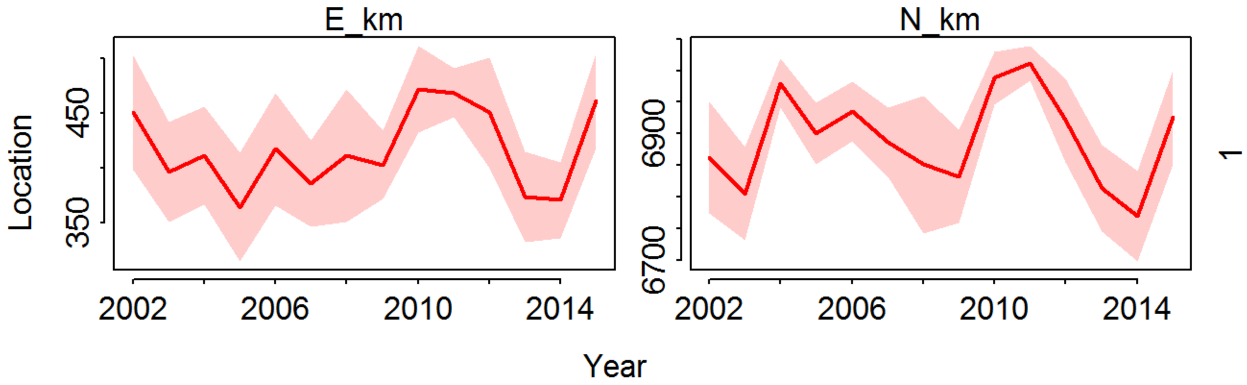


Figure 3. Northward and eastward center of gravity (distribution) in units of km for Pacific herring on the eastern Bering Sea during late summer, 2002-2015.

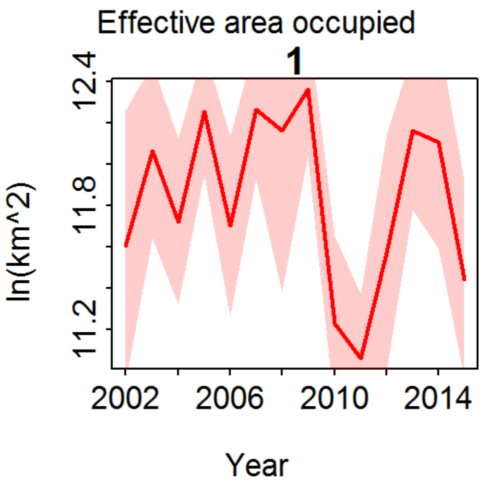


Figure 4. The effective area (ln(km^2)) occupied by Pacific herring on the eastern Bering Sea shelf during late summer, 2002-2015.

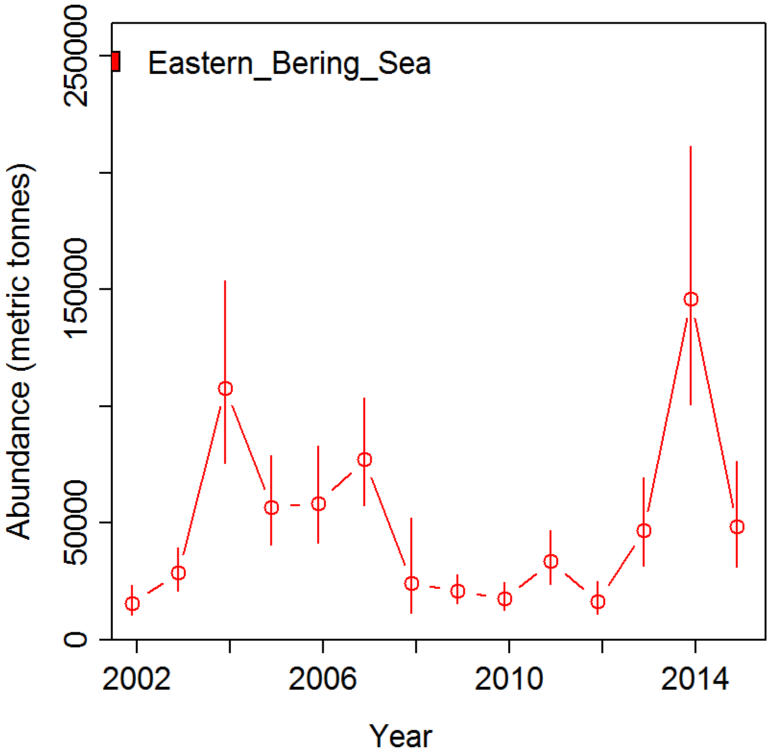
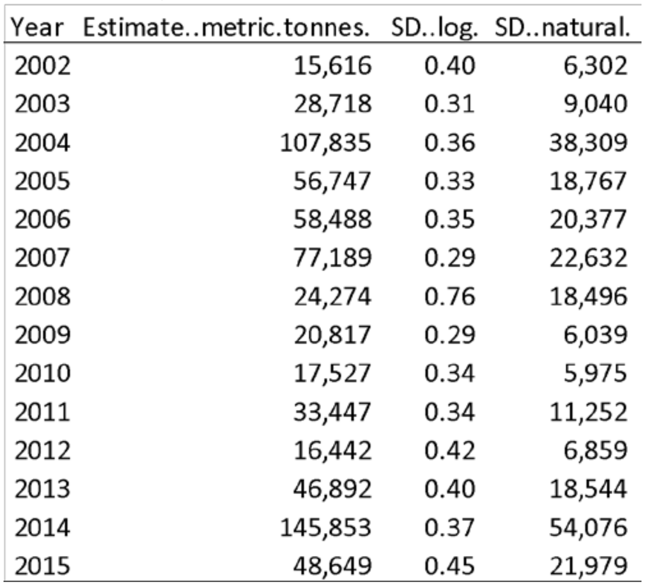


Figure 5. Estimated index of abundance with 95% confidence intervals for Pacific herring in the eastern Bering Sea during late summer, 2002-2015. Abundance was estimated using the geostatistical delta-generalized linear mixed model from Thorson et al. (2015).

Table 1. Estimated abundance in metric tonnes of Pacific herring in the eastern Bering Sea during late summer, 2002-2015. SD is standard deviation.



Year	Estimate..metric.tonnes.	SD..log.	SD..natural.
2002	15,616	0.40	6,302
2003	28,718	0.31	9,040
2004	107,835	0.36	38,309
2005	56,747	0.33	18,767
2006	58,488	0.35	20,377
2007	77,189	0.29	22,632
2008	24,274	0.76	18,496
2009	20,817	0.29	6,039
2010	17,527	0.34	5,975
2011	33,447	0.34	11,252
2012	16,442	0.42	6,859
2013	46,892	0.40	18,544
2014	145,853	0.37	54,076
2015	48,649	0.45	21,979

Spatial and temporal trends in the abundance and distribution of groundfish in pelagic waters of the eastern Bering Sea during late summer, 2002-2016 -ABL

Description of index: Pelagic fish and jellyfish were sampled using a trawl net towed in the upper 20 m of the eastern Bering Sea during the Alaska Fisheries Science Centers’ Bering Arctic Subarctic Integrated Surveys (BASIS) during late summer, 2002-2016. Stations were approximately 30 nautical miles apart and a trawl was towed for approximately 30 minutes. Area swept was estimated from horizontal net opening and distance towed.

Fish catch was estimated in kilograms. Surveys were not conducted in the south (<60 °N) during 2013 and 2015 and north (≥60 °N) during 2008 but fish densities in these areas were estimated using geostatistical modeling methods (Thorson et al. 2015). Four species were commonly caught with the surface trawl: age-0 Pacific cod (*Gadus macrocephalus*), age-0 pollock (G*adus chalcogrammus*), Atka mackerel (*Pleurogrammus monopterygius*), and yellowfin sole (*Limanda aspera*). Biomass was calculated for each species and compared across species and oceanographic domains on the Bering Sea shelf.

Abundance and distribution (center of gravity and area occupied) were estimated for each jellyfish species using the VAST package for multispecies version 1.1.0 (Thorson 2015; Thorson et al. 2016a, b, c) in RStudio version 0.99.896 and R software version 3.3.0 (R Core Team 2016). The abundance index is a standardized geostatistical index developed by Thorson et al. (2015, 2016a, 2016b, 2016c) to estimate indices of abundance for stock assessments. We specified a gamma distribution and estimated spatial and spatio-temporal variation for both encounter probability and positive catch rate components at a spatial resolution of 100 knots. Parameter estimates were within the upper and lower bounds.

Abundance and distribution (center of gravity and area occupied) were estimated for using the VAST package for multispecies version 1.1.0 (Thorson 2015; Thorson et al. 2016a, b, c) in RStudio version 0.99.896 and R software version 3.3.0 (R Project 2017). The abundance index is a standardized geostatistical index developed by Thorson et al. (2015, 2016) to estimate indices of abundance for stock assessments. We specified a gamma distribution and estimated spatial and spatio-temporal variation for both encounter probability and positive catch rate components at a spatial resolution of 100 knots. Parameter estimates were within the upper and lower bounds and final gradients were less than 0.0005.

Status and trends: Temporal trends in the estimated abundance of these groundfish species indicated a decline in the productivity of groundfish in pelagic waters of the eastern Bering Sea in 2016 (Figure 1-5, Table 1). Juvenile age-0 pollock were the most abundant juvenile pelagic groundfish species in our survey areas followed by yellow fin sole, Atka mackerel, and then Pacific cod (Table 1).

Distribution of groundfish in pelagic waters varied among species and years (Figure 2-5). Age-0 P. cod were distributed on the southern Bering Sea shelf near the Unimak Pass (Figure 2). Age-0 pollock were the most widely distributed species and primarily on the southeastern Bering Sea middle domain (50-100 m bottom depth) but distributed farther north during warm years (Figure 3). Atka mackerel were captured primarily in the outer domain of the southeastern Bering Sea shelf (Figure 4). Yellowfin sole distributed in the southern inner and middle domains of the southeastern Bering Sea shelf (Figure 5).

Temporal trends in the distribution (center of gravity) that age-0 pollock were distributed farther north during recent warm years (Figure 6). No warm and cold year trends was observed in the distribution of age-0 P. cod, yellowfin sole. Atka mackerel were generally distributed farther north during warm stanzas and farther south during the cold stanza (Figure 6). Area occupied indicated that pollock had an expanded range during warm years relative to cold years (Figure 7).

Factors causing trends: Lower abundances of groundfish in pelagic waters during 2016, third consecutive warm year, indicate poor environmental conditions for the growth and survival in the eastern Bering Sea during summer or movement out of the survey area. Age-0 pollock appeared to respond to warming with an expansion in their range and a distribution farther north. Movement of age-0 pollock and Atka mackerel farther north during warm years indicate a response to warming by their changing distribution.

Implications: Lower abundances of groundfish in surface waters during 2016 indicate a change in productivity in pelagic waters. The age-0 pollock distributed primarily in the southeastern Bering Sea middle domain, but were farther north during warm years during higher population densities possibly in search of food during years of low lipid-rich prey such as large zooplankton (Coyle et al. 2011).

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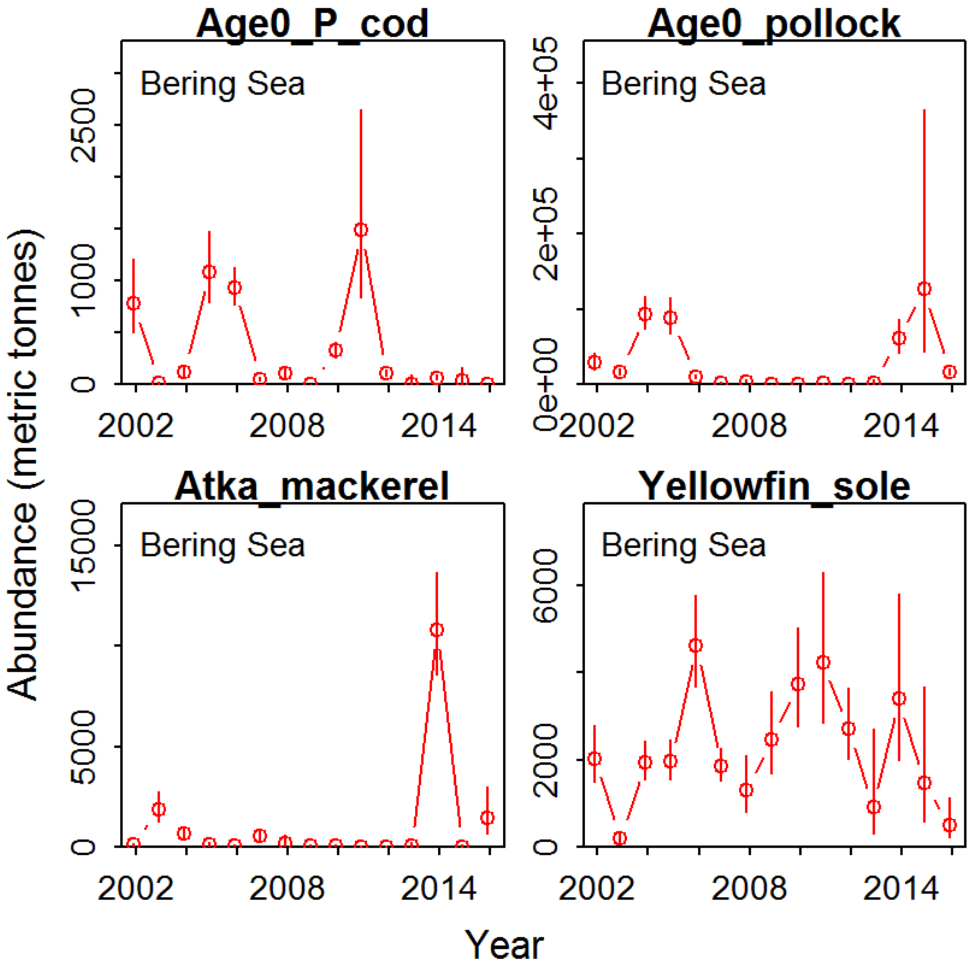

Figure 1. Index of abundance (metric tonnes) plus/minus 1 standard error for groundfish species in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

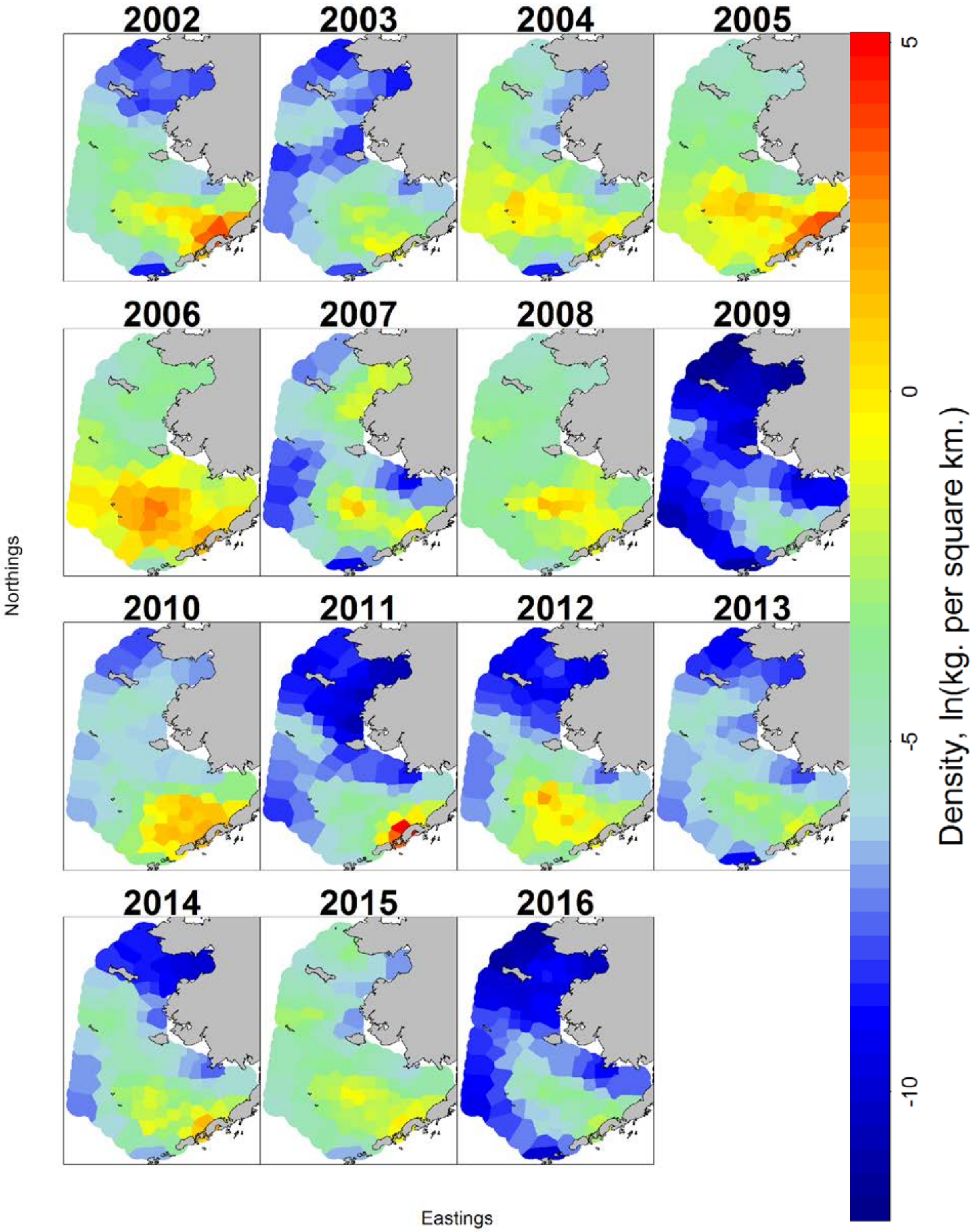

Figure 2. Predicted field densities of age-0 Pacific cod in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

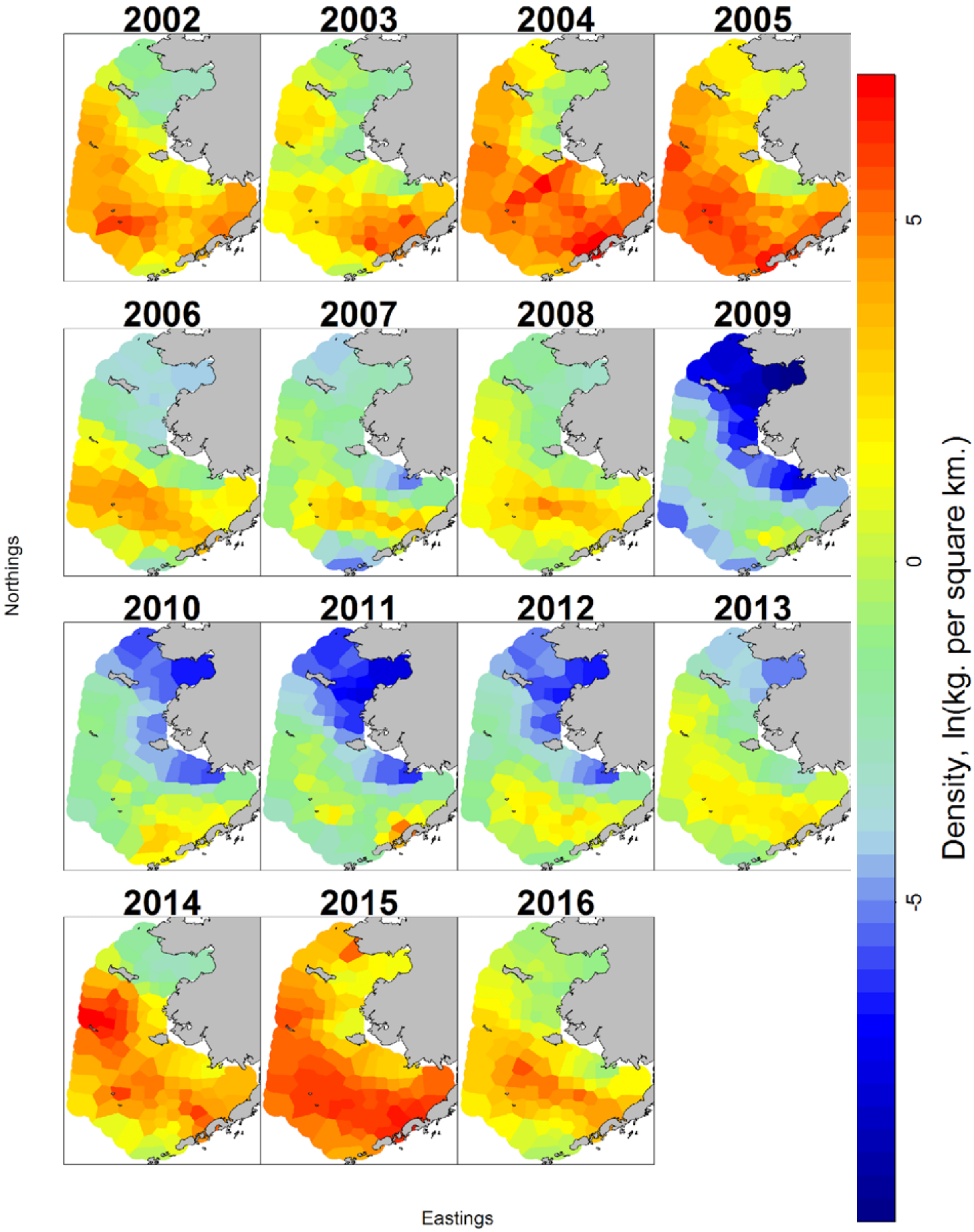

Figure 3. Predicted field densities of age-0 pollock in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

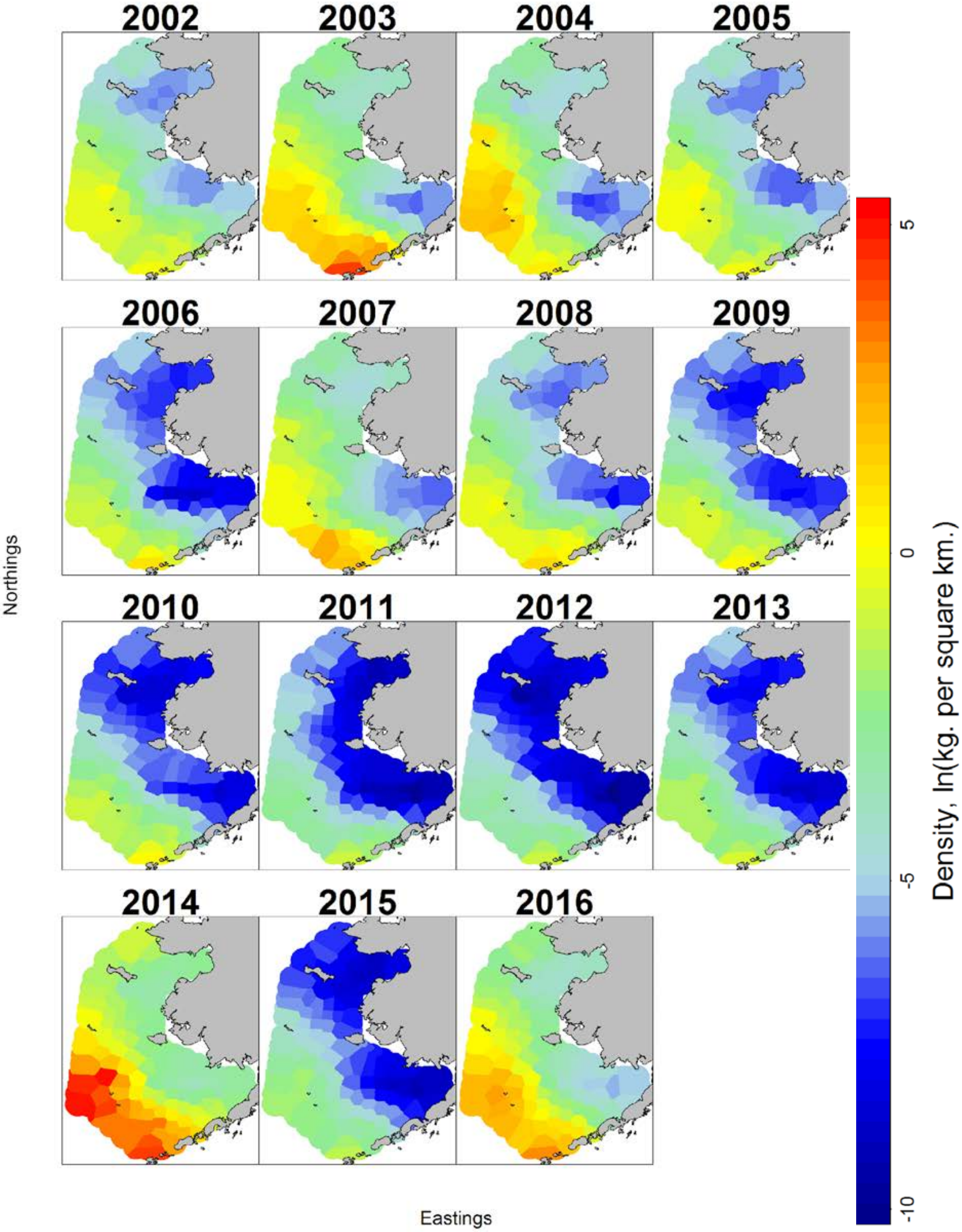

Figure 4. Predicted field densities of Atka mackerel in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

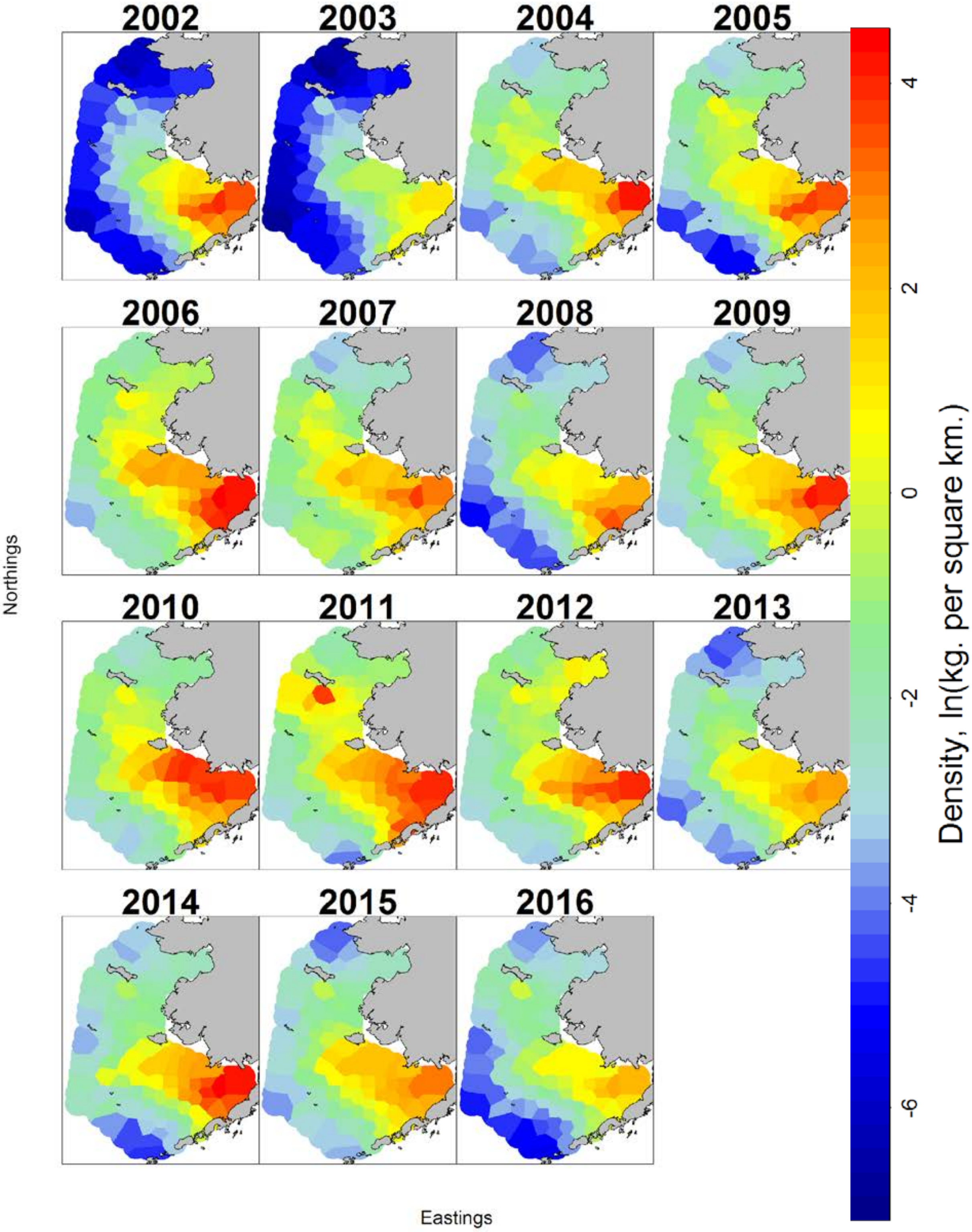

Figure 5. Predicted field densities of yellowfin sole in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

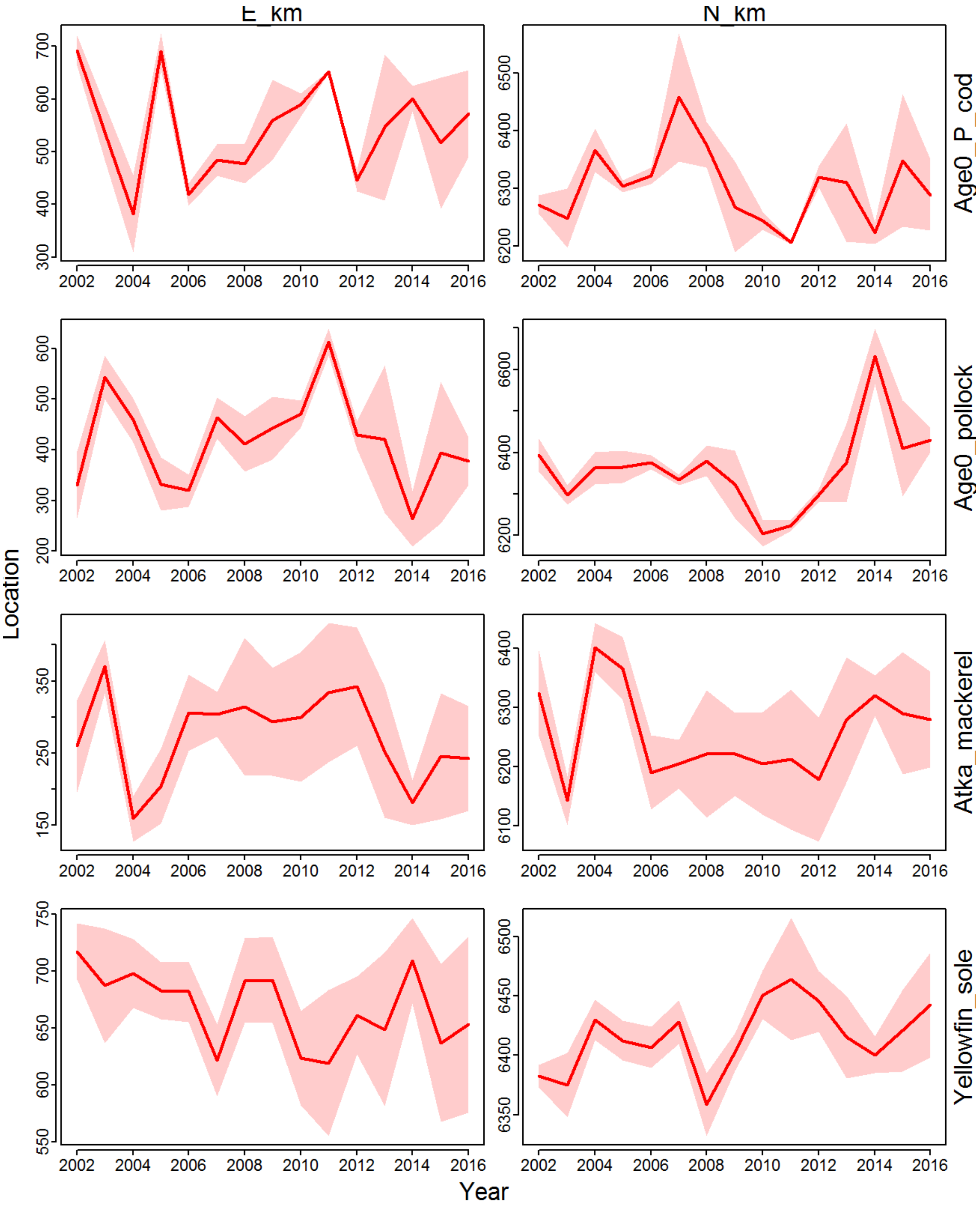

Figure 6. Center of gravity indicating temporal shifts in the mean east-to-west and north-to-south distribution plus/minus 1 standard error in UTM (km) for groundfish in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

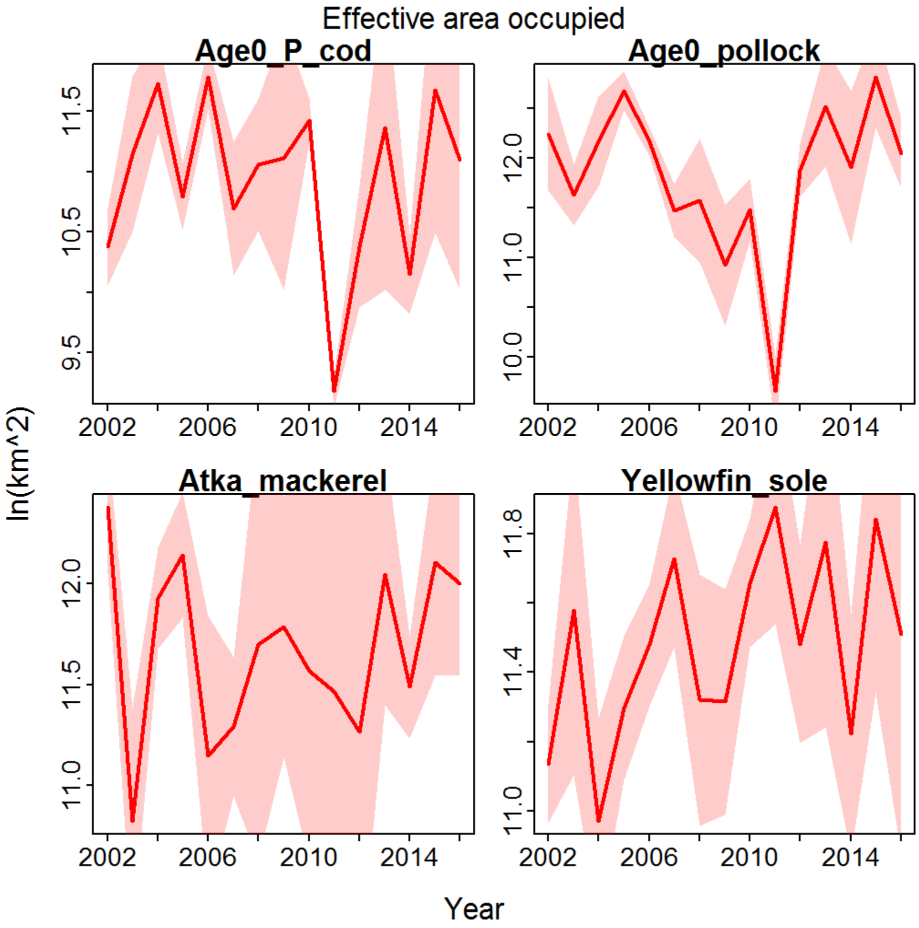

Figure 7. Effective area occupied ($\ln(km^2)$) indicating range expansion/contraction plus/minus 1 standard error for groundfish in pelagic waters of the eastern Bering Sea shelf during late summer, 2002-2016.

Table 1. Index of abundance (metric tonnes) plus/minus 1 standard error (SE), and the coefficient of variation (%) for groundfish in pelagic waters of the eastern Bering Sea during late summer, 2002-2016.

	Age-0 P. cod			Age-0 pollock			Atka mackerel			Yellowfin sole		
	Estimate	S.E.	C.V.	Estimate	S.E.	C.V.	Estimate	S.E.	C.V.	Estimate	S.E.	C.V.
2002	776	345	44%	28,989	10,705	37%	113	61	54%	2,028	644	32%
2003	15	10	69%	16,866	4,027	24%	1,857	733	39%	194	104	53%
2004	122	37	31%	92,590	21,439	23%	638	270	42%	1,928	439	23%
2005	1,086	335	31%	88,836	23,511	26%	125	65	52%	1,956	455	23%
2006	937	179	19%	10,371	2,076	20%	79	37	46%	4,608	1,042	23%
2007	51	15	28%	2,325	547	24%	529	193	36%	1,860	368	20%
2008	105	39	37%	4,254	1,587	37%	156	215	138%	1,308	623	48%
2009	1	1	118%	82	41	51%	72	47	66%	2,448	913	37%
2010	324	80	25%	809	259	32%	53	38	72%	3,724	1,107	30%
2011	1,490	856	57%	1,562	924	59%	15	18	122%	4,231	1,685	40%
2012	110	29	26%	751	150	20%	12	13	108%	2,706	815	30%
2013	9	21	238%	1,565	2,139	137%	29	63	221%	922	994	108%
2014	66	24	36%	60,583	22,268	37%	10,831	2,537	23%	3,393	1,820	54%
2015	36	54	152%	126,858	134,018	106%	18	33	181%	1,464	1,347	92%
2016	3	3	86%	16,437	4,358	27%	1,432	1,063	74%	493	407	83%
Mean	342	135	67%	30,192	15,203	44%	1,064	359	85%	2,218	851	46%

For more information contact: Ellen.yasumiishi@noaa.gov

Small Neritic Fishes in Coastal Marine Ecosystems: Late-Summer Conditions in the Western Gulf of Alaska - RPP

Matthew T. Wilson and Lauren A. Rogers

The Ecosystems & Fisheries Oceanography Coordinated Investigations (EcoFOCI) Program monitors and researches small neritic fishes to improve our understanding and management of the Gulf of Alaska ecosystem and fisheries. Small neritic fishes include the juvenile stages of economically and ecologically important species (e.g., walleye pollock, Pacific cod, Pacific Ocean perch and other rockfishes, sablefish, and arrowtooth flounder). They also include species managed exclusively as forage fishes (e.g., capelin and eulachon) that support the fishes, seabirds, and marine mammals that characterize the piscivore-dominated GOA ecosystem. Longstanding objectives of EcoFOCI late-summer field work in the western Gulf of Alaska are to extend a time series of age-0 walleye pollock abundance estimates, monitor the neritic environment including zooplankton and abiotic conditions, and collect samples for research (e.g., trophic and spatial ecology, bioenergetics, age and growth).

During 21 August -15 September 2017, the NOAA vessel Oscar Dyson sampled the western Gulf of Alaska. The survey grid west of the Shumagin Islands was truncated due to weather. At each of 130 stations, water temperature and salinity were profiled, zooplankton were sampled, and target midwater fishes were collected using a Stauffer trawl (aka anchovy trawl) equipped with a small-mesh (2x3 mm) codend liner towed obliquely to a maximum depth of 200 m. Time series of abundance for age-0 pollock and for capelin were constructed based on catches from late-summer surveys since 2000 (only odd years since 2001) for the consistently sampled region between Kodiak Island and the Shumagin Islands. Mean catch per unit area was calculated using an area-weighted mean. Due to significant differences in catches of capelin during day versus night, mean CPUE for the night stations only is also shown.

Age-0 pollock were particularly abundant through Shelikof Strait and to the east of Kodiak Island (Figure 1). The mean CPUE estimate for 2017, which does not include the stations near Kodiak, suggests the second highest abundance of age-0 pollock in our time series (Figure 2), averaging 380,000 age-0 pollock per square kilometer (0.38 fish/m^2). This high abundance reflects the number of surviving larvae from spawning in the spring and survival processes through the summer. Pollock densities tapered off towards the Shumagin Islands in the southwest. This spatial distribution is in contrast to a previous high abundance year (2013) when catches were highest southwest of the Shumagin Islands (Figure 1). The observed spatial distribution of pollock may result from transport processes and/or reflect production from different spawning groups. This late-summer survey also provides an assessment of the abundance, size, and condition of young-of-year pollock before entering their first winter, giving an early indicator of potential year class strength. Strong catches of juvenile pollock, together with previously observed high larval abundance, suggest a return to productive conditions in the Gulf of Alaska following the \Blob" warm anomaly in 2014-2016.

Capelin abundance remained low in 2017, continuing a trend of low abundance since 2011.

However, in Figure 2, note that no sampling occurred in even years and the time series estimate does not include catches from near Kodiak, where capelin catches are typically higher. Investigations into factors driving changes in the spatial distribution and abundance of capelin and juvenile pollock are underway.

This section is a slightly modified excerpt from Ecosystem Considerations 2017: Status of the Gulf of Alaska marine ecosystem, which is available at https://www.afsc.noaa.gov/REFM/Docs/2017/ecosysGOA.pdf

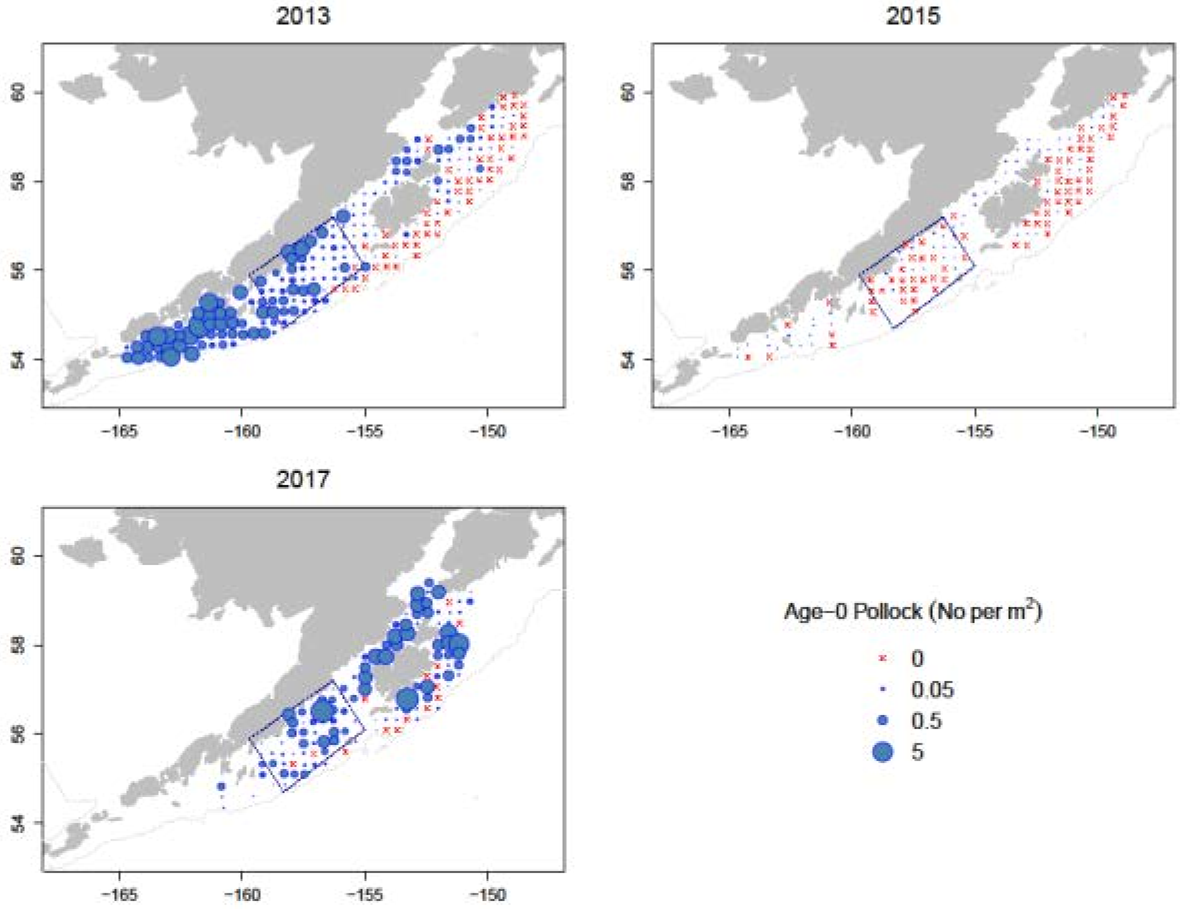

Figure 1. Catches of age-0 walleye pollock in the EcoFOCI late-summer small-mesh trawl survey for 2013, 2015, and 2017. The area in the blue dashed box indicates the region most consistently sampled since 2000 and includes the stations used to develop CPUE time series.

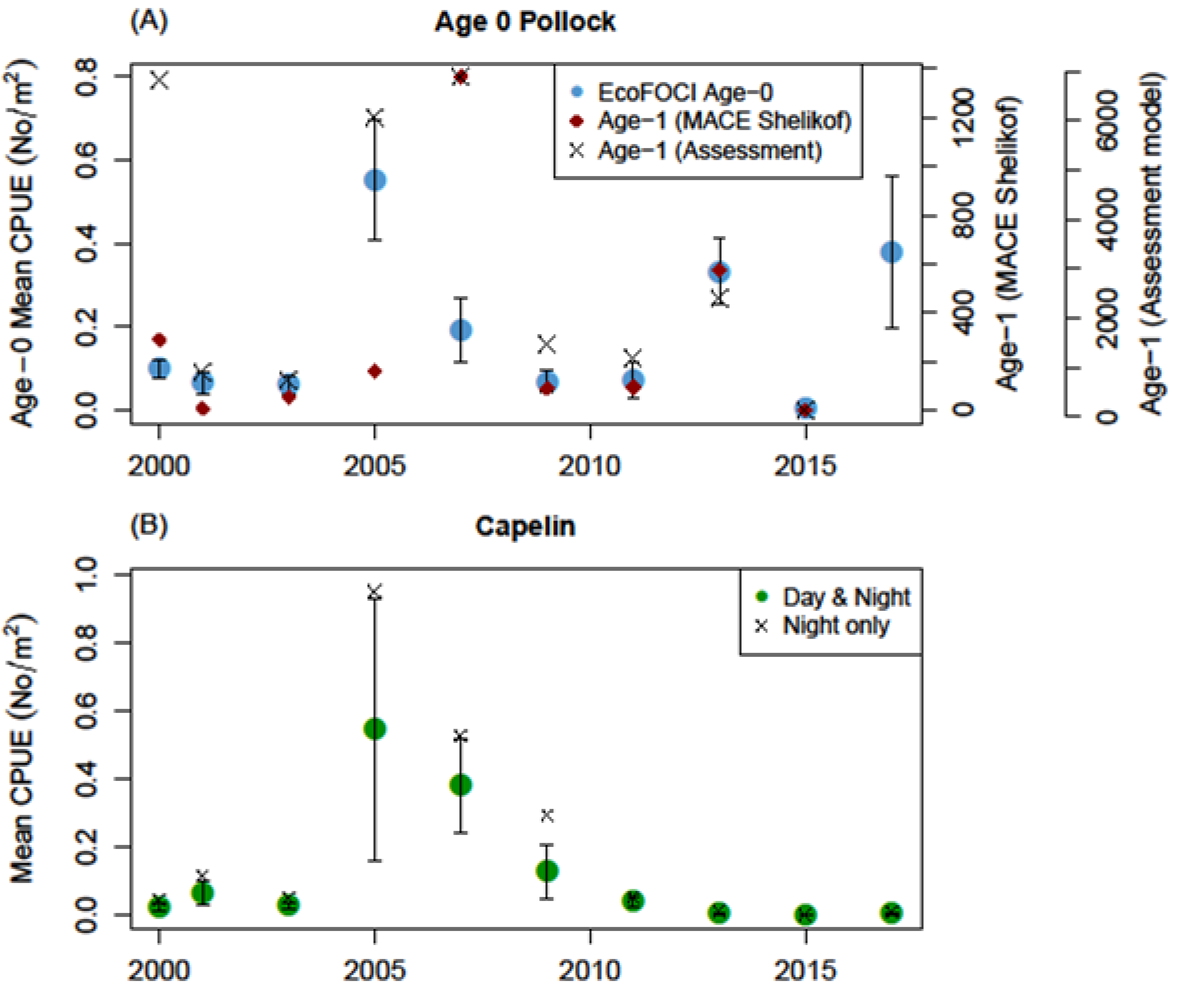

Figure 2. Mean catch per unit effort (CPUE) of age-0 walleye pollock (top) and capelin (bottom) in the EcoFOCI late-summer small-mesh trawl survey for 2000 - 2017. Mean CPUE is based on data from a consistently sampled region (see Fig. 1 dashed blue box).

For More Information Contact Matt.Wilson@noaa.gov

Marine Fishes Caught in the Southeast Coastal Monitoring (SECM) Survey - ABL

Jordan T. Watson, Andy Gray, Emily Fergusson, James M. Murphy

Description of indicator: The Southeast Coastal Monitoring (SECM) program has collected fish, zooplankton, and oceanographic samples in southeast Alaska since 1997 (Fergusson et al. 2013; Orsi et al. 2014; Orsi et al. 2015). Sampling has been focused most consistently in Icy Strait, the primary northern migratory pathway to the Gulf of Alaska for juvenile salmon originating from over 2000 southeast Alaska streams and rivers. Research objectives of the SECM program are to provide insight into the production dynamics and early ocean ecology of Southeast Alaska salmon.

Surface trawls (0-20m) are used to sample epipelagic fish species, including all five commercial species of Pacific salmon (*Oncorhynchus* sp.) in southeast Alaska. Juvenile pink salmon (*O. gorbuscha*) are, on average, the most abundant species in the epipelagic habitat in SECM surveys. In addition to juvenile salmon, SECM surveys catch a suite of non-salmonid fish species, including occasional large numbers of walleye pollock (*Gadus chalcogrammus*), capelin (*Mallotus villosus*), and Pacific herring (*Clupea pallasii*). We provide summaries of the annual catch rates for the five salmon species (pink; coho *O. kisutch*; sockeye, *O. nerka*; chum, *O. keta*; and Chinook, *O. tshawytscha*; Figure 1) and the three important ground and forage fish species (Figure 2).

Status and trends: In 2017, juvenile salmon catch rates were among the lowest of the time series for all five salmon species. Meanwhile, adult chum salmon catch rates continued an upward trend, though these rates remain nearly an order of magnitude lower than those of adult pink salmon.

Although catch rates for groundfish and forage fish are typically low during the SECM surveys, record catches of capelin, pollock, and herring have occurred in recent years. Herring was the only species with above average catch rates in 2017, with the second highest catch rate of the time series.

Factors influencing observed trends: Ocean conditions in 2017 were preceded by several anomalously warm years. Warm ocean conditions are likely to have influenced recruitment patterns through multiple years of altered community structure and stock dynamics. We continue to seek relationships between observed trends and environmental covariates (e.g., sea surface temperature).

Implications: Understanding recruitment processes of fish stocks is an important aspect of managing fish stocks, particularly during periods of substantial climate change. Juvenile abundance and oceanographic data collected during SECM have provided reliable forecasts of pink salmon returns to Southeast Alaska (Orsi, et al. 2015) and are used for pre-season fisheries management decisions in the purse seine and drift gillnet fisheries of Southeast Alaska (Wertheimer et al., 2015). By extending the application of SECM fish catches beyond pink salmon, we are poised to better resolve the relationships between other salmon and groundfish species and ecosystem indicators that help to describe their production dynamics. Furthermore, as SECM surveys continue annually, they fill a valuable gap in data that occurs during off-years for the Gulf of Alaska Ecosystem Surveys.

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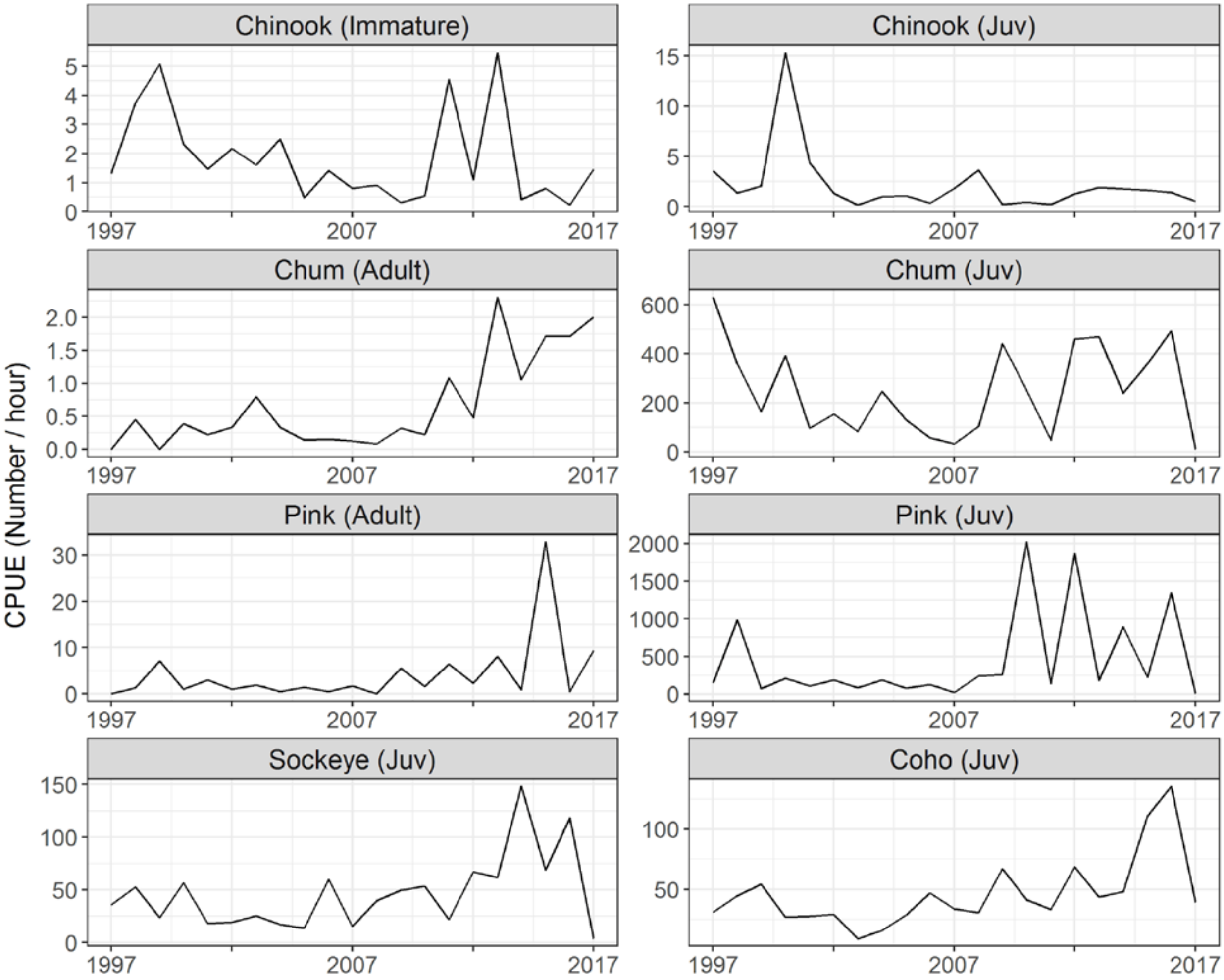

Figure 1. Time series of juvenile, immature (Chinook only), and adult salmon catch rates (number of fish per hour) during SECM surveys from 1997 – 2017.

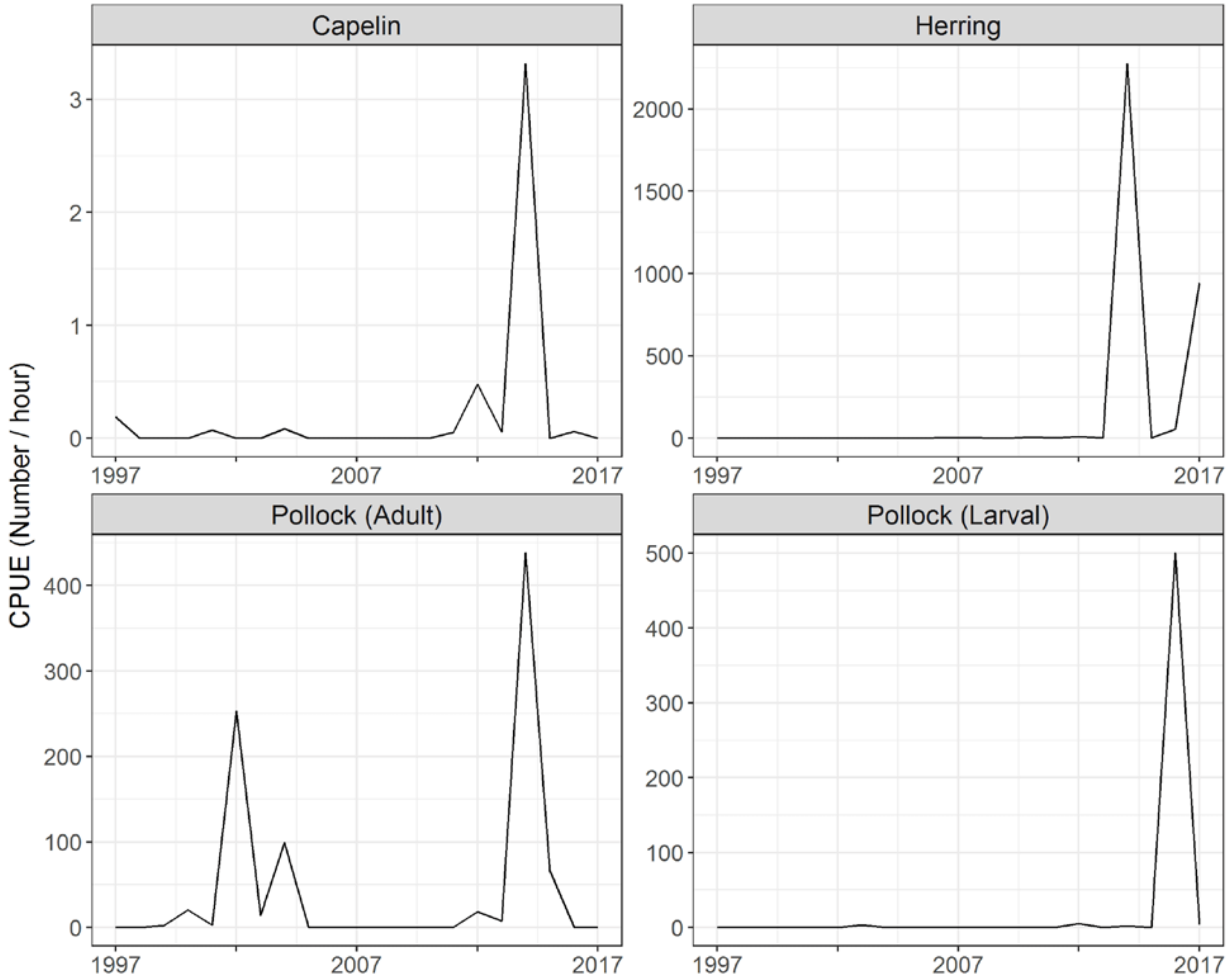

Figure 2. Time series of the most common non-salmonid fishes catch rates during SECM surveys from 1997 – 2017.

For more information contact: jordan.watson@noaa.gov

Using Vessel Monitoring System Data to Estimate Spatial Effort in Bering Sea Fisheries for Unobserved Trips-REFM/ESSR

Alan Haynie*, Patrick Sullivan, and Jordan Watson

**For further information, contact Alan.Haynie@NOAA.gov*

A primary challenge of marine resource management is monitoring where and when fishing occurs. This is important for both the protection and efficient harvest of targeted fisheries. Vessel monitoring system (VMS) technology records the time, location, bearing, and speed for vessels. VMS equipment has been employed on vessels in many fisheries around the world and VMS data has been used in enforcement, but a limited amount of work has been done utilizing VMS data to improve estimates of fishing activity. This paper utilizes VMS and an unusually large volume of government observer-reported data from the United States Eastern Bering Sea pollock fishery to predict the times and locations at which fishing occurs on trips without observers onboard. We employ a variety of techniques and specifications to improve model performance and out-of-sample prediction and find a generalized additive model that includes speed and change in bearing to be the best formulation for predicting fishing. We assess spatial correlation in the residuals of the chosen model, but find no correlation after taking into account other VMS predictors. We compare fishing effort to predictions for vessels with full observer coverage for 2003-2010 and compare predicted and observer-reported activity for observed trips. In this project, we have worked to address challenges that result from missing observations in the VMS data, which occur frequently and present modeling complications. We conclude with a discussion of policy considerations. Results of this work will be published in a scientific journal. We are also working with the NMFS Alaska Regional Office to attempt to improve the Region's spatial effort database and we will extend the model to other fisheries.

Using Vessel Monitoring System (VMS) Data to Identify and Characterize Trips made by Bering Sea Fishing Vessels-REFM/ESSR

Jordan Watson and Alan Haynie*
**For further information, contact Alan.Haynie@NOAA.gov*

Catch per unit effort (CPUE) is among the most common metrics for describing commercial fisheries. However, CPUE is a relatively fish-centric unit that fails to convey the actual effort expended by fishers to capture their prey. By resolving characteristics of entire fishing trips, in addition to their CPUE, a broader picture of fishers' actual effort can be exposed. Furthermore, in the case of unobserved fishing, trip start and end times may be required in order to estimate CPUE from effort models and landings data. In this project, we utilize vessel monitoring system (VMS) data to reconstruct individual trips made by catcher vessels in the Eastern Bering Sea fishery for walleye pollock (Gadus chalcogrammus) from 2003 – 2013. Our algorithm implements a series of speed, spatial and temporal filters to determine when vessels leave and return to port. We then employ another set of spatial filters and a probabilistic model to characterize vessel trips as fishing versus non-fishing. Once trips are identified and characterized, we summarize the durations of trips and the distances traveled -- metrics that can be subsequently used to characterize changes in fleet behaviors over time. This approach establishes a baseline of trip behaviors and will provide an improved understanding of how fisheries are impacted by management actions, changing economics, and environmental change. A publication on trip-identification algorithm is forthcoming in *PLOS ONE* and an additional manuscript will be submitted to a peer-reviewed journal.

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Watson, J.T. and A.C. Haynie. 2016. "Using vessel monitoring system data to identify and characterize trips made by fishing vessels in the United States North Pacific." In Press. *PLOS ONE*.

2017, Resource Ecology and Ecosystem Modeling Program (REFM/REEM)

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

Groundfish Stomach Sample Collection and Analysis

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 2017, AFSC personnel analyzed the stomach contents of 33 species sampled from the eastern Bering Sea, Gulf of Alaska and Aleutian Islands regions. The contents of 16,177 stomach samples were analyzed in the laboratory in addition to 3,073 stomach samples analyzed at sea during the Gulf of Alaska groundfish survey. This resulted in the addition of 56,554 records to AFSC's Groundfish Trophic Interactions Database. In addition, bill-load and diet samples from 1,155 seabirds were analyzed for the U.S. Fish and Wildlife Service, and 22 benthic grab samples were analyzed for an Essential Fish Habitat study. New information was added to the Stomach Examiner's Tool including 413 new images to aid in prey identification.

Collection of additional stomach samples was accomplished through resource surveys, research surveys, and sampling during commercial fishing operations. About 8,240 stomach samples were collected from large and abundant predators during bottom trawl surveys of the eastern Bering Sea continental shelf and the northern Bering Sea. Over 1,500 stomach samples were collected from the Gulf of Alaska to supplement the 3,073 stomach contents that were analyzed at sea during the bottom trawl survey in that region. Fishery Observers continued collection of stomach samples from Alaskan fishing grounds in 2017, resulting in 194 additional samples. REEM worked with FMA to design and implement new procedures for vessel assignment and specimen selection to broaden the temporal and spatial dispersion of the collected stomach samples from Pacific cod, walleye pollock and arrowtooth flounder.

Predator-Prey Interactions 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.

Ecosystem Considerations 2017: The Status of Alaska's Marine Ecosystems Completed and Posted Online

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. In 2017, new information became available to update the reports for the eastern Bering Sea and the Gulf of Alaska. 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.

Developing Better Understanding of Fisheries Markets-REFM/ESSR

Ron Felthoven and Ben Fissel *For more information, contact ben.fissel@noaa.gov*

Despite collecting a relatively broad set of information regarding the catch, products produced, and the prices received at both the ex-vessel and first-wholesale levels, our understanding of fishery and product markets and the factors driving those markets in the North Pacific is relatively incomplete. The primary goal of this project is 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. To the extent practicable for a given product, the analysis addresses product value (revenues), quantities, prices, market share, supply chain, import/export markets, major participants in the markets, product demand, end-use, current/recent issues (e.g., certification), current/recent news, and future prospects. An extract of the market profiles was included in *Status Report for the Groundfish Fisheries Off Alaska, 2014*. 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). We are currently seeking funding to update the market profiles in 2017.

Alaska Groundfish Wholesale Price Projections REFM/ESSR

Benjamin Fissel* *For further information, contact* Ben.Fissel@NOAA.gov

For a significant portion of the year there is a temporal lag in officially reported first-wholesale prices. This is lag occurs because the prices are derived from the Commercial Operators Annual Report which is not available until after data processing and validation of the data, in August of each year. The result is a data lag that grows to roughly a year and a half (e.g. prior to August 2015 the most recent available official prices were from 2014). To provide information on the current state of fisheries markets, nowcasting is used to estimate 2014 first-wholesale prices from corresponding export prices which are available in near real time. Nowcasting provided fairly accurate predictions and displayed rather modest prediction error with most of the confidence bounds within 5-10% of the price. In addition, time series models are used to project first-wholesale prices for 2016 - 2019. Resampling methods are used estimate a prediction density of potential future prices. Confidence bounds are calculated from the prediction density to give the probability that the prices will fall within a certain range. Prediction densities also provide information on the expected volatility of prices. As prices are projected past the current year the confidence bounds grow reflecting increasing uncertainty further out in the future. The results of this project will be presented in the *Status Report for the Groundfish Fisheries Off Alaska, 2014*. A technical report, Fissel (2015), details the methods used for creating the price projections.

Literature Cited

Fissel, B. 2015. “Methods for the Alaska groundfish first-wholesale price projections: Section 6 of the Economic Status of the Groundfish Fisheries off Alaska.” *NOAA Technical Memorandum* NMFS-AFSC-305, 39 p. U.S. Department of Commerce

Economic Indices for the North Pacific Groundfish Fisheries: Calculation and Visualization--REFM/ESSR

Benjamin Fissel* **For further information, contact* Ben.Fissel@NOAA.gov

Fisheries markets are complex; goods have many attributes such as the species, product form, and the gear with which it was caught. The price that fisheries goods command and the products they compete against are both functions of these various attributes. For example, whitefish products of one species may compete with whitefish products of another species. Additionally, markets influence a processing company’s decision to convert their available catch into different product types. During any given year it is determining whether to produce fillets or surimi, or perhaps to adjusting gear types to suit markets and consumer preferences. This myriad of market influences can make it difficult to disentangle the relative influence of different factors in monitoring aggregate performance in Alaska fisheries. This research employs a method that takes an aggregate index (e.g. wholesale-value index) and decomposes it into subindices (e.g. a pollock wholesale-value index and a Pacific cod wholesale-value index). These indices provide management with a broad perspective on aggregate performance while simultaneously characterizing and simplifying significant amounts of information across multiple market dimensions. A series of graphs were designed and organized to display the indices and supporting statistics. Market analysis based on these indices has been published as a section in the Economic Status of the Groundfish Fisheries Off Alaska since 2010. A technical report, Fissel (2014), details the methods used for creating the indices.

Literature Cited

Fissel, B. 2014. “Economic Indices for the North Pacific Groundfish Fisheries: Calculation and Visualization.” *NOAA Technical Memorandum* NMFS-AFSC-279, 59 p. U.S. Department of Commerce.

Economic Data Reporting in Groundfish Catch Share Programs-REFM/ESSR

Brian Garber-Yonts and Alan Haynie

**For further information, contact Brian.Garber-Yonts@NOAA.gov*

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 will begin in 2016 to gather baseline data on costs, earnings, and employment for vessels and processors participating in GOA groundfish fisheries.

Amendment 91 EDR

The A91 EDR program was developed by the NPFMC with the specific objective of assessing the effectiveness of Chinook salmon prohibited species catch (PSC) avoidance incentive measures implemented under A91, including sector-level Incentive Plan Agreements (IPAs), prohibited species catch (PSC) hard caps, and the performance standard. The data are intended to support this assessment over seasonal variation in salmon PSC incidence and with respect to how timing, location, and other aspects of pollock fishing and salmon PSC occur. The EDR is a mandatory reporting requirement for all entities participating in the AFA pollock trawl fishery, including vessel masters and businesses that operate one or more AFA-permitted vessels active in fishing or processing BSAI pollock, CDQ groups receiving allocations of BSAI pollock, and representatives of sector entities receiving allocations of Chinook salmon PSC from NMFS. The EDR is comprised of three separate survey forms: the Chinook salmon PSC Allocation Compensated Transfer Report (CTR), the Vessel Fuel Survey, and the Vessel Master Survey. In addition to the EDR program, the data collection measures developed by the Council also specified modification of the Daily Fishing Logbook (DFL) for BSAI pollock trawl CVs and CPs to add a "checkbox" to the tow-level logbook record to indicate relocation of vessels to alternate fishing grounds for the purpose of Chinook PSC avoidance.

AFSC economists presented a report to the NPFMC in February 2014 on the first year of A91 EDR data collection (conducted in 2013 for 2012 calendar year operations) and preliminary analysis of the data. The goal of the report was to identify potential problems in the design or implementation of the data collections and opportunities for improvements that could make more efficient use of reporting burden and may ultimately produce data that would be more effective for informing Council decision making.

Notable findings in the report were that the Vessel Fuel Survey and Vessel Master Survey have been successfully implemented to collect data from all active AFA vessels and have yielded substantial new information that will be useful for analysis of Amendment 91. Quantitative fuel use and cost data have been used in statistical analyses of fishing behavior, and qualitative information reported by vessel masters regarding observed fishing and PSC conditions during A and B pollock seasons and perceptions regarding management measures and bycatch avoidance incentives has been useful to analysts for interpretation of related fishery data.

No compensated transfers (i.e., arms-length market transactions) of Chinook PSC have been reported to date (for 2012-2015), however, and it remains uncertain whether an in-season market for Chinook PSC as envisioned by the CTR survey will arise in the instance of high-Chinook PSC incidence or if the CTR survey as designed will be effective in capturing the nature of trades. A more detailed discussion of the A91 Chinook EDR is presented elsewhere in this document.

GOA Trawl and Amendment 80 EDR

During 2014, AFSC economists collaborated with NPFMC and Alaska Region staff and industry members to develop draft data collection instruments and a preliminary rule following NPFMC recommendations for implementing EDR data collection in the GOA trawl groundfish fishery. New EDR forms for GOA groundfish trawl catcher vessels and processors were developed, evaluated, and revised in workshop meetings and individual interviews with members of industry, and modifications to the existing A80 Trawl CP EDR form have been made to accommodate Council recommendations to extend the A80 data collection to incorporate A80 CPs GOA activity and capture data from non-A80 CPs in the GOA. The draft data collection forms and proposed rule were reviewed and approved by the Council at their April, 2014 meeting, and the proposed rule was published August 11, 2014 (79 FR 46758; see http://alaskafisheries.noaa.gov/sustainablefisheries/trawl/edr.htm for more information). The final rule was published in December 2014, authorizing mandatory data collection to begin with reporting of 2015 calendar year data (submitted in 2016). AFSC has been working with industry to test and refine the draft EDR forms to ensure data to be collected will meet appropriate data quality standards, including modifications to reduce the reporting burden in the A80 EDR program and improve the utility of data collected from CP vessels in non-AFA groundfish fisheries in the BSAI as well as in the GOA. The first year of data is currently under quality assurance and quality control review.

The Economic Impacts of Technological Change in North Pacific Fisheries-REFM/ESSR

Benjamin Fissel, Ben Gilbert and Jake LaRiviere*

**For further information, contact* Ben.Fissel@NOAA.gov

Technological advancements have had a significant impact on fishing fleets and their behavior. Technology has expanded both the range of fish stocks we are able to target and the efficiency with which we capture, process, and bring products to market. Technology induced changes in the feasibility and efficiency of fishing can impact the composition and behavior the fishing fleet. Fissel and Gilbert (2014) provide a formal bioeconomic model with technological change showing that marked technology advances can explain over-capitalization as a natural fleet behavior for profit maximizing fishermen when total catch and effort are unconstrained and the technological advancements are known. Extending this analysis to North Pacific fisheries requires research on the theory of technological change in TAC-based and catch share management regimes as well as statistical methods for identifying unknown technological events as this data hasn’t been historically collected. Fissel, Gilbert and LaRiviere (2013) extends the theory of technological change to by considering the incentive to adopt new technologies under in an open-access resource setting, finding that low stock levels in particular increase adoption incentives. This ongoing project develops the theory and methods necessary to analyze technological change in North Pacific fisheries through two in-progress manuscripts. Fissel (2013) adapts statistical methods for identifying marked changes in financial times series to the fisheries context using both simulation and empirics to show and validate the methods. North Pacific fisheries are considered with these methods as a case where technological change is unknown. This manuscript is expected to be completed in 2015. Future research on this project will use the results from these papers to analyze the impact of technological advancement in North Pacific fisheries with particular attention toward the impact of on-board computers.

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FishSET: a Spatial Economics Toolbox to better Incorporate Fisher Behavior into Fisheries Management-REFM/ESSR

Alan C. Haynie* and Corinne Bassin
**For further information, contact Alan.Haynie@NOAA.gov*

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.

One element of the project is the development of best practices and tools to improve data organization. A second core component is the development of estimation routines that enable comparisons of state-of-the-art fisher location choice models. FishSET enables new models to be more easily and robustly tested and applied when the advances lead to improved predictions of fisher behavior. Pilot projects that utilize FishSET are in different stages of development in different regions in the United States, which will ensure that the data challenges that confront modelers in different regions are confronted at the onset of the project. Implementing projects in different regions will also provide insight into how economic and fisheries data requirements for effective management may vary across different types of fisheries. In Alaska, FishSET is currently being utilized in pilot projects involving the Amendment 80 and AFA pollock fisheries, but in the future models will be developed for many additional fishing fleets.

Using Vessel Monitoring System Data to Estimate Spatial Effort in Bering Sea Fisheries for Unobserved Trips-REFM/ESSR

Alan Haynie*, Patrick Sullivan, and Jordan Watson
**For further information, contact Alan.Haynie@NOAA.gov*

A primary challenge of marine resource management is monitoring where and when fishing occurs. This is important for both the protection and efficient harvest of targeted fisheries. Vessel monitoring system (VMS) technology records the time, location, bearing, and speed for vessels. VMS equipment has been employed on vessels in many fisheries around the world and VMS data has been used in enforcement, but a limited amount of work has been done utilizing VMS data to improve estimates of fishing activity. This paper utilizes VMS and an unusually large volume of government observer-reported data from the United States Eastern Bering Sea pollock fishery to predict the times and locations at which fishing occurs on trips without observers onboard. We employ a variety of techniques and specifications to improve model performance and out-of-sample prediction and find a generalized additive model that includes speed and change in bearing to be the best formulation for predicting fishing. We assess spatial correlation in the residuals of the chosen model, but find no correlation after taking into account other VMS predictors. We compare fishing effort to predictions for vessels with full observer coverage for 2003-2010 and compare predicted and observer-reported activity for observed trips. In this project, we have worked to address challenges that result from missing observations in the VMS data, which occur frequently and present modeling complications. We conclude with a discussion of policy considerations. Results of this work will be published in a scientific journal. We are also working with the NMFS Alaska Regional Office to attempt to improve the Region’s spatial effort database and we will extend the model to other fisheries.

Optimal Multi-species Harvesting in Ecologically and Economically Interdependent Fisheries-REFM/ESSR

Stephen Kasperski*

**For further information, contact Stephen.Kasperski@NOAA.gov*

Single-species management of multi-species fisheries ignores ecological interactions in addition to important economic interactions to the detriment of the health of the ecosystem, the stocks of fish species, and fishery profits. This study uses a model to maximize the net present value from a multispecies groundfish fishery in the Bering Sea where species interact ecologically in the ecosystem, and economically through vessels’ multi-product harvesting technology, switching gear types, and interactions in output markets. Numerical optimization techniques are used to determine the optimal harvest quota of each species over time. This study highlights the need to incorporate both ecological and economic interactions that occur between species in an ecosystem.

This study uses the arrowtooth flounder, Pacific cod, and walleye pollock fisheries in the Bering Sea/Aleutian Islands region off Alaska as a case study and finds the net present value of the three-species fishery is over $20.7 billion dollars in the multispecies model, over $5 billion dollars more than the net present value of the single species model. This is a function of the interdependence among species that affects other species growth. Because arrowtooth negatively impacts the growth of cod and pollock, substantially increasing the harvest of arrowtooth to decrease its stock is optimal in the multispecies model as it leads to increased growth and therefore greater potential harvests of cod and pollock. The single species model does not incorporate the feedback among species, and therefore assumes each species is unaffected by the stock rise or collapse of the others. The vessels in this fishery are also shown to exhibit cost anti-complementarities among species, which implies that harvesting multiple species jointly is more costly than catching them independently. As approaches for ecosystem-based fisheries management are developed, the results demonstrate the importance of focusing not only on the economically valuable species interact, but also on some non-harvested species, as they can affect the productivity and availability of higher value species. A paper describing this project was published in *Environmental and Resource Economics* (Kasperski 2015).

Literature Cited

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Optimal Multispecies Harvesting in the Presence of a Nuisance Species-REFM/ESSR

Stephen Kasperski*
**For further information, contact Stephen.Kasperski@NOAA.gov*

The need for ecosystem based fisheries management is well recognized, but substantial obstacles remain in implementing these approaches given our current understanding of the biological complexities of the ecosystem and the economic complexities surrounding resource use. This study develops a multispecies bioeconomic model that incorporates ecological and economic interactions to estimate the optimal catch and stock size for each species in the presence of a nuisance species. The nuisance species lowers the value of the fishery by negatively affecting the growth of the other species in the ecosystem, and has little harvest value of its own. This study empirically estimates multispecies surplus production growth functions for each species and uses these parameters to explore the impact of a nuisance species on the management of this ecosystem. Multiproduct cost functions are estimated for each gear type in addition to a count data model to predict the optimal number of trips each vessel takes. These functions are used, along with the estimated stock dynamics equations, to determine the optimal multispecies quotas and subsidy on the harvest of the nuisance species to maximize the total value of this three species fishery.

This study uses the arrowtooth flounder, Pacific cod, and walleye pollock fisheries in the Bering Sea/Aleutian Islands region off Alaska as a case study and finds the net present value of the fishery is decreased from $20.7 billion to $8.5 billion dollars by ignoring arrowtooth’s role as a nuisance species on the growth of Pacific cod and walleye pollock. The optimal subsidy on the harvest of arrowtooth summed over all years is $35 million dollars, which increases the net present value by $273 million dollars, after accounting for the subsidy. As arrowtooth flounder is a low value species and has a large negative impact on the growth of cod and pollock, it is optimal to substantially increase the harvesting of arrowtooth, lowering its population which results in increased growth and harvesting in the two profitable fisheries. Ignoring the role of the nuisance species results in a substantially less productive and lower value fishery than if all three species are managed optimally. This study highlights the role of both biological and technological interactions in multispecies or ecosystem approaches for management, as well as the importance of incorporating the impacts non-harvested species can have on the optimal harvesting policies in an ecosystem. The paper describing these results was published in *Marine Policy.*

Literature Cited

Kasperski, S. 2015. “Optimal Multispecies Harvesting in the Presence of a Nuisance Species” *Marine Policy* 64: 55-63.

The Regional and Community Size Distribution of Fishing Revenues in the North Pacific-REFM/ESSR

By Chris Anderson, Jennifer Meredith, and Ron Felthoven*
**For further information, contact Ron.Felthoven@NOAA.gov*

The North Pacific fisheries generate close to $2 billion in first wholesale revenues annually.

However, the analysis supporting management plans focuses on describing the flow of these monies through each fishery (e.g., NOAA AFSC 2013), rather than across the individual cities and states in which harvesters live and spend their fishing returns. In the last two decades North Pacific fisheries have undergone a series of management changes aimed at ensuring healthy and sustainable profits for those participating in harvesting and processing, and healthy fish stocks. The formation of effective cooperatives and rationalization programs that have been designed by harvesters and processors support an economically successful industry. However, a variety of narratives have emerged about the distributional effects of these management changes, and in particular their effects on the participation of people in coastal communities in the North Pacific.

Previous work has adopted a variety of perspectives to establish the effects of a changing fishing industry in the North Pacific. Carothers (2008) focuses on individual communities in the Aleutian Islands and argues that shifts in the processing industry, away from small canneries in strongly place-identified communities, are exacerbated by rationalization that monetizes historical fishing access and draws fishing activity out of small communities when fishermen fall under duress. Carothers et al. (2010) adopts a state-wide perspective on a single fishery, and finds that small fishing communities as a category were more likely to divest of halibut IFQ in the years immediately following the creation of the program. Sethi et al. (2014) propose a suite of rapid assessment community-level indicators that integrate across fisheries, and identify that Alaskan communities are affected by trends of reduced fishery participation and dependence, characterized by fewer fishermen who participate in fewer fisheries and growth in other sectors of the economy during 1980-2010. However, they also observe that this effect is primarily distributional, as total fishing revenues within communities are stable and increasing.

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.

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Tools to Explore Alaska Fishing Communities-REFM/ESSR

Amber Himes-Cornell*

**For further information, contact Stephen.Kasperski@noaa.gov*

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. These profiles provide detailed information on elements of each fishing community, including location, demographics, history, infrastructure, governance, facilities, and involvement in state and federal fisheries targeting commercial, recreational and subsistence resources. A total of 196 communities from around Alaska were profiled as part of this effort.

However, these profiles are static and require manual updates as more recent data become available. In order to address this in a more effective way, social scientists in the AFSC Economic and Social Science Research Program have developed two web-based tools to provide the public with information on communities in Alaska: fisheries data maps and community snapshots. There are three distinct fisheries data maps providing a time series on community participation in commercial, recreational, and subsistence fishing. The community snapshots take the pulse of Alaskan fishing communities using information about their fishing involvement and demographic characteristics. Each snapshot provides information on:

- What commercial species are landed and processed in the community;
- The number of crew licenses held by residents;
- The characteristics of fishing vessels based in the community;
- Processing capacity
- Participation in recreational fishing (including both charter businesses and individual anglers);
- Subsistence harvesting dependence;
- Demographic attributes of the community (including educational attainment, occupations by industry, unemployment, median household income, poverty, median age, sex by age, ethnicity and race, and language and marginalization);
- Social vulnerability indices (These indices represent social factors that can shape either an individual or community’s ability to adapt to change. These factors exist within all communities regardless of the importance of fishing. The indices include: Poverty, Population Composition, Personal Disruption, and Housing Disruption.); and
- Fishing engagement and reliance indices (These indices portray the importance or level of dependence of commercial or recreational fishing to coastal communities. The indices include: Commercial Engagement, Commercial Reliance, Recreational Engagement and Recreational Reliance

These web-based tools are updated as new data become available and currently include the years in parentheses below.

To access the community profiles; go to:
http://www.afsc.noaa.gov/REFM/Socioeconomics/Projects/CPU.php

To access the *NEW* community snapshots (available for years 2000-2011); go to:
http://www.afsc.noaa.gov/REFM/Socioeconomics/Projects/communitysnapshots/main.php

To access the commercial fisheries data maps (available for years 2000-2014); go to:
http://www.afsc.noaa.gov/maps/ESSR/commercial/default.htm

To access the recreational fisheries data maps (available for years 1998-2014); go to:
http://www.afsc.noaa.gov/maps/ESSR/recreation/default.htm

To access the subsistence fisheries data maps (available for years 2000-2008); go to:
http://www.afsc.noaa.gov/maps/ESSR/subsistence/default.htm

Developing Comparable Socio-economic Indices of Fishing Community Vulnerability and Resilience for the Contiguous US and Alaska-REFM/ESSR

Amber Himes-Cornell and Stephen Kasperski*
**For further information, contact Stephen.Kasperski@noaa.gov*

The ability to understand the vulnerability of fishing communities is critical to understanding how regulatory change will be absorbed into multifaceted communities that exist within a larger coastal economy. Creating social indices of vulnerability for fishing communities provides a pragmatic approach toward standardizing data and analysis to assess some of the long term effects of management actions. Over the past several years, social scientists working in NOAA Fisheries' Regional Offices and Science Centers have been engaged in the development of indices for evaluating aspects of fishing community vulnerability and resilience to be used in the assessment of the social impacts of proposed fishery management plans and actions (Colburn and Jepson, 2012; Himes-Cornell and Kasperski, 2015). These indices are standardized across geographies, and quantify conditions which contribute to, or detract from, the ability of a community to react positively towards change. National-level indicators for all U.S. coastal communities can be found using the "Explore the Indicator Map" link from the main NMFS social indicators webpage here: http://www.st.nmfs.noaa.gov/humandimensions/social-indicators/.

The Alaska Fisheries Science Center (AFSC) has compiled socio-economic and fisheries data for over 300 communities in Alaska and developed developed indices specific to Alaska communities (Himes-Cornell and Kasperski, 2016) using the same methodology as Jepson and Colburn (2013). To the extent feasible, the same sources of data are being used in order to allow comparability between regions. However, comparisons indicated that resource, structural and infrastructural differences between the NE and SE and Alaska require modifications of each of the indices to make them strictly comparable. The analysis used for Alaska was modified to reflect these changes. The data are being analyzed using principal components factor analysis (PCFA), which allows us to separate out the most important socio-economic and fisheries related factors associated with community vulnerability and resilience in Alaska within a statistical framework.

These indices are intended to improve the analytical rigor of fisheries Social Impact Assessments, through adherence to National Standard 8 of the Magnuson-Stevens Fishery Conservation and

Management Reauthorization Act, and Executive Order 12898 on Environmental Justice in components of Environmental Impact Statements. Given the often short time frame in which such analyses are conducted, an advantage to this approach is that the majority of the data used to construct these indices are readily accessible secondary data and can be compiled quickly to create measures of social vulnerability and to update community profiles.

Although the indices are useful in providing an inexpensive, quick, and reliable way of assessing potential vulnerabilities, they often lack external reliability. Establishing validity on a community level is required to ensure indices are grounded in reality and not merely products of the data used to create them. However, achieving this requires an unrealistic amount of ethnographic fieldwork once time and budget constraints are considered. To address this, a rapid and streamlined groundtruthing methodology was developed to confirm external validity from a set of 13 sample communities selected based on shared characteristics and logistic feasibility (Himes Cornell, et al. 2016). This qualitative data was used to test the construct validity of the quantitative well-being indices. Specifically, this methodology used a test of convergent validity: in theory, the quantitative indices should be highly correlated with the qualitative measure. This comparison helps us understand how well the estimated well-being indices represent real-world conditions observed by researchers. Study findings suggest that some index components exhibit a high degree of construct validity based on high correlations between the quantitative and qualitative measures, while other components will require refinement prior to their application in fisheries decision-making. Further, the results provides substantial evidence for the importance of groundtruthing quantitative indices so they may be better calibrated to reflect the communities they seek to measure.

Groundtruthing the results using this type of methodology will facilitate use of the indices by the AFSC, NOAA’s Alaska Regional Office, and the North Pacific Fishery Management Council staff to analyze the comparative vulnerability of fishing communities across Alaska to proposed fisheries management regulations, in accordance with NS8. This research will provide policymakers with an objective and data driven approach to support effective management of North Pacific fisheries.

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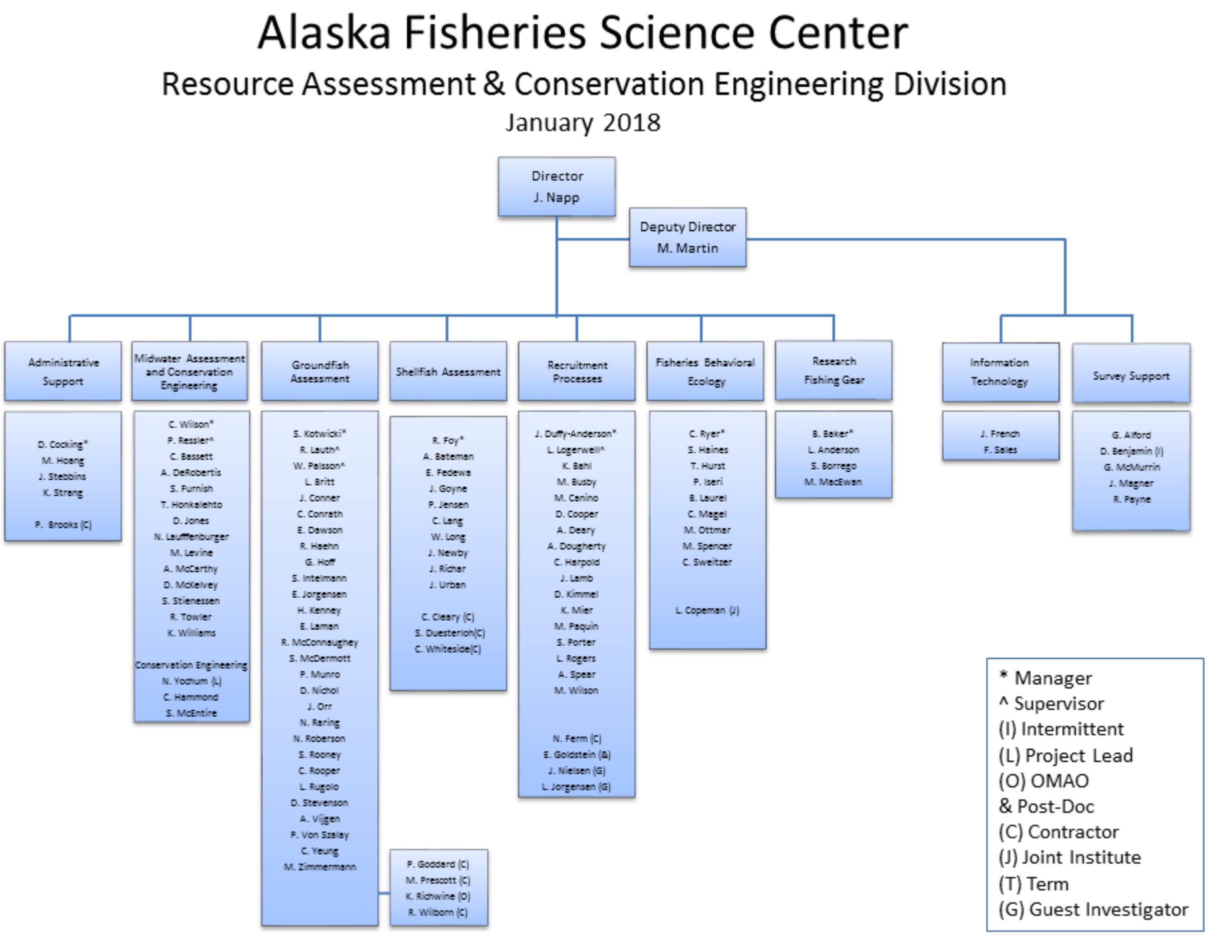
APPENDIX I. RACE ORGANIZATION CHART



APPENDIX II. REFM ORGANIZATION CHART

REFM DIVISION ORGANIZATION CHART

(as of March 31, 2017)

Division Directorate
Ron Felthoven
(Division Director)

Deputy Director
D. Ito
(NEPA Coordinator)

International Coordinator (AFSC & AKR)
Vacant

REFM/RACE/FMA Support
- D. Cocking -- Supervisor
- P. Brooks
- M. Hoang
- J. Stebbins
- K. Strang

Logistics & Safety
- B. Goiney

IT Staff
- S. Wennberg
- M. Blaisdell

Status of Stocks and Multispecies Assessment
- A. Hollowed -- Program Manager
- S. Barbeaux
- M. Dorn
- J. Ianelli
- P. Spencer
- W. Stockhausen
- G. Thompson
- J. Turnock
- S. Lowe -- Supervisor
- M. Bryan
- L. Conners
- C. McGilliard
- O. Ormseth
- I. Spies
- T. Wilderbuer

Contractors and Others
- G. Lambert
- L. Li

Resource Ecology and Ecosystems Modeling
- K. Aydin -- Program Manager
- T. Buckley
- S. Fitzgerald
- K. Holsman
- G. Lang
- M. Yang
- S. Zador

Contractors and Others
- R. Hibpshman
- K. Kearny
- I. Ortiz
- C. Robinson
- J. Reum
- S. Rohan
- K. Sawyer
- A. Whitehouse

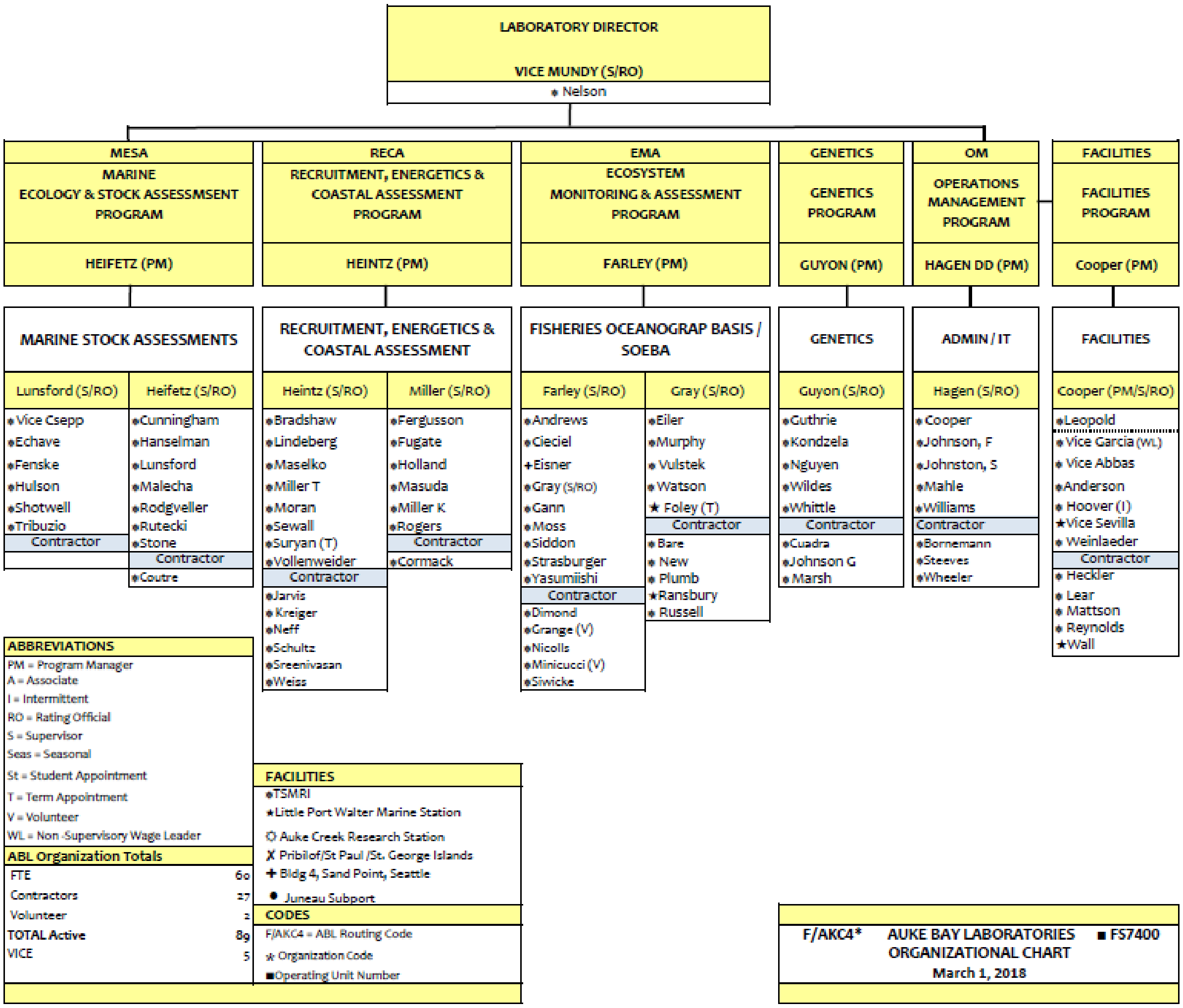
Age and Growth
- T. Helser -- Program Manager
- C. Kastelle
- J. Short
- C. Hutchinson
- S. Neidetcher
- T. TenBrink
- D. Anderl -- Project Leader
- J. Brogan
- B. Matta
- J. Pearce
- K. Williams
- B. Goetz -- Project Leader
- I. Benson
- C. Gburski
- C. Piston

Contractors and Others
- C. Blood
- J. Harris
- M. Arrington

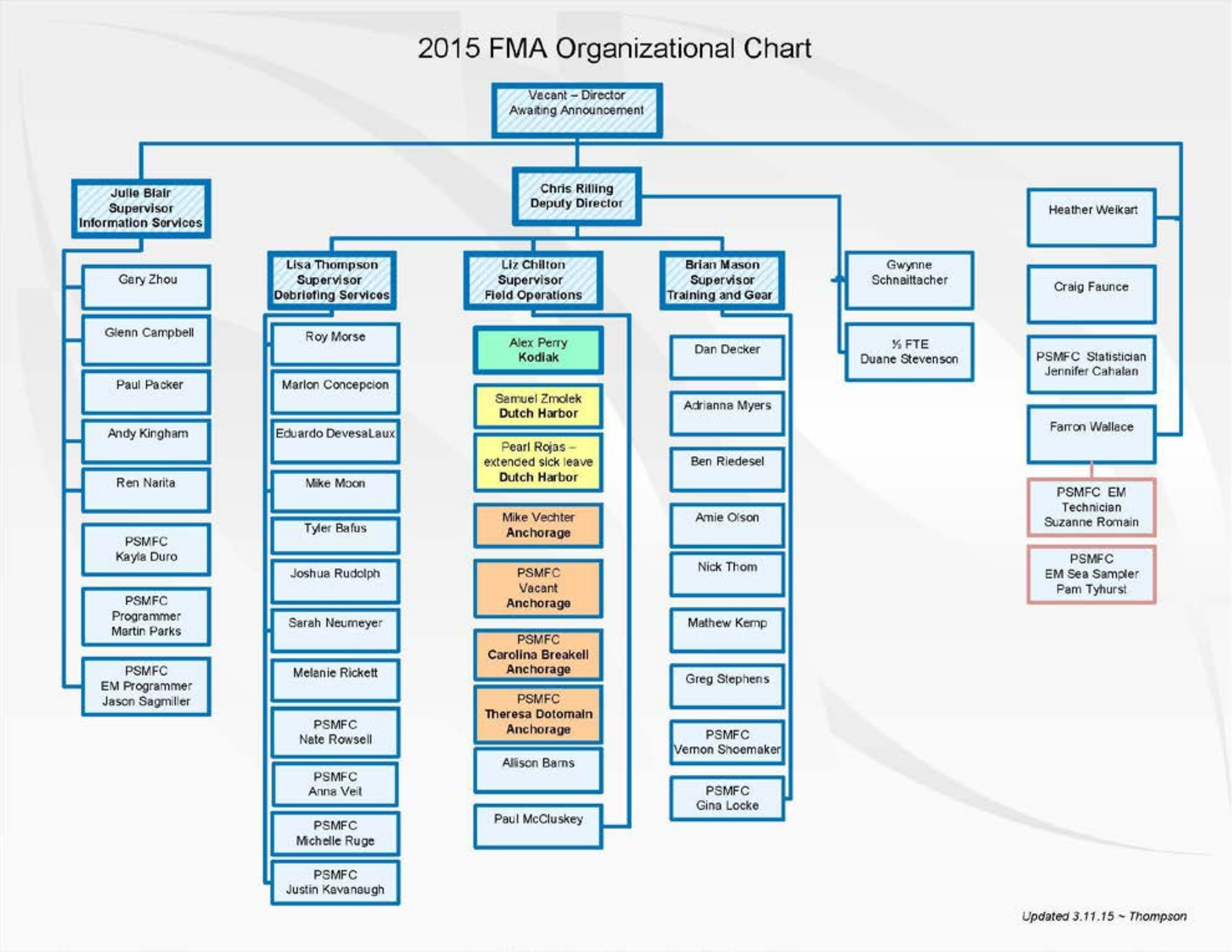
Economics and Social Sciences Research
- S. Kasperski -- Program Manager
- M. Dalton
- B. Fissel
- B. Garber-Yonts
- A. Haynie
- D. Lew
- C. Seung

Contractors and Others
- A. Chen
- A. Faig
- J. Lee
- A. Santos
- K. Sparks

APPENDIX III – AUKE BAY LABORATORY ORGANIZATIONAL CHART



APPENDIX IV – FMA ORGANIZATIONAL CHART



2015 FMA Organizational Chart

Vacant – Director
Awaiting Announcement

Julie Blair
Supervisor
Information Services

Gary Zhou
Glenn Campbell
Paul Packer
Andy Kingham
Ren Narita
PSMFC Kayla Duro
PSMFC Programmer Martin Parks
PSMFC EM Programmer Jason Sagmiller

Chris Rilling
Deputy Director

Lisa Thompson
Supervisor
Debriefing Services

Roy Morse
Marlon Concepcion
Eduardo DevesaLaux
Mike Moon
Tyler Bafus
Joshua Rudolph
Sarah Neumeyer
Melanie Rickett
PSMFC Nate Rowsell
PSMFC Anna Veit
PSMFC Michelle Ruge
PSMFC Justin Kavanaugh

Liz Chilton
Supervisor
Field Operations

Alex Perry **Kodiak**
Samuel Zmolek **Dutch Harbor**
Pearl Rojas – extended sick leave **Dutch Harbor**
Mike Vechter **Anchorage**
PSMFC Vacant **Anchorage**
PSMFC **Carolina Breakell Anchorage**
PSMFC **Theresa Dotomain Anchorage**
Allison Barns
Paul McCluskey

Brian Mason
Supervisor
Training and Gear

Dan Decker
Adrianna Myers
Ben Riedesel
Amie Olson
Nick Thom
Mathew Kemp
Greg Stephens
PSMFC Vernon Shoemaker
PSMFC Gina Locke

Gwynne Schnaittacher
½ FTE Duane Stevenson

Heather Weikart
Craig Faunce
PSMFC Statistician Jennifer Cahalan
Farron Wallace
PSMFC EM Technician Suzanne Romain
PSMFC EM Sea Sampler Pam Tyhurst

Updated 3.11.15 ~ Thompson