Alaska Fisheries Science Center of the National Marine Fisheries Service

2016 Agency Report to the Technical Subcommittee of the Canada-US Groundfish Committee

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VIII. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT IN 2016

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). The RACE and REFM Divisions are divided along regional or disciplinary lines into a number of programs and tasks. The FMA Division performs all aspects of observer monitoring of the groundfish fleets operating in the North Pacific. The ABL conducts research and stock assessments for Gulf of Alaska and Bering Sea groundfish. 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 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 surveys and related ecological and oceanographic research to measure and describe the distribution and abundance of commercially important fish and crab stocks in the eastern Bering Sea, Aleutian Islands, and Gulf of Alaska and to 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 both regular surveys and associated research are analyzed by Center stock assessment scientists and supplied to fishery management agencies and to the commercial fishing industry. RACE Division Programs include Fisheries Behavioral Ecology, Groundfish Assessment Program (GAP), Midwater Assessment and Conservation Engineering (MACE), Recruitment Processes, Shellfish Assessment Program (SAP), and Research Fishing Gear/Survey Support. These Programs operate from three locations in Seattle, WA, Newport, OR, and Kodiak, AK.

In 2016 one of the primary activities of the RACE Division continued to be fishery-independent stock assessment surveys of important groundfish 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). Three Alaskan bottom trawl surveys of groundfish and invertebrateresources were conducted during the summer of 2016 by RACE Groundfish Assessment Program (GAP) scientists: the annual Eastern Bering Sea Shelf Bottom Trawl Survey, the biennial Eastern Bering Sea Slope survey, and the biennial Aleutian Islands Bottom Trawl Survey.

RACE scientists of the Habitat Research Team (HRT) continue research on essential habitats of groundfish including identifying suitable predictor variables for building quantitative habitat models, developing tools to map these variables over large areas, investigating activities with potentially adverse effects on EFH, such as bottom trawling, and benthic community ecology work to characterize groundfish habitat requirements and assess fishing gear disturbances.

The Midwater Assessment and Conservation Engineering (MACE) Program conducted echo integration-trawl (EIT) surveys of midwater pollock abundance during the summer in the eastern Bering Sea as well as winter acoustic trawl surveys in the eastern Bering Sea and Gulf of Alaska. Research cruises investigating bycatch issues also continued.

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 and 2 post docs. ABL’s

Ecosystem Monitoring and Assessment Program (EMA) and Recruitment Energetics and Coastal Assessment Program (RECA) also conduct groundfish-related research.

In 2016 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 and; 6) analysis of juvenile groundfish collected on AFSC surveys to assess their growth, nutritional condition and trophodynamics conducted by the RECA Program.

Ongoing analytic activities in 2016 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 Laboratory Director Phil Mundy at (907) 789-6001 or phil.mundy@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 Chris Rilling, (206) 526-4194.

II. Surveys

2016 Eastern Bering Sea Continental Shelf Bottom Trawl Survey – RACE GAP

The thirty-fifth annual, standardized eastern Bering Sea (EBS) continental shelf bottom trawl survey was conducted between 26 May 2016 and 30 July 2016 aboard the AFSC chartered fishing vessels *Vesteraalen* and *Alaska Knight*, which together bottom trawled at 387 stations over a survey area of 492,898 km^2. The data collected by these annual resource surveys serves to provide 1) fishery-independent abundance estimates and population dynamics of ecologically and commercially exploited groundfish and crab stocks to the State of Alaska and to the NPFMC, 2) information on inter-annual changes to the distribution and abundance of groundfish and crab species to the fishing industry, other stakeholders and the public, and 3) a time-series of environmental data and abundance indices for a variety of demersal macrofauna to be used for ecosystem forecast modeling in support of ecosystem-based fisheries management. On the survey, researchers processed and recorded the data from each trawl catch by identifying, sorting, and weighing all the different crab and groundfish species and then measuring samples of each species. The bottom trawl survey also collected supplementary biological and oceanographic data to improve the understanding of life history of the groundfish and crab species and the ecological and physical factors affecting their distribution and abundance.

A total of 376 stations were successfully sampled in 2016. During the 2016 bottom trawl survey, a total of 94 fish taxa and 232 individual invertebrate taxa were identified.**1** Survey estimates of total biomass on the eastern Bering Sea shelf for 2016 were 4.9 million metric tons (t) for walleye pollock, 986.0 thousand t for Pacific cod, 2.86 million t for yellowfin sole, 1.46 million t for northern rock sole, 22.4 thousand t for Greenland turbot, and 153.7 thousand t for Pacific halibut. The estimated survey biomass decreased for most major fish taxa compared to 2015 levels. Walleye pollock biomass decreased 23%, Pacific cod 11%, Greenland turbot 11%, and Pacific halibut 11%. The estimated survey biomass increased by 48% for yellowfin sole and 4% for northern rock sole.

The summer 2016 survey period was warmer than the long-term average for the third consecutive year. Sea surface temperatures recorded during the 2016 survey ranged from 3.1 °C to 14.1 °C. The mean bottom temperature increased from 2015 to 4.5 °C, and was the warmest average near-bottom temperatures for this time series. The mean surface temperature was 9.5 °C, which was greater than the grand mean over 35 years, and was the warmest average sea surface temperature observed during this period.

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

2016 Biennial Bottom Trawl Survey of Groundfish and Invertebrate Resources of the Aleutian Islands – RACE GAP

The National Marine Fisheries Service Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering (RACE) Division chartered the fishing vessels *Alaska Provider* and *Sea Storm* to conduct the 2016 Aleutian Islands Biennial Bottom Trawl Survey of groundfish resources. This was the fourteenth 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 70 days. The cruise originated from Dutch Harbor, Alaska on June 6th and after the vessels were loaded and other preparations (*e.g.*, wire measuring, wire marking, and test towing), the first survey tows were conducted on ?? June. The cruise progressed from Unimak Pass in the east and progressed to west to Stalemate Bank. A few unoccupied stations were sampled on the return leg and the survey concluded back at Dutch Harbor on August 18th (Figure 1). Sampled depths range from approximately 15 to 500 m. The cruise was divided into three legs with breaks at Adak to change crews and re-provision.

A primary objective of this survey is to continue the data time series begun in 1980 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 2016 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 45 strata of depths and regions and applied to a list of known, trawlable stations identified from previous surveys. 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 419 of 420 planned stations in the entire shelf and upper slope to a depth of 500 m. Trawling operations began on June 7th and were completed on August 8th. RACE GAP biologists attempted 468 bottom trawl hauls at 426 stations, 419 of which were successfully sampled, in depths ranging from 45-460 m along the shelf and upper slope of the Aleutian archipelago. There were 138 fish and 518 invertebrate taxa were collected weighing 491,120 kg and 11,186 kg. During this survey, biologists vouchered at least 374 specimens for further identification. Totals of 118,590 lengths and 6,638 otoliths were collected for ageing, constructing population length composition, and to support special collections for ecological studies and life history characterization.

Pacific ocean perch or POP (*Sebastes alutus*) was the most abundant species with an estimated biomass of 982,522 metric tons (t). Atka mackerel (*Pleurogrammus monopterygius*) and northern rockfish (*Sebastes polyspinis*) were also abundant with estimated biomasses of 447,976 and 253,215 t, respectively. Catches of POP were large throughout the survey area at intermediate depths. Arrowtooth flounder (*Atheresthes stomias*) was the most abundant flatfish species, having almost twice the biomass of second-place northern rock sole (*Lepidopsetta polyxystra*). The skate assemblage was primarily comprised of three skate species, whiteblotched (*Bathyraja maculata*), Aleutian (*B. aleutica*), and leopard (*B. panthera*) skates, with a wide diversity of species captured in the eastern portion of the survey area.

A validated data set was finalized on 27 September 2016, and final estimates of abundance and length composition of managed species and species groupings were delivered to the Groundfish Plan Team (Plan Team) of the NPFMC at that time. Data and distributin maps are available at https://www.afsc.noaa.gov/RACE/groundfish/survey_data/data.htm and at https://www.afsc.noaa.gov/RACE/groundfish/survey_data/default.htm. The Plan Team incorporated these survey results directly into Aleutian Islands stock assessment and ecosystem forecast models that form the basis for groundfish harvest advice on the 2016 ABCs and TACs.

The data report from the 2015 GOA Bottom Trawl Survey (von Szalay et al. 2016) is available at https://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-325.pdf

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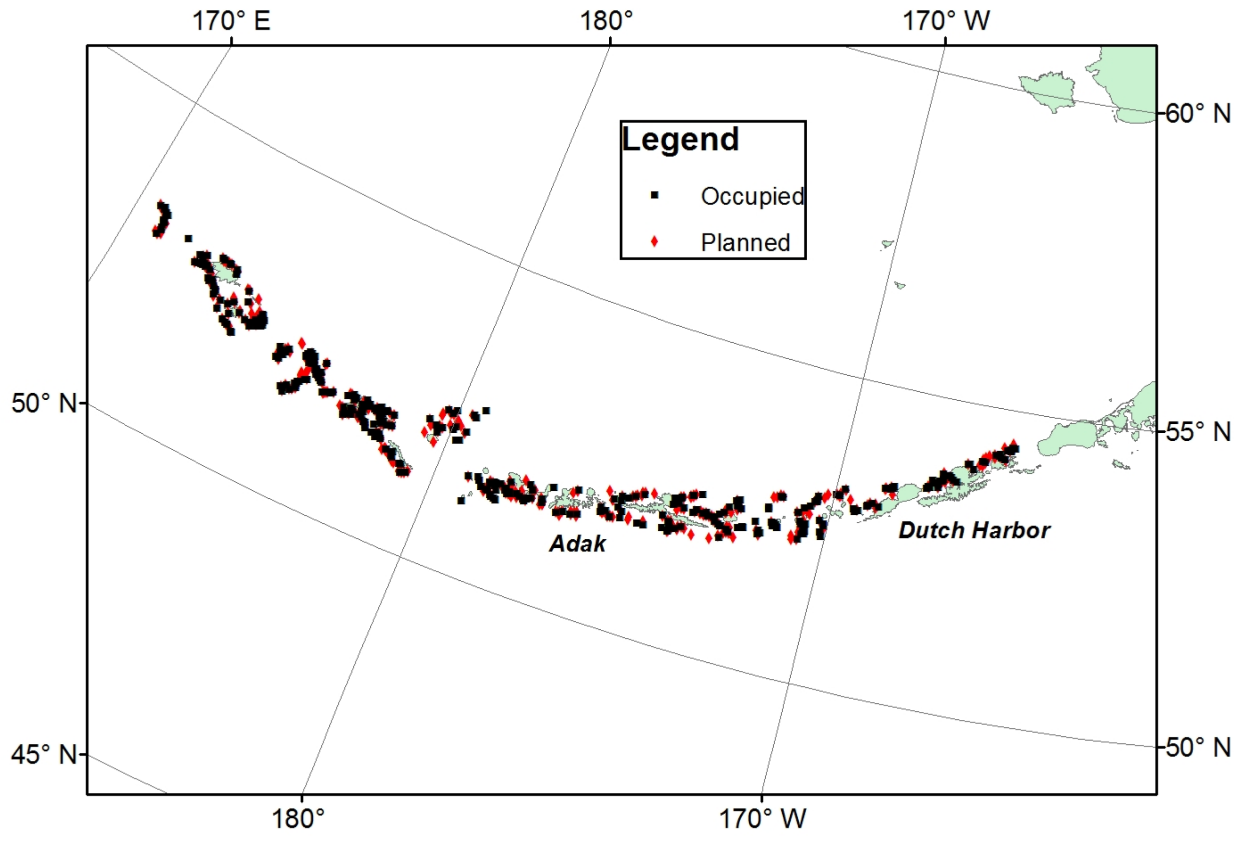

Figure 1. Planned and occupied stations during the 2016 Aleutian Island Biennial Bottom Trawl Survey.

Winter Acoustic-Trawl Surveys in the Gulf of Alaska -- MACE Program
Two AT surveys of walleye pollock (*Gadus chalcogrammus*) were conducted in the GOA during the winter of 2016. The first (cruise DY2016-02) surveyed the Shumagin Islands area (comprising Shumagin Trough, Stepovak Bay, Renshaw Point, Unga Strait, and West Nagai Strait), Sanak Trough, and Morzhovoi and Pavlof bays from 13-17 February. A second AT survey (cruise

DY2016-04) covered Shelikof Strait and Marmot Bay from 14-24 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) to estimate the abundance of walleye pollock. Backscatter data were also collected at 4 other frequencies (18-, 70-, 120-, and 200-kHz) to support multifrequency species classification techniques. The trawl hauls conducted in the GOA winter surveys included a CamTrawl stereo camera attached to the net forward of the codend. The CamTrawl was used to capture stereo images for species identification and fish length measurements as fishes passed through the net toward the codend, primarily as a comparison with lengths measured from fish caught in the net in support of research on automated image analysis.

In the Shumagin Islands, acoustic backscatter was measured along 756 km (408 nmi) of transects. The survey transects were spaced 1.9 km (1.0 nmi) apart directly south and east of Renshaw Point and in the eastern half of Unga Strait, 4.6 km (2.5 nmi) apart in Stepovak Bay and West Nagai Strait, and 3.7 km (2.0 nmi) in the western half of Unga 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 45 cm fork length (FL), which is characteristic of age-4 walleye pollock, and suggests the continued success of the 2012 year-class. This size range accounted for 93% of the numbers and 90% of the biomass of all pollock observed in this area. These walleye pollock were present in the inner portion of Shumagin Trough, off Renshaw Point, in Stepovak Bay, and in the West Nagai Strait area. Although adult pollock > 45 cm FL have historically been detected off Renshaw Point, they were basically absent from this area in 2016. The majority of the pollock were scattered throughout the water column below 25 m, and occasionally formed small, very dense (i.e., “cherry ball”) schools. The maturity composition of males > 40 cm FL (n = 71) was 17% immature, 20% developing, 38% pre-spawning, 24% spawning, and 1% spent. The maturity composition of females > 40 cm FL (n = 133) was 17% immature, 29% developing, 53% pre-spawning, 0% spawning, and 1% spent. The biomass estimate of 20,706 t (with a relative estimation error of 7.2%), based on data from acoustic transects and specimens collected from eight AWT hauls, is nearly one-third of the 2015 estimate (61,369) and 26% of the historical mean of 75,351 t for this survey.

In Sanak Trough, acoustic backscatter was measured along 191 km (103 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 24 and 70 cm FL with a dominant length mode between 35 and 45 cm FL. This mode accounted for 81% of the numbers and 72% of the biomass of all pollock observed in Sanak Trough and likely represents age-4 fish. Pollock > 45 cm accounted for 27% of the pollock biomass in this area. The majority of walleye pollock was located in the eastern portion of the middle of the surveyed Trough and was scattered throughout the water column below 40 m. The maturity composition of males > 40 cm FL (n = 37) was 0% immature, 30% developing, 57% pre-spawning, 14% spawning, and 0% spent. The maturity composition of females > 40 cm FL (n = 31) was 0% immature, 39% developing, 55% pre-spawning, 6% spawning, and 0% spent. The biomass estimate of 3,556 t (with a relative estimation error of 6.9%), based on data from acoustic transects and specimens collected from two AWT hauls, is 20% of the 2015 estimate (17,863 t) and 8% of the historic mean of 43,107 t for this survey.

In Morzhovoi Bay, acoustic backscatter was measured along 70 km (38 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 28 and 65 cm FL with a dominant length mode between 35 and 45 cm FL (Fig. 5). This mode accounted for 65% of the numbers and 50% of the biomass of all pollock observed in Morzhovoi Bay and likely represents age-4 fish.

Pollock > 45 cm accounted for 49% of the pollock biomass in this area, the highest percentage of all areas surveyed during the 2016 winter GOA cruises. The majority of walleye pollock was located in the southern portion of the surveyed area and was scattered throughout the water column below 40 m. The maturity composition of males > 40 cm FL (n = 14) was 0% immature, 14% developing, 36% pre-spawning, 29% spawning, and 21% spent. The maturity composition of females > 40 cm FL (n = 41) was 15% immature, 12% developing, 51% pre-spawning, 15% spawning, and 7% spent. The biomass estimate of 11,412 t, based on data from acoustic transects and specimens collected from one AWT haul (with a relative estimation error of 12.0%), is comparable to the biomass estimate observed during the first year the Bay was surveyed (2006 = 11,700 t) and 5 times higher than the three estimates generated between 2007 and 2013 (mean 2,259 t; standard deviation = 397 t).

In Pavlof Bay, acoustic backscatter was measured along 84 km (45 nmi) of transects spaced 3.7 km (2 nmi) apart. Walleye pollock ranged between 33 and 67 cm FL with a dominant length mode between 35 and 45 cm FL (Fig. 5). This mode accounted for 78% of the numbers and 66% of the biomass of all pollock observed in Pavlof Bay and likely represents age-4 fish. Pollock > 45 cm accounted for 33% of the pollock biomass in this area. The majority of walleye pollock was located in the mouth of the bay and was scattered throughout the water column below 60 m. The maturity composition of males > 40 cm FL (n = 30) was 0% immature, 10% developing, 40% pre-spawning, 40% spawning, and 10% spent. The maturity composition of females > 40 cm FL (n = 77) was 8% immature, 12% developing, 61% pre-spawning, 12% spawning, and 8% spent. The biomass estimate of 2,130 t (with a relative estimation error of 14.7%), based on data from acoustic transects and specimens collected from one AWT haul, is the first estimate generated for this area. A survey of Pavlof Bay was also conducted in 2002 and 2010, but an equipment malfunction and inclement weather, respectively, prevented trawling.

In the Shelikof Strait sea valley, acoustic backscatter was measured along 1,496 km (808 nmi) of transects spaced 13.9 km (7.5 nmi) apart. The majority of walleye pollock in Shelikof Strait were between 35 and 45 cm fork length (FL), which is characteristic of age-4 walleye pollock, and suggests the continued success of the 2012 year-class. This size range accounted for 90% of the numbers and 88% of the biomass of all pollock observed in this area. Smaller fish (< 35 cm FL) made up a very small portion of the biomass (3%), and no pollock less than 22 cm FL were observed. Large adults (≥ 45 cm) also contributed little (9%) to overall biomass in 2016. Walleye pollock biomass was observed throughout the surveyed area and was most abundant in the north-central part of the surveyed area between 75 and 250 m. Dense midwater pollock aggregations of 35-45 cm FL pollock were encountered throughout the survey area. Spawning aggregations historically observed in the northwestern part of the Strait were not seen in 2016, which is in contrast to previous years. The maturity composition of males > 40 cm FL (n = 237) was 4% immature, 3% developing, 12% pre-spawning, 80% spawning, and 2% spent. The maturity composition of females > 40 cm FL (n = 259) was 10% immature, 14% developing, 64% pre-spawning, 5% spawning, and 5% spent. The biomass estimate of 1,633 million fish weighing 665,059 t (with a relative estimation error of 6.5%), based on acoustic data and specimens collected from 19 AWT hauls, is nearly 80% of the 2015 estimate (2,212 million fish weighing 845,306) and 37% higher than the mean of 2,787 million fish weighing 486,391 t observed 1992-2015.

In Marmot Bay, acoustic backscatter was measured along 139 km (75 nmi) of transects spaced 3.7 km (2 nmi) apart in the Spruce Island Gully and inner Marmot Bay. Weather and available time limited acoustic backscatter in the outer Bay to be measured along 43 km (23 nmi) of zig-zag trackline. Walleye pollock ranged between 24 and 66 cm FL with a dominant length mode between 35 and 45 cm FL. This mode accounted for 77% of the numbers and 65% of the biomass of all pollock observed in Marmot Bay and likely represents age-4 fish. The majority of walleye pollock biomass occurred in aggregations in the inner Bay north of Spruce Island and in Spruce Island Gully and was scattered throughout the water column below 30 m. The maturity composition of males > 40 cm FL (n = 66) was 0% immature, 0% developing, 0% pre-spawning, 91% spawning, and 9% spent. The maturity composition of > than 40 cm FL (n = 108) was 0% immature, 6% developing, 35% pre-spawning, 28% spawning, and 31% spent. The biomass estimate of 37, 161 t (with a relative estimation error of 9.9% in the inner trough and 17.9% in the outer trough), based on data from acoustic transects and specimens collected from three AWT hauls plus one Cam-Trawl only (i.e., open codend) haul, is the highest in the history of the Marmot survey and 24,481 t higher than the historic mean for this survey (12,680).

Winter acoustic-trawl surveys of walleye pollock in the Aleutian Basin near Bogoslof Island
An acoustic-trawl survey of walleye pollock in the southeastern Aleutian Basin near Bogoslof Island was conducted 4-8 March, 2016 aboard the NOAA Ship *Oscar Dyson* (cruise DY2016-03). Acoustic backscatter was measured at 38 kHz along 36 north-south parallel transects, which were spaced 5.6 km (3-nmi) apart. The survey covered 1,400 nmi^2 of the Central Bering Sea Convention Specific Area.

Eleven trawl hauls were conducted midwater to identify the species composition of acoustic backscatter. Pollock were the dominant catch by weight and by number, and they ranged from 34 cm to 69 cm fork length, with modes at 45 and 47 cm fork length. Across the entire surveyed region, over 60% of the female pollock were in the post-spawning maturity condition, with only about 7% in the pre-spawning stage. For the pre-spawning females, the average gonado-somatic-index was 0.09.

The pollock abundance estimates for the southeastern Aleutian Basin near Bogoslof Island were 866 million fish, weighing 507 thousand t (relative estimation error 11%). The 2016 estimates represent a 665% increase in abundance and a 352% increase in biomass from the 2014 survey estimates. Fifty eight percent of the 2016 estimated biomass was distributed in the Samalga Pass region, and 42% was distributed in the Umnak region.

The estimated pollock population in 2016 was dominated by younger pollock. Ninety-one percent of the 2016 population was 50 cm or smaller and 97% was less than 9 years of age. The most abundant year class was represented by 7-year-old fish from the 2009 year class (42%), followed by 4-year-old fish from the 2012 year class (20%), and 6-year-old fish from the 2010 year class (19%).

Summer acoustic-trawl survey of walleye pollock in the eastern Bering Sea
The MACE Program conducted an AT survey of midwater walleye pollock between 12 June and 17 August 2016 aboard the NOAA ship *Oscar Dyson* (cruise DY2016-08). This survey has been conducted since 1979; triennially through 1994, and biennially or annually since then. The survey design covered the EBS shelf between roughly the 50 m and 1000 m isobaths, from about 161° W to the U.S.–Russian Convention Line. Permission to survey pollock in the Cape Navarin area of Russia was requested, but not granted for the first time since 2006. The 2016 survey consisted of 28 north-south transects spaced 37 km (20 nautical miles (nmi)) apart, totaling 9323 km (5034 nmi) and covering a 334,951 km^2 (100,674 nmi^2) area. The primary objective was to collect daytime, 38-kHz acoustic backscatter and trawl data to estimate the abundance of walleye pollock. Backscatter

data were also collected at 4 other frequencies (18-, 70-, 120-, and 200-kHz) to support multifrequency species classification techniques. Additional survey sampling included conductivity-temperature-depth (CTD) measurements to characterize the Bering Sea shelf temperature conditions, and supplemental trawls to improve acoustic species classification and to obtain an index of euphausiid abundance using multiple frequency techniques. Specialized sampling devices used during the survey included a trawl-mounted stereo camera (CamTrawl) designed to identify species and determine size and density of animals as they pass by the camera during a haul, a broadband acoustic instrument for estimating fish sizes, and large and small lowered cameras with either red or white strobe lights for a fish-camera avoidance experiment. We deployed 2 Saildrones equipped with echosounders, compared their acoustic systems to the *Oscar Dyson*, and used them in a fur seal prey experiment.

Biological data and specimens were collected from 162 trawl hauls, 104 with an Aleutian wing 30/26 trawl (AWT), 4 with an 83-112 Eastern bottom trawl, 48 with a Methot trawl and 6 with a modified Marinovich trawl. The majority of hauls targeted backscatter during daytime for species classification. Among midwater hauls used to classify backscatter for the survey, walleye pollock was the most abundant species by weight (90%) and by number (94%), followed by northern sea nettle jellyfish (*Chrysaora melanaster*) (8% by weight and 4% by number). Among bottom trawls, pollock was the most abundant species (81% by weight and 74% by number) followed by rock sole spp. (5% by weight and 9% by number). In Marinovich hauls, *Aequorea* sp. (42%) and northern sea nettle (35%) jellyfish dominated the catch by weight, while euphausiids (56%) and age-0 pollock (26%) dominated the catch numerically. Finally, Methot hauls were dominated by northern sea nettles (58%), euphausiids (21%), and moon jellies (10%) by weight, respectively, and numerically, by euphausiids (91%).

Mean EBS shelf water temperatures in 2016 (surface and near bottom) as measured during the AFSC bottom trawl survey were the highest on record since the early 1980s, continuing a warming trend evident since 2013. About 56% of the summed acoustic backscatter at 38 kHz observed between near the surface and 3 m off bottom during the 2016 survey was attributed to adult or juvenile walleye pollock. This was similar to that in the past two AT surveys (45% in 2014 and 56% in 2012). The remaining non-pollock water column backscatter was attributed to an undifferentiated plankton-fish mixture (42%), or in a few isolated areas, to rockfishes (*Sebastes* spp.) or other fishes (~2%). Most walleye pollock were distributed evenly across the shelf from a region north of Port Moller on the Alaska Peninsula to the Convention Line, between roughly the 50 m and 200 m isobaths. Midwater pollock aggregations were observed farther east in Bristol Bay in 2016 than they had been during the previous decade.

Estimated pollock abundance in midwater (between 16 m from the surface and 3 m off bottom) in the U.S. EEZ portion of the Bering Sea shelf was 10.8 billion fish weighing 4.06 million t (relative estimation error 2.1%). This was about 18% higher than the 2014 biomass estimate (3.439 million t) and higher than has been observed since the late 1980s. Pollock abundance east of 170° W was 2.82 billion fish, weighing 1.52 million t (37% of total midwater biomass); 4-year-old pollock (41 cm modal FL) from the large 2012 year-class comprised 75% of that biomass. This was an increase in biomass from 2014, and was the highest pollock biomass observed east of the Pribilof Islands in over 2 decades. Pollock biomass increased by a similar amount inside the Steller sea lion conservation area (SCA); annual variation in SCA biomass is well correlated with the entire survey estimates ($r^2 = 0.79$, $p < 0.001$). In U.S. waters west of 170° W, pollock numbered 7.95 billion and weighed 2.54 million t (63% of total shelf-wide biomass). Dominant modal lengths were 24, 33, and 40 cm fork length, corresponding to pollock aged 2, 3, and 4 years, and comprising 2%, 43% and 34% of the biomass west of the Pribilofs, respectively.

In terms of age composition, the 2016 survey estimated the largest group of four-year olds in the AT survey time series since prior to 1994. Most of these 4-year old fish were observed east of the Pribilof Islands. Pollock ages 2, 3, and 4 were dominant numerically (accounting for 9%, 41% and 38% of the total shelf-wide population, respectively.) These three age groups represented 80% of the total biomass. Pollock (ages 5+) totaled 12% of the population numerically, and made up 20% of the total biomass. Age-1 pollock were rarely observed in 2016 and made up less than 0.03% of the total biomass.

Summer 2014-2015 acoustic vessel of opportunity (AVO) index for midwater Bering Sea walleye pollock

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 for a portion of the eastern Bering Sea shelf, from near surface to 3 m off bottom, was used to develop an abundance index that strongly correlated with the total estimated AT survey pollock biomass (r^2 = 0.904, p = 0.004, 2006-2012). 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 2014-2015. The 2014 AVO index increased 29% from the 2013 index value, and 36% from 2012. The 2015 AVO index increased slightly (6%) from 2014. Both estimates (2014, 2015) exceeded all earlier time series estimates (2006-2013) based on non-overlapping 95% confidence intervals. Most pollock backscatter appeared to be distributed broadly across the shelf between 50 and 200 m isobaths in 2014 and 2015. The percentage of pollock backscatter east of the Pribilof Islands (east of 170° W longitude) in the AVO index was 24% in 2014 and 25% in 2015. This was similar to the percentage in 2013 (26%), but much greater than reported for summers 2010-2012 (range 4-9%). This implies that there has been more midwater pollock biomass east of the Pribilof Islands in recent years, consistent with findings from the biennial AT survey; comparison of the AVO index and AT survey time series continues to show a strong correlation (r^2 = 0.90, p = 0.0011).

Midwater hauls were conducted for the first time in 2014 to sample midwater pollock aggregations during the 2014 (n = 31) and 2015 (n = 32) BT surveys to investigate the feasibility of using these hauls to convert the AVO backscatter index to abundance at length or age. Some portions of the AVO index area were not sampled by these hauls in both years. Preliminary analyses of these haul data (ability to target and catch pollock, catch composition, and length-frequency comparisons) showed 1) hauls targeted appropriate fish layers and were dominated by pollock, 2) bottom trawls and midwater trawls caught pollock of different length compositions and 3) length modes in midwater hauls from BT and AT surveys were similar, but occurred in different proportions even when restricted to the same subarea. Due to a number of factors including logistical and staffing constraints, and to consensus that the AVO backscatter index time series provides useful information to the stock assessment in its current form, full evaluation of how well BT survey haul data could be used to convert AVO backscatter to number of fish at length or age was deferred to a later time.

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 2016. 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 2016, the thirty-seventh annual longline survey of the upper continental slope of the Gulf of Alaska and eastern Aleutian Islands was conducted. One hundred-forty-eight 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 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 74,139 sablefish, with an estimated total round weight of 200,725 kg (442,523 lb), were caught during the survey. This represents an increase of 16,000 sablefish over the 2015 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 2,238 sablefish. Killer whales (*Orcinus orca*) depredating on the catch occurred at five stations in the western Gulf of Alaska. Sperm whales *(Physeter macrocephalus)* were observed during survey operations at 18 stations in 2016. Sperm whales were observed depredating on the gear at one station in the Aleutian Islands, five stations in the central Gulf of Alaska, five stations in the West Yakutat region, and six stations in the East Yakutat/Southeast region.

Several special projects were conducted during the 2016 longline survey. Satellite pop-up tags were deployed on sablefish throughout the Gulf of Alaska. Information from these tags will be used to investigate movement patterns within and out of the Gulf of Alaska and potentially help identify spawning areas for sablefish. Stable isotope samples were collected from major prey species of sperm whales to create baseline data for a sperm whale stable isotope diet project. Finally, opportunistic photo identification of both sperm and killer whales were collected for use in whale identification projects.

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 theshallower 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 Chris Lunsford at (907) 789-6008 or chris.lunsford@noaa.gov.

2016 Northern Bering Sea Integrated Ecosystem Survey – ABL

A surface trawl survey was conducted by the Ecosystem Monitoring and Assessment program of the Alaska Fisheries Science Center from Aug 27 to Sep 14, 2016 aboard the F/V Cape Flattery and included the collection of data on pelagic fish species and oceanographic conditions in the Northern Bering Sea shelf from 60°N to 65.5°N (Fig. 1). Overall objectives of the survey were 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) the North Pacific Research Board proposal #1423, Defining critical periods for Yukon and Kuskokwim river Chinook salmon, that includes expanding the southeastern Bering Sea integrated ecosystem model to the Northeast Bering Sea shelf, and 4) sample collections within Region 2 of the Distributed Biological Observatory. Participating institutions included: 1) Alaska Fisheries Science Center (AFS), Auke Bay Laboratories, Juneau, AK, 2) Alaska Department of Fish and Game (ADFG), Commercial Fisheries Division, Anchorage, AK, 3) U.S. Fish and Wildlife Service (USFWS), Office of Migratory Bird Management, Anchorage, AK, 4) Ocean Associates (contracting agency for AFSC), and 5) the National Institute of Fisheries Science, Korea.

Physical and biological data were collected from 32 surface trawl stations and oceanographic data were collected at 3 Distributed Biological Observatory stations in 2016. Headrope and footrope depth and temperature were monitored with temperature and depth loggers (SBE39) at each station.

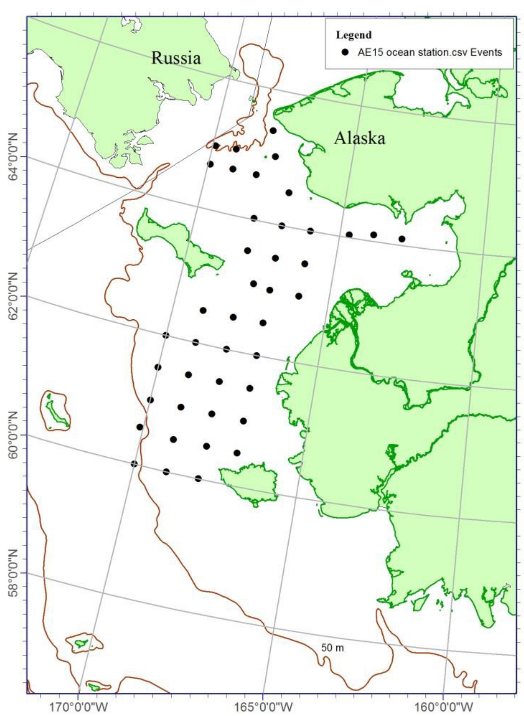

Figure 1. Stations planned to be sampled during the August 27 to September 14, 2016 integrated ecosystem survey in the northern Bering Sea.

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

2016 Gulf of Alaska Integrated Ecosystem Survey – ABL

The Gulf of Alaska assessment is a fisheries and oceanographic survey conducted in the eastern Gulf of Alaska during the summer season. This survey has been completed each year since 2010, and is a continuation of the monitoring efforts established by the Gulf of Alaska Integrated Ecosystem Research Project. The scientific objective of the survey is to assess Young of the Year (YOY) groundfish, salmon, zooplankton, and oceanographic conditions in the coastal, shelf, slope, and offshore waters of the eastern Gulf of Alaska. In 2016, the chartered fishing vessel Northwest Explorer (B&N Fisheries) was the sampling platform used to provide information on species distribution, ecosystem structure, and marine productivity in response to changes in climate patterns and temperature anomalies (i.e. the warm blob, and El Niño). All collection locations for fish, plankton, and oceanography were made at pre-determined master station locations.

Specific objectives listed in the Cruise Plan:

1) Observe epi-pelagic fish communities by sampling with a rope trawl at the surface. Fish species of interest that were retained from trawl: age-0 arrowtooth flounder (*Atheresthes stomias*), age-0 rockfish species (*Sebastes* spp.), age-0 walleye pollock (*Gadus chalcogrammus*), age-0 Pacific cod (*Gadus macrocephalus*), juvenile Pacific salmon (*Onchorhynchus* spp.), age-0 sablefish (*Anoplopoma fimbria*) and forage fishes.
2) Collect electronic oceanographic data including CTD (Conductivity-temperature-depth) vertical profiles of temperature, salinity, light transmission, chlorophyll a fluorescence, and photosynthetically available radiation (PAR).
3) Collect biological oceanographic samples by oblique bongo tows and water sampling via carousel and niskin botles.

Survey transect lines run parallel to one another and perpendicular to the coast. Along the coast, transect lines are spaced 20 nautical miles apart, with the exception of the 10 nm Cross Sound and Yakutat Valley lines (Figure 1). This was to increase the spatial resolution in these high interest areas. Onshore-offshore spacing was variable. Over the shelf, stations were spaced 10 nm apart, over the slope and basin, stations were spaced 20 nm apart. In the areas south of Yakutat Valley and North of Yakobi Island (south end of Cross Sound), transect lines stretched to 100 nm offshore with spacing previously described. An additional offshore grid, following these same conventions, was added in 2016 to survey out to the Exclusive Economic Zone for age-0 rockfishes and sablefish. Operations were completed between 0700 and 1900 daily.

The total sampling effort during 2016 included 109 occupied stations where fish sampling occurred. A total of 89 casts were made with a SeaBird Electronics 25 CTD. A total of 74 bongo tows were made using standard bongo array. A total of 369 chlorophyll a, 429 nutrient samples, and 30 salinity samples were collected.

Average surface (top ten meters) temperatures ranged from 11.780º to 15.650º Celsius. Average surface salinity ranged from 27.49‰ to 32.28‰. Surface temperatures rose in 2014, and continue to be elevated through the 2016 survey season. Maximum temperatures observed during 2015 were above 16º Celsius.

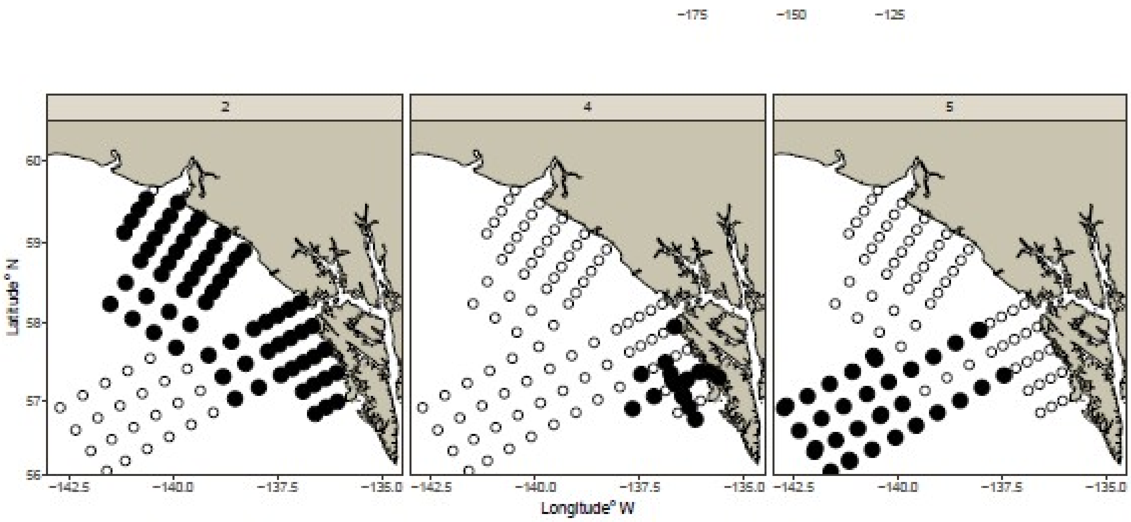

Figure 1. Station locations for the 2016 Gulf of Alaska integrated ecosystem survey conducted during July to August.

For more information contact Wes Strasburger at (907) 789-6009 or **wes.strasburger@noaa.gov**

2016 Southeastern Bering Sea Integrated Ecosystem Survey – ABL

Late-Summer Pelagic Trawl Survey (BASIS) in the Southeastern Bering Sea, September – October 2016

Scientists from the Recruitment Processes Alliance (RPA) of the Alaska Fisheries Science Center (AFSC) conducted a fisheries-oceanographic survey in the southeastern Bering Sea (SEBS) during the early fall aboard the NOAA Vessel *Oscar Dyson* from August 20 to October 7, 2016. The survey design covered the SEBS shelf between roughly the 50 m and 200 m isobaths, from 162º W to 171º W (Figure 1). Surface trawls (top 20 m) were conducted at selected stations and a midwater trawl was used to obliquely sample the entire water column (200 m maximum) at each station. In addition, the survey included sampling the 70 m isobath and the Distributed Biological Observatory (DBO) stations, that are two long-term time series describing the physical and biological properties of the Bering Sea shelf, from approximately 56.5º N to 63.5º N. Prior to the RPA surveys, fisheries-oceanographic surveys were conducted annually (2002-2012, 2014) as part of the Bering-Aleutian Salmon International Survey (BASIS) and eventually the Bering Sea Project (BSP). The main objective of the RPA surveys in the SEBS is to collect ecosystem data with a priority to provide mechanistic understanding of the factors that influence recruitment of walleye pollock (*Gadus chalcogrammus*), Pacific cod (*Gadus macrocephalus*), and arrowtooth flounder (*Atheresthes stomias*).

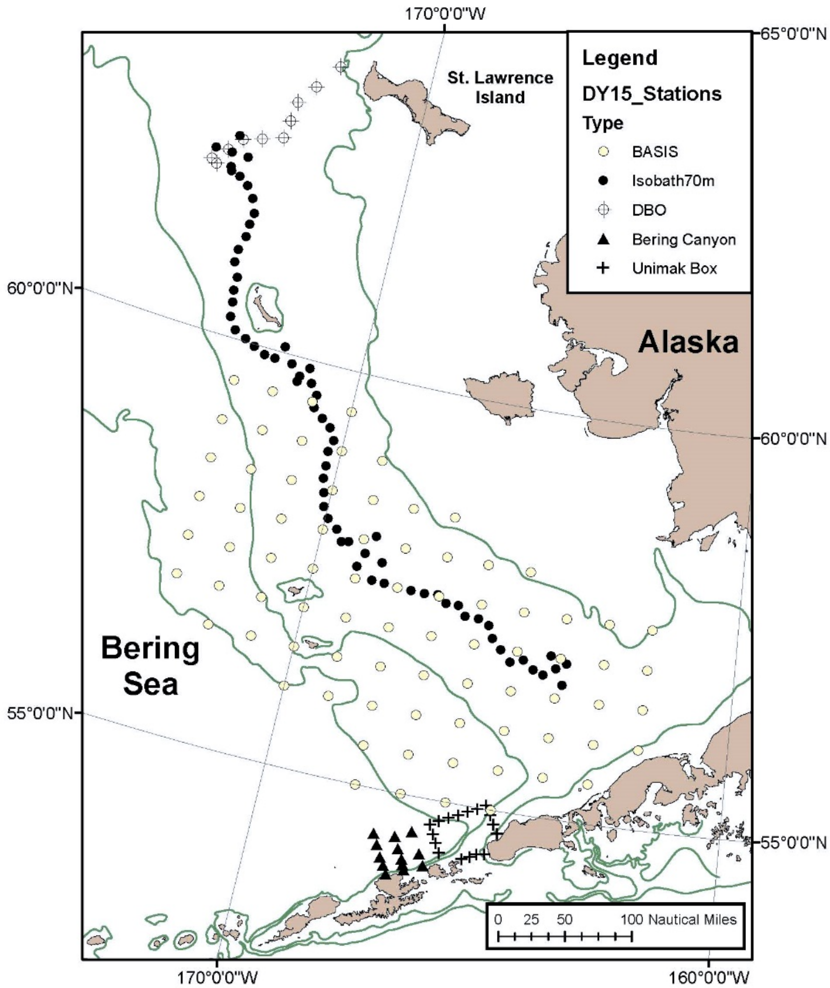

Figure 1. Station locations for the August to October 2016 southeastern Bering Sea integrated ecosystem survey also known as BASIS.

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 Groundfish and Halibut 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.

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.
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.

Vessels in the partial coverage category had the option to "Opt in" to a voluntary Electronic Monitoring (EM) Program for 2016. The overall goal of the 2016 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 is being used to inform decisions and future Council alternatives for integrating electronic monitoring into the Observer Program.

For more information on the North Pacific Groundfish and Halibut Observer Program contact Chris Rilling at (206) 526-4194 or chris.rilling@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 total of 183 satellite pop-off archival satellite tags (PSATs) have been deployed on spiny dogfish since 2009. Data has been successfully recovered from 153 tags. Eight tags have been physically recovered and complete data sets, with more detailed data, have been downloaded. Six spiny dogfish tagged in Puget Sound were tagged with acoustic tags in addition to PSATs, in an attempt to compare the light based geolocation used by the PSATs with known positions from the acoustic receivers. Recovered data from the PSATs, which includes temperature, depth, and geographic

location derived from light, are still being analyzed. 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. A manuscript examining the availability of spiny dogfish to the GOA groundfish bottom trawl survey was published as part of the 2015 Lowell Wakefield Symmposium (Hulson et al. 2016) and another manuscript detailing the results of the double tagged fish in Puget Sound is in preparation.

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. Continued sample collection and development of nuclear markers (microsatellites) is currently underway and will allow for a better understanding of the level of introgression, if any, between these two 'populations' of sharks.

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. The GOA assessment coincides with the biennial GOA trawl survey in odd years (the last survey was in 2015) and the BSAI assessment is in even years, when there are trawl surveys in the BSAI. 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 2016 assessments, 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 2015. The 2015 survey biomass estimate (51,916 t, CV = 25%) is about a third of the 2013 biomass estimate of 160,384 t (CV = 40%); this variability is typical for spiny dogfish. 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 2017 and 2018.

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 126 t, which is not close to the ABC or OFL. Pacific sleeper shark are the primary species caught. 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 2016 EBS shelf survey biomass estimate was substantially higher than in 2014 and the 2016 assessment featured the following new information: The total 2015 year-end catch was updated and incomplete 2016 catches were provided. New biomass estimates from the 2016 eastern Bering Sea (EBS) shelf, EBS slope and Aleutian Islands bottom trawl surveys were added. The Alaska skate model now incorporates EBS shelf survey biomass estimates through 2016, EBS shelf size composition through 2016, fishery length compositions through 2015, catch data through 2016, and an additional length-at-age dataset from vertebrae collected during 2015 on the EBS shelf trawl survey.

There were no changes to the assessment methodology. Model 14.2, accepted in 2014, continues to be the preferred model to estimate the dynamics of Alaska skate. Model 14.2 was updated to include new catch and survey data as well as a new length-at-age dataset. The random effects model continues to be used for estimating biomass for the “other skates” group, and was updated to include 2015 and 2016 survey biomass estimates.

The results of the Alaska skate model were similar to those presented in 2014. Even though the 2016 EBS shelf survey biomass estimate was substantially higher than in 2014, the model predicted a slight decline in spawning biomass. Total skate biomass increased on the EBS shelf after 2014, while it declined in the Aleutian Islands. Total skate biomass on the EBS slope was slightly lower in 2016 relative to 2012.

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 projected spawning biomass for 2017 (108,926 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 2017 and 2018 ABCs are 33,634 t and 31,498 t, respectively, and the Alaska skate portions of the 2016 and 2017 OFLs are 39,050 t and 36,570 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 2017 and 2018 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 2017 and 2018 total 49,063 t and 46,583 t, respectively, and ABCs for 2017 and 2018 total 41,144 t and 39,008 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 normally assessed on a biennial schedule, with full assessments presented in odd years to coincide with the timing of survey data. The 2016 assessment is an executive summary prepared with updated catch data.
The survey biomass trend was mixed between the stocks covered. Big skate biomass increased, other skates decreased, and longnose skates were stable.

Catch as currently estimated does not exceed any gulf-wide OFLs, and therefore, is not subject to overfishing. It is not possible to determine the status of stocks in Tier 5 with respect to overfished status. The random effects model was used for estimating proportions by area. Big and longnose skates have area-specific ABCs and gulf-wide OFLs; other skates have a gulf-wide ABC and OFL.

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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.
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Climate Change and Location Choice in the Pacific Cod Longline Fishery-REFM/ESSR
Alan Haynie* and Lisa Pfeiffer
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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 2016 (944,621 t) was down by 35% from 2015 (1,102,261 t) and biomass in 2016 was 14% less than in 2014 (1,079,712 t). As estimated in the present model, spawning biomass is well above $B_{40\%}$ and has been increasing since 2010 due to a number of strong year-classes including 2006, 2008, 2011 and 2013. However, spawning biomass is projected to begin declining again in the near future.

Substantive changes have been made in the EBS Pacific cod assessment since 2015.
1. Catch data for 1991-2015 were updated, and preliminary catch data for 2016 were incorporated.
2. Commercial fishery size composition data for 2015 were updated, and preliminary size composition data from the 2016 commercial fisheries were incorporated.
3. Size composition data from the 2016 EBS shelf bottom trawl survey were incorporated.
4. The numeric abundance estimate from the 2016 EBS shelf bottom trawl survey was incorporated (the 2016 estimate of 640 million fish was down about 35% from the 2015 estimate).
5. Age composition data from the 2015 EBS shelf bottom trawl survey were incorporated.

Additionally, many changes were made or considered in the stock assessment model since the 2015 assessment (Thompson 2015). Six models were presented in this year's preliminary assessment (Appendix 2.1), as requested in May and June by the Joint Team Subcommittee on Pacific Cod Models and the SSC. After reviewing the preliminary assessment, the BSAI Plan Team and SSC requested that two models from the preliminary assessment (one of which is the base model that has been used for setting harvest specifications since the 2011 assessment) and four new models be presented in the final assessment.

Changes to the model of choice used in setting harvest specifications for 2017 and 2018 include elimination of intra-annual seasons, collapsing all gear types into a single fishery, internal estimation of the natural mortality rate and trawl survey catchability, forcing the fishery and survey selectivity schedules to be asymptotic, and removal of all time variability from both fishery and survey selectivity.

This stock is assigned to Tier 3a. The maximum 2017 ABC in this tier as calculated using the present model fit is 239,000 t, and the recommend ABC is the same. An ABC of 255,000 t was set for the preliminary 2018 ABC. The 2017 OFL from this new model is 284,000 t, which is less than the projected OFL from the previous assessment. The 2018 projected OFL is 302,000 t.

EBS Pacific cod is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

Gulf of Alaska

The 2017 spawning biomass is projected at 91,198 t, well-above the $B_{40\%}$ estimate was 78,711 t. Recruitment was above average for the 2005-2013 period and below average for 2014-2016. Spawning biomass is expected to increase in 2018 and then decline thereafter.

The fishery catch data was updated for 2015 and 2016 (2016 expected total year catch was projected). Fishery size composition data were updated for 2015, preliminary fishery size composition were included for 2016, and weight and age at length and age composition data for the 2015 bottom trawl survey were included. For the first time, AFSC longline survey relative population numbers (RPNs) and length composition data for 1990 – 2016 were included. A major difference in the new models examined was that all the data were annually aggregated rather than stratified by season.

The author evaluated several models and presented a subset of models that included the model configuration from 2015 with updated data (Model 15.3), models similar to those presented at the September Plan Team meeting with updated data and extension of modeled ages to 20 years, and five additional model configurations. Model tuning was also evaluated.

Model 16.08.25 was recommended by the author and the Plan Team concurred. This model's performance in both fit to available data and retrospective patterns was better than other models. Major features of this model included dome shaped selectivity for pot and trawl fishery length compositions and survey length and age compositions. Natural mortality and survey catchability (Q) was estimated within the model. The estimate of natural mortality was considerably higher than the fixed value used in Model 15.3 (0.47 vs 0.38). The higher M resulted in a higher proportion of the population observed by the surveys compared to last year's assessment. The higher M (0.47) implies higher productivity but lower overall abundance than in previous assessments, which results in a higher $F_{40\%}$. This stock is in Tier 3a because the 2017 spawning biomass is estimated to be greater than $B_{40\%}$. The $F_{35\%}$ and $F_{40\%}$ are 0.652 and 0.530, respectively. The maximum permissible ABC of 88,342 t is a 10.4% decrease from the 2016 ABC of 98,600 t.

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

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E. Walleye Pollock

1. Research

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

Description of indicator: 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 between 2003-2014 and from oblique (water column) trawls in 2015. 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 and age-3 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 and recruitment success to age-3.

Status and trends: 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 southeastern Bering Sea 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 2007-2012 (i.e., cold conditions). Warm conditions returned in 2014 and have persisted through at least 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 46% of the variation in the number of age-1 recruits per spawner and 47% of the variation in the number of age-3 recruits per spawner (Fig. 2).

Factors influencing observed trends: 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).

Implications: The current model indicates that the 2015 year-class is predicted to have intermediate overwinter survival to age-1 and recruitment success to age-3. The SEBS is experiencing warm conditions, although age-0 pollock in 2015 may have utilized the cold pool as a refuge which may act as a buffer against recruitment declines for this year class (Duffy-Anderson et al., submitted).

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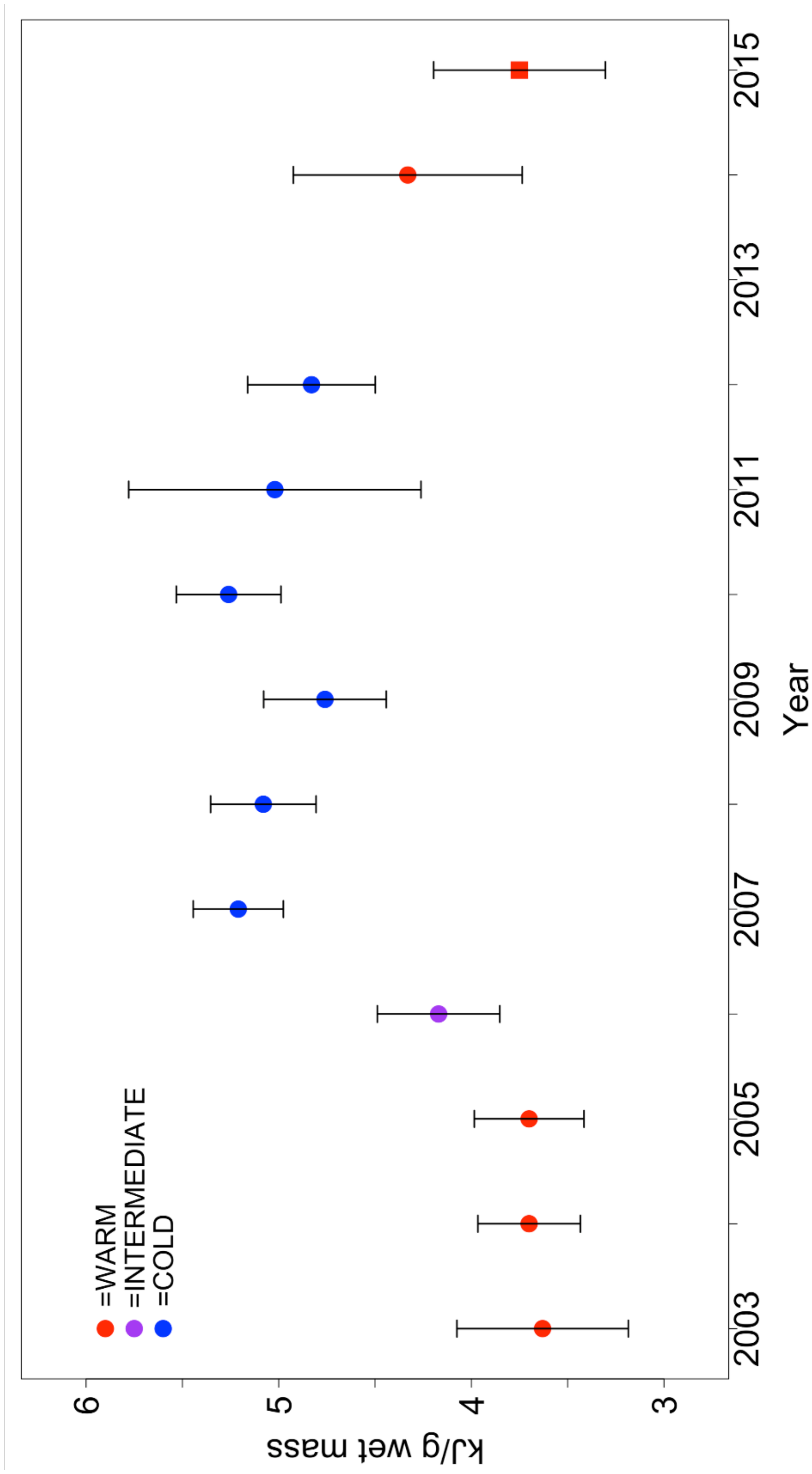

Figure 1. Average energy density (kJ/g) of young-of-the-year Walleye Pollock (*Gadus chalcogrammus*) collected during the late-summer BASIS survey in the eastern Bering Sea 2003-2015. Fish were collected with a surface trawl in 2003-2014 and an oblique trawl in 2015.

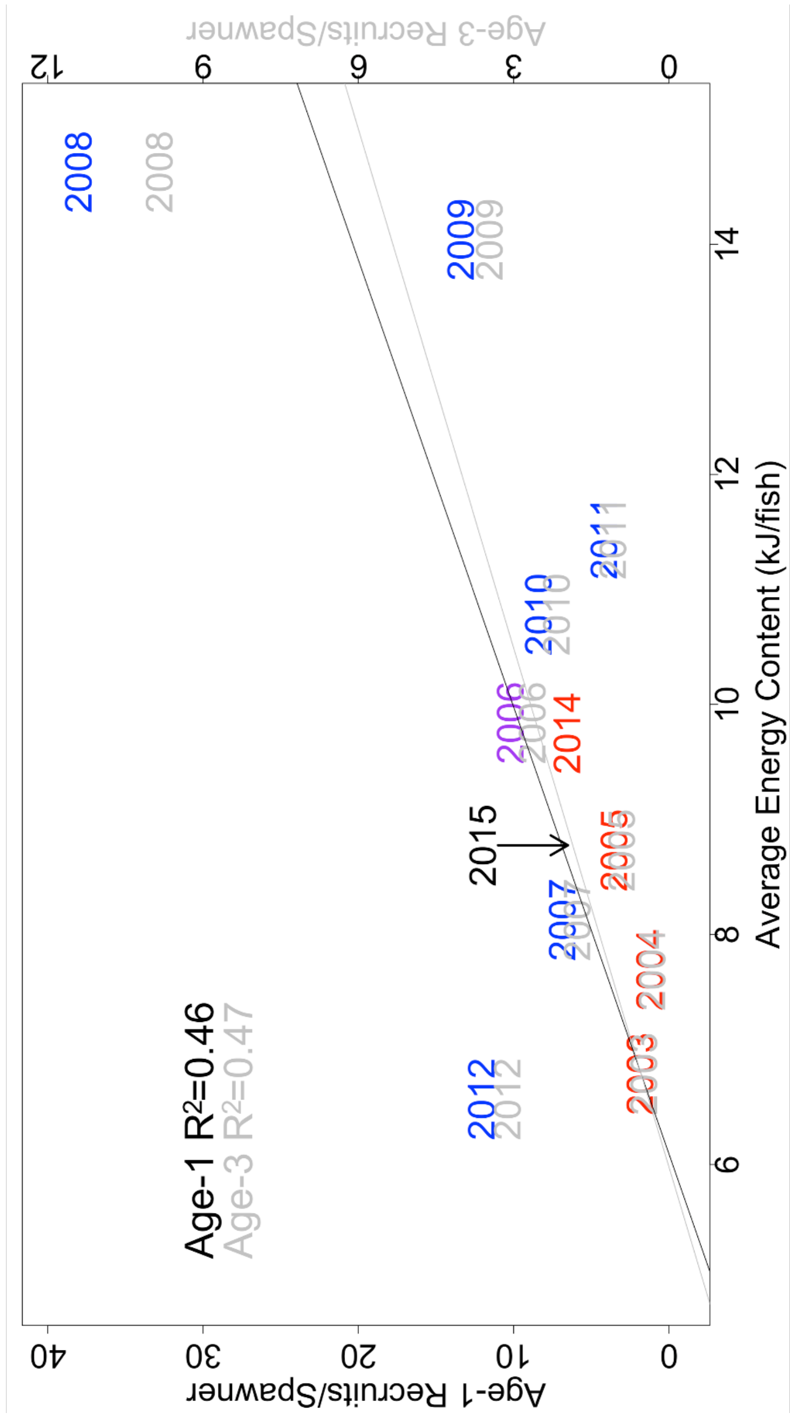

Figure 2. Relationship between average energy content (AEC) of individual young-of-the-year Walleye Pollock (*Gadus chalcogrammus*) and the number of age-1 and age-3 recruits per spawner from the 2015 stock assessment (Ianelli et al., 2015). Fish were collected with a surface trawl in 2003-2014 and an oblique trawl in 2015.

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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 preand 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/cgibin/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 2016 TC index value is -3.19, higher than the 2015 TC index value of -5.96, indicating improved conditions for pollock from 2015 to 2016 due to the lower difference in sea temperature from late summer to the following spring. However, both the late summer sea surface temperature (11.7 °C) in 2015 and the spring sea temperatures (8.5 °C) in 2016 were warmer than the long-term average of 9.7 °C in late summer and 5.1 °C in spring since 1950. The TC index was positively correlated with subsequent recruitment of pollock to age-1 through age-4 from 1964 to 2015, but not significantly correlated for the shorter period (1995-2015).

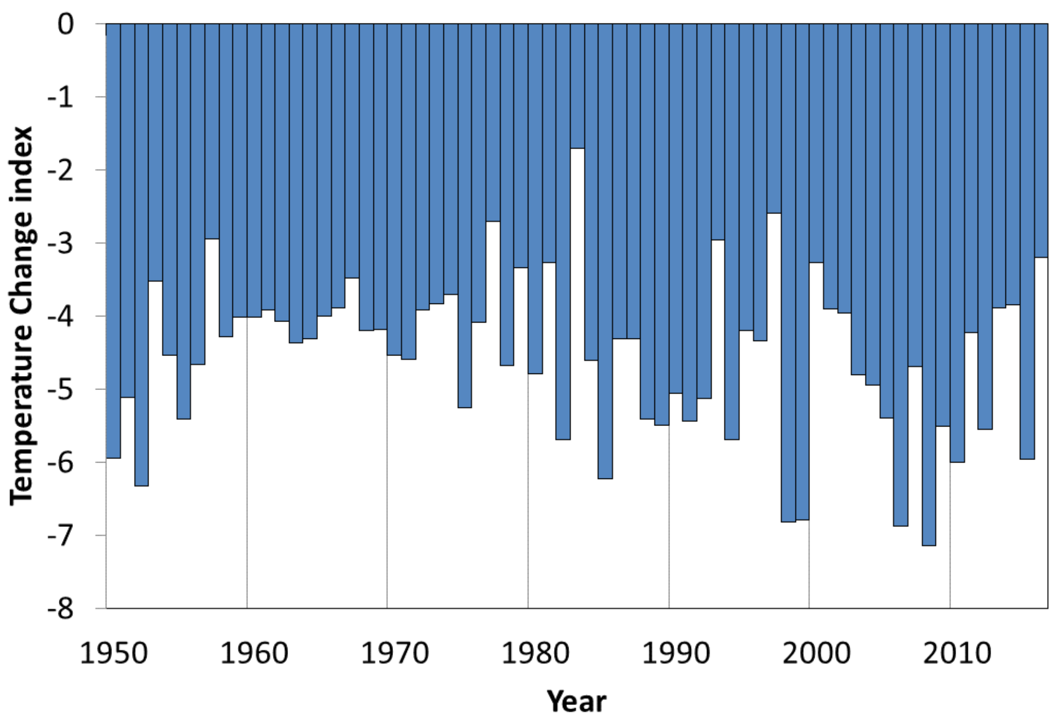

Figure 1: The Temperature Change index values from 1950 to 2015.

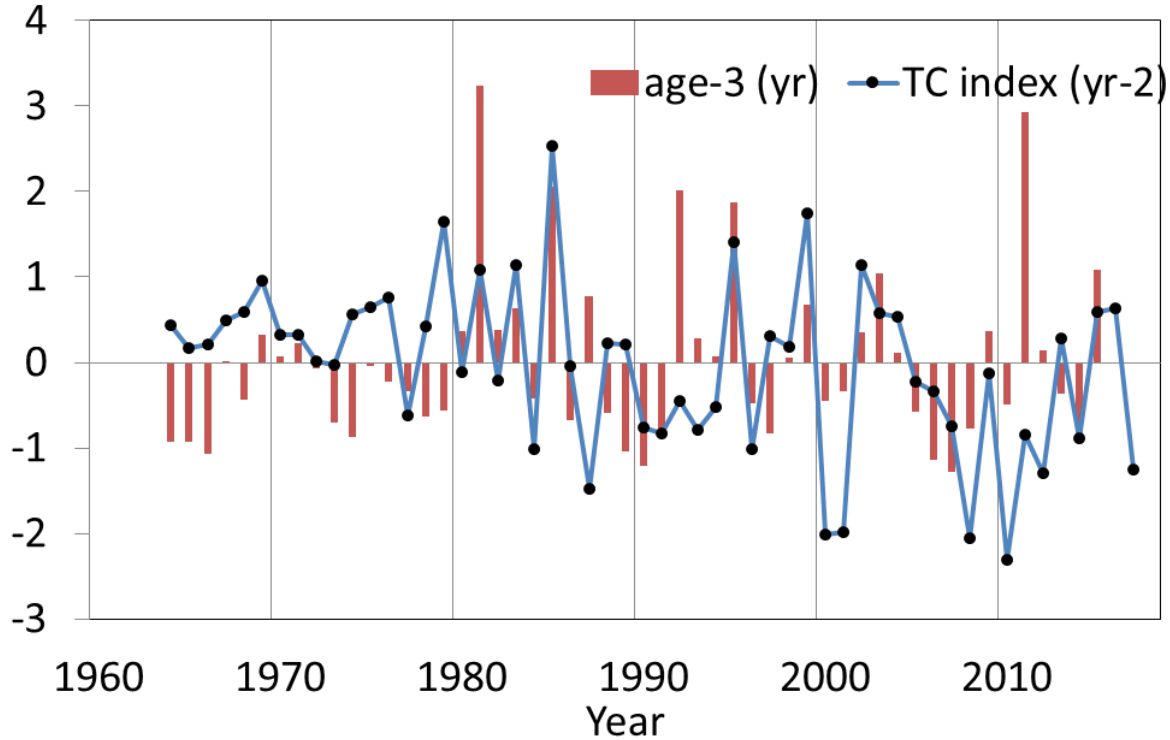

Figure 2: Normalized time series values of the temperature change index (t-2) and the estimated abundance of age-3 walleye pollock in the eastern Bering Sea (t) from Table 1.25 in Ianelli et al. 2015.

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	**0.35**	**0.34**	**0.31**	0.26	0.22	0.22
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.

Implications: The 2015 TC index values of -5.96 was below the long-term average, therefore we expect lower than average recruitment of pollock to age-3 in 2017 from the 2014 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.

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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) and abundance per biomass (thousands of tons) of spawner for year classes 2002-2012 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 and 2014 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 one warm year (2014) using methods in Eisner et al. (2014). Pollock abundance and biomass was available from the stock assessment report for the 2002-2015 year classes (Ianelli et al., 2015).

Status and trends: A positive significant (P = 0.04) linear relationship was found between mean abundance of large zooplankton during the age-0 stage of pollock and estimated abundance of age-1pollock from Ianelli et al. (2015) for the 2002-2012 year classes (Fig.1). Age-1 pollock abundance is primarily derived from age-3 data, therefore relationships between large zooplankton and age-1 and age-3 abundances are similar. No significant relationship occurred between large zooplankton abundance and recruits-per-spawner for the 2002-2012 year classes, unlike the prior update for

2003-2010 data. The prior update also used geometric instead of arithmetic mean large zooplankton abundance. Using the 2014 zooplankton abundance (185 m^{-3}), we compared the model prediction with the "observed" abundance of age-1 pollock for the 2014 year class from Ianelli et al. (2015) (Fig. 2). Our regression models predicted an abundance of 27,303 million age-1 pollock with a standard error of 4,897 million and an abundance of 7,303 million age-3 pollock with a standard error of 1,268 million for the 2014 year class.

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 forage fish. 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 increases in the availability of large zooplankton prey during the first year at sea were favorable for age-0 pollock overwinter survival to age-1 and recruitment into the fishery at age-3. If the relationship between large zooplankton and age-1 (age-3) pollock remains significant in our analysis, the index may be used to predict the recruitment of pollock one (three) years in advance of recruiting to age-1 (age-3), from zooplankton data collected one (three) 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).

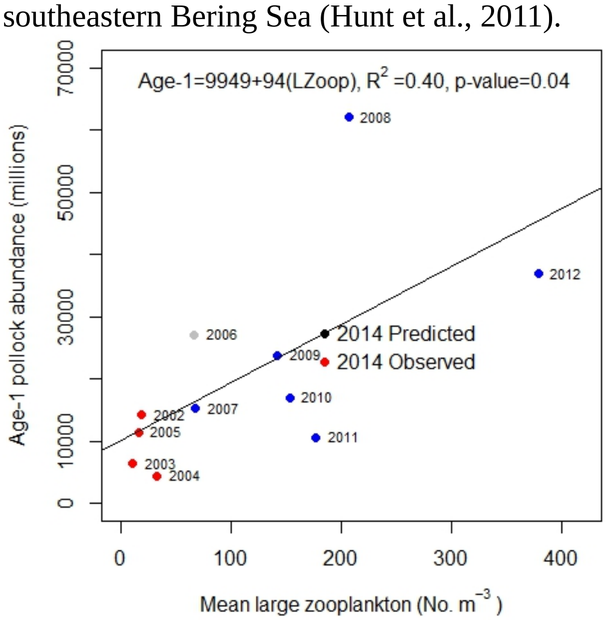

Figure 1. Linear relationships between mean large zooplankton abundance during the age-0 life stage of pollock and the estimated abundance of age-1 pollock abundance of the year class 2002-2012, from Ianelli et al. (2015). The 2014 points are the "observed" stock assessment estimates of age-1 pollock from Ianelli et al. (2015) and the "predicted" age-1 pollock estimates are from our

regression model using large zooplankton abundance for 2014. Points are labeled with year class. Red points are warm (low ice) years, blue are cold (high ice) years, and gray is an average year.

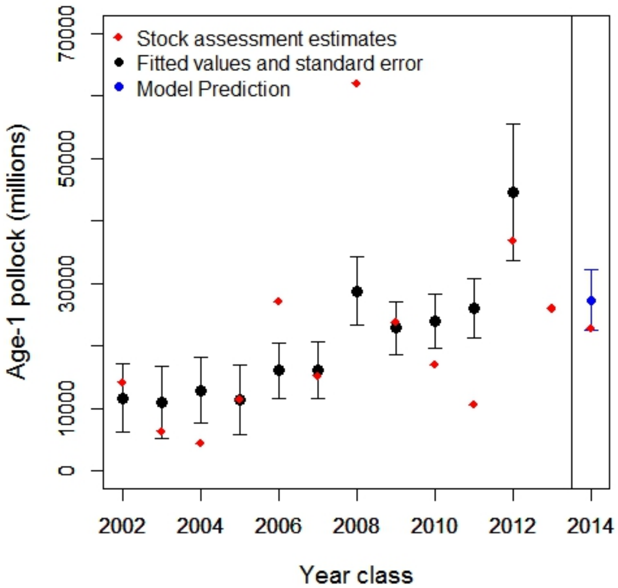

Figure 2. Fitted values and standard errors of age1 pollock abundance, estimated from the linear regression model relating the abundance of age-1 pollock from Ianelli et al. (2015) to the abundance of large zooplankton during the age-0 life stage of pollock. Red symbols are stock assessment estimates (Ianelli et al., 2015).

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Salmon, Sea Temperature, and the Recruitment of Bering Sea Pollock - ABL

Description of indicator: Chum salmon growth, sea temperature, and adult pink salmon abundance were used to predict the year class strength of walleye pollock (*Gadus chalcogrammus*) (Yasumiishi et al. 2015). The intra-annual growth in body weight of immature and maturing age-4 chum salmon incidentally captured in the commercial fisheries for walleye pollock in the eastern Bering Sea was used as a proxy for ocean productivity experienced by age-0 pollock on the eastern Bering Sea shelf. A linear regression model was used to describe stock assessment estimates of pollock abudance from Ianelli et al. (2015) for the 2001-2011 year classes as a function of chum salmon growth, sea temperature, and adult pink salmon, provided by Irvine and Ruggerone (2016). Model parameters and updated biophysical indices were used to predict the abundance of age-1 and age-3 pollock for the 2013-2015 year classes.

Status and trends: For last years model (2015 model), an alternating year pattern was observed in the residuals, so this year we added adult pink salmon abundance as a predictor in the model due to their alternating life cycle and interaction with age-0 and age-1 pollock. The best fit 2016 model (lowest Bayesian information criterion) included chum salmon growth during the age-0 stage, spring sea temperature during the age-1 stage, and adult pink salmon returns during the age-0 stage, indicating that adult pink salmon are possible predators of age-0 pollock ($R^2 = 0.85$; p –value = 0.003).

The model parameters (2001-2011) and biophysical indices from 2013 to 2016 were used to predict the abundance of age-1 and age-3 pollock for the 2013-2015 year classes (Figure 1). For the 2013 year class, high chum salmon growth (0.97 kg) in 2013, average spring sea temperatures (3.95°C) in 2014, and high adult pink salmon returns to Asia and North America in 2013 (806,999 metric tonnes) produced a forecast of 7,166 million age-1 pollock (S.E.=155 million) and 39 million age-3 pollock (S.E.=1,855). For the 2014 year class, average chum salmon growth (0.79 kg), warm spring sea temperatures (4.00°C), and low adult pink salmon returns (493,683 million) produced a forecast of 9,095 million age-1 pollock (S.E.=5,252) and 2,349 million age-3 pollock (S.E.=1,359 million). For the 2015 year class, low chum salmon growth (0.53 kg), a warm spring sea temperatures (5.50°C), and high adult pink salmon returns (742,601 million) produced a negative forecast. Our model predicted low abundance of pollock at age-3 for the 2013-2015 year classes.

Factors influencing observed trends: The 2016 biophysical indices indicated below average ocean productivity (chum salmon growth), warm spring sea temperatures in 2016 (less favorable), and high pink salmon abundances (less favorable; predation on age-0 pollock by adult pink salmon during the spring and early summer) (Coyle et al. 2011). These factors are expected to result in below average recruitment of pollock for the 2013-2015 year classes (Figure 1).

Implications: The biophysical indicators and 2016 model predicts a below average recruitment of pollock to age-1 and age-3 for the 2013-2015 year classes.

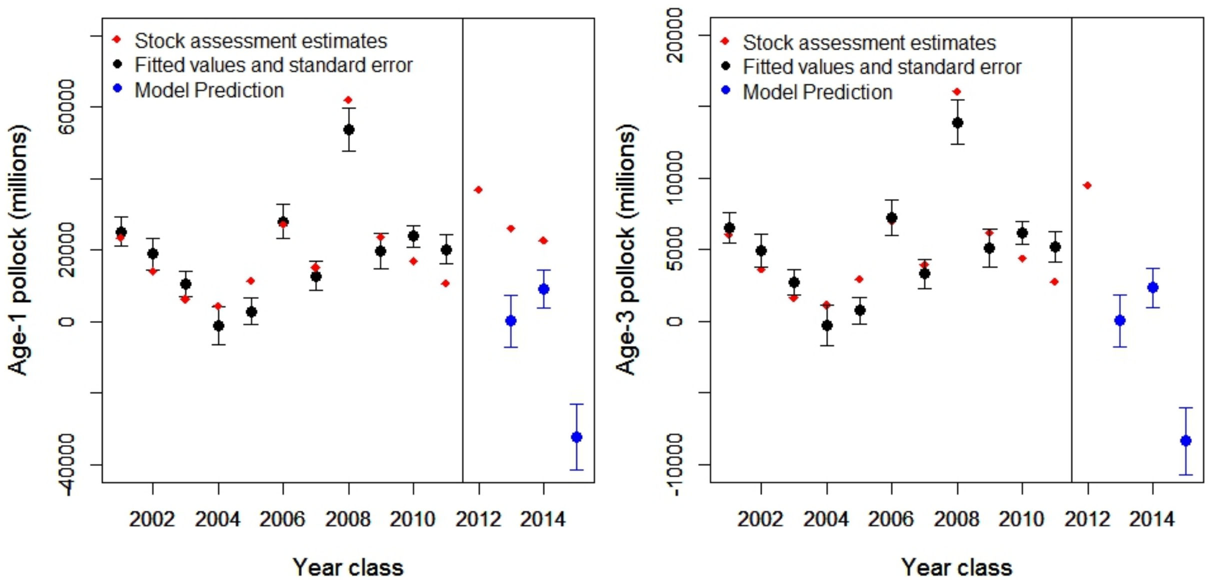

Figure 1. Output from the linear regression model relating the estimated pollock abundance from Ianelli et al. (2015) to the intra-annual growth of age-4 chum salmon during the age-0 life stage of pollock, abundance of adult pink salmon returns to Asia and North America during the age-0 stage, and spring sea temperatures in the southeastern Bering Sea during the age-1 life stage of pollock.

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Age-0 walleye pollock distribution in the southeast Bering Sea during summer 2016-RPP

A midwater trawl (NETS 156 trawl) was deployed for the second year as part of the 2016 BASIS southeastern Bering Sea ecosystem survey. The midwater trawl was deployed in an oblique manner to a depth of 10 meters off bottom at a grid of 34 stations, along with the standard BASIS survey surface Canada trawl. Age-0 pollock was the largest component of the trawl fish catch by both number and by weight (Figure 1). Age-0 pollock midwater catches were highest in the middle and inner domains (Figure 2), and generally corresponded to the areas of the highest age-0 pollock catches in the surface trawl, although the two trawl types do not fish the same part of the water column and catch selectivity for both trawls is unknown. Several jelly taxa comprised the top 99% by weight of the invertebrate catch (Figure 1).

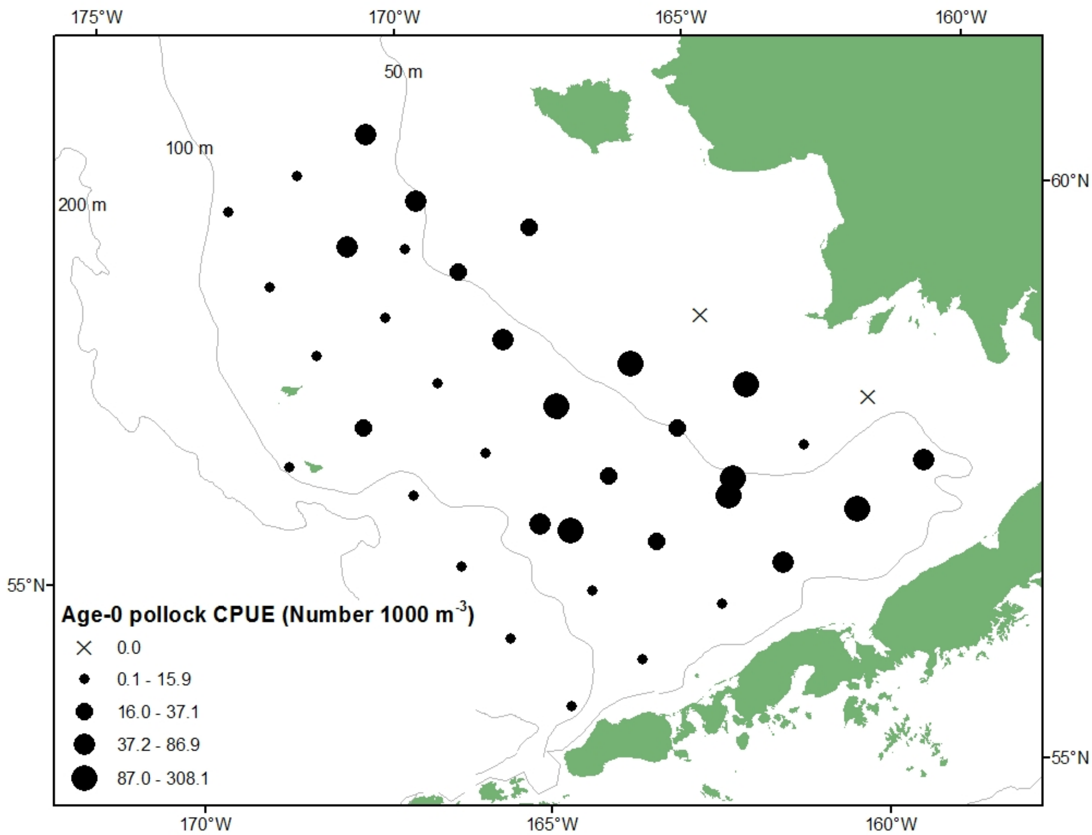

Figure 1. Age-0 pollock catch per unit effort (Number of fish 1000m^{-3}) in the NETS 156 midwater trawl.

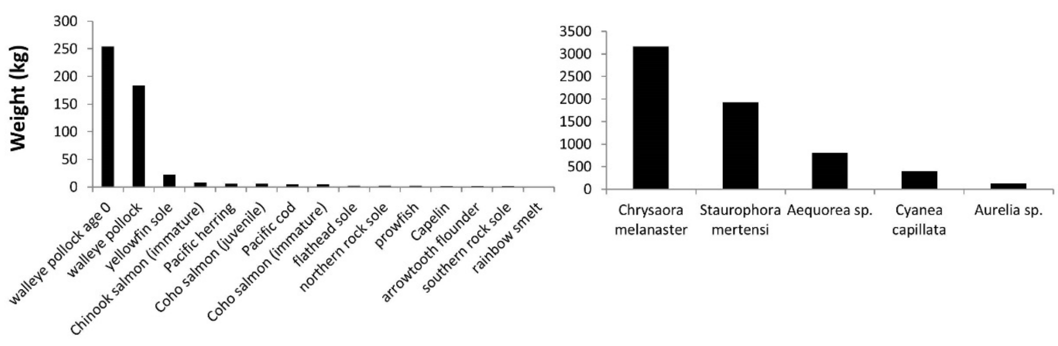

Figure 2. Weight of fish (left panel) and invertebrate (right panel) taxa caught using the NETS 156 trawl during the 2016 BASIS cruise. Only the taxa with the greatest catch weights comprising 99% of the total catch are shown.

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Responses of walleye pollock early life stages to the 2015 warm anomaly in the Gulf of Alaska-RPP

In 2014 and 2015, anomalous ecological conditions were reported across the NE Pacific Ocean coinciding with persistent and widespread ocean warming (nicknamed "The Blob"). Studying the ecological responses to such an event can provide insights into the mechanisms underlying recruitment success and links to climate conditions. In this study, we revisit proposed mechanisms linking climate and recruitment in Walleye Pollock in the Gulf of Alaska, and evaluate these mechanisms in light of the 2015 year class. In spring of 2015, pollock larvae were observed at their lowest abundance in 31 years of surveys by the AFSC EcoFOCI program. A subsequent survey at end of summer caught few age-0 pollock, and those observed were in poor condition. Estimated survival rates were low for both larval and early juvenile stages relative to past years (Figure 1). In previous years, warm conditions during spring have been associated with favorable conditions for larval survival, especially during the first week post-hatch (Bailey et al. 1996); however, more recent results suggest that larvae hatch earlier and at a smaller size under warm temperatures (Dougherty et al. in review), which may have consequences for their fitness. Work is ongoing to characterize the zooplankton community in spring and late-summer to assess the importance of temperature-driven changes in zooplankton for pollock condition and survival in the Gulf of Alaska. Results suggest that responses of pollock to the 2014/2015 warm event differed from previous warm years (e.g. 2005). This highlights the importance of looking beyond environmental covariates in order to understand the mechanisms linking climate conditions to recruitment, which will be critical for forecasting species-specific responses to climate change.

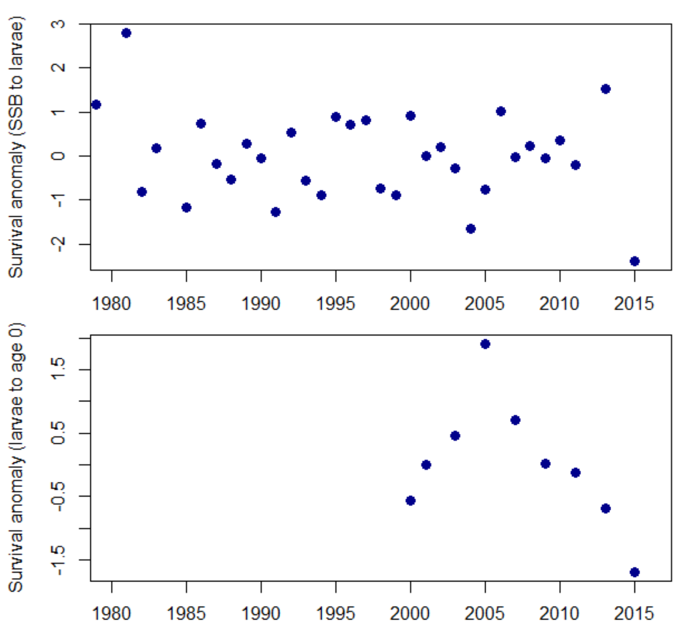

Figure 1: Survival anomalies calculated from time-series of estimated spawning stock biomass (SSB), larval abundance indices, and abundance of age-0 pollock

in late summer. Larval and age-0 pollock abundances are estimated from spring and late-summer EcoFOCI surveys in the Gulf of Alaska.

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Geographic variation in otolith chemistry of age-0 juvenile walleye pollock (*Gadus chalcogrammus*) in relation to regional hydrography.--RPP

For many coastal marine fishes, uncertainty about juvenile habitat quality and nursery location greatly impedes our understanding of their recruitment process. Among age-0 walleye pollock (*Gadus chalcogrammus*) in the western Gulf of Alaska (GOA), we demonstrate for the first time that otolith elemental composition regionally discriminates age-0 juveniles in association with Alaska Coastal Current (ACC)- related hydrography. Identifying nursery location is one step toward resolving factors that affect replenishment and possible meta-population structure of important local fished populations such as pre-spawning adult walleye pollock in Shelikof Strait, and summertime aggregations in sea valleys along the Gulf side of Kodiak Island. We asked, “Can otolith chemistry be used to determine whether these populations are supported by local nurseries or one that is common to both populations?”

Elemental composition of 228 otoliths from age-0 juveniles was examined in relation to 3 hydrographic regions: Kodiak, Semidi-inner, and Semidi-outer (Fig. 1). The Semidi regions are thought to be the major nursery of walleye pollock that replenish the adult population in Shelikof Strait. Samples and data were collected with an instrumented small-mesh midwater trawl during September 2007 and October 2011. Laser ablation-inductively coupled plasma mass spectrometry was used to measure elemental composition along otolith edge and life-history (otolith edge to core) transects.

Near-surface salinity was lower in the Semidi regions than in the Kodiak region. This was consistent with greater ACC influence in the Semidi regions. The relatively low ACC salinities have been shown to reflect terrestrial runoff. The expected effect on water chemistry is barium (Ba) enrichment and strontium (Sr) dilution in ACC-influenced regions.

All within-year differences in otolith edge elemental composition were between Kodiak and Semidi regions. Semidi fish had relatively low strontium:calcium (Sr:Ca) and high barium:calcium (Ba:Ca) ratios, which was consistent with ACC influence. Canonical discriminant analysis indicated 73% (2007) and 86% (2011) successful discrimination of region by otolith chemistry (Fig. 2).

Along life history transects, Sr:Ca decreased and Ba:Ca increased markedly among Semidi juveniles ca. August-September (Fig. 3) consistent with late-summer baroclinic spin-up of the ACC. Subsequent otolith accretion in October 2011 was less regionally distinct due perhaps to fish seasonal and ontogenetic-related descent. Signal-based discrimination between Kodiak and Semidi regions was 77% (2007) and 88% (2011).

Our results indicate that otolith chemistry, especially Ba:Ca and Sr:Ca, will be useful for determining whether the pre-spawning adults in Shelikof Strait are replenished from one nursery while those in sea valleys along the Gulf side of Kodiak Island are replenished by another. If so, tracking a cohort through each population should provide insight on possible mixing between populations. It could be that larval supply to local nurseries is the principal means of mixing between these populations. If so, then post-larval mortality would be expected to exacerbate or ameliorate, depending on relative local intensity, geographic variation in population density.

For more information contact Matthew Wilson (matt.wilson@noaa.gov), Annette Dougherty, Mary Elizabeth Matta, Kathryn Mier, or Jessica Miller

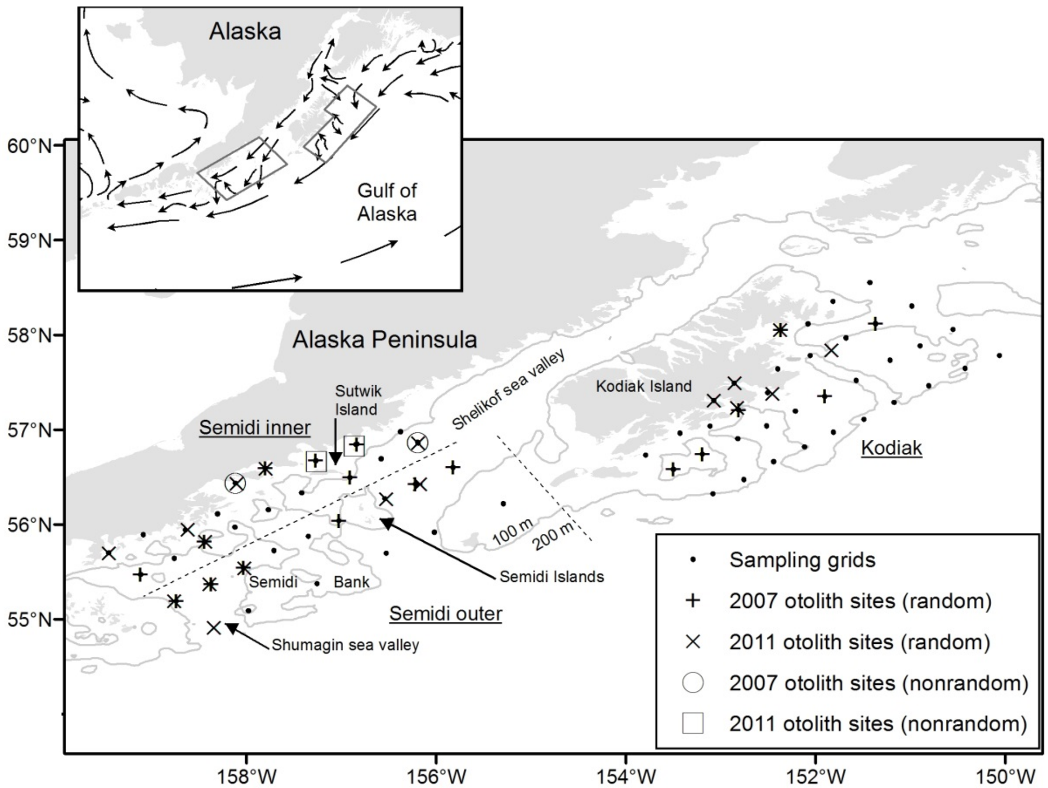

Figure 1. Sampling was conducted over 2 sampling grids (Kodiak and Semidi) in the Gulf of Alaska during September 2007 and October 2011 to measure water properties and collect age-0 juvenile walleye pollock. Sites used in statistical analyses (random) are distinguished from non-randomly selected sites (see text). Dotted lines delineate 3 geographic strata: Kodiak, and Semidi inner and outer. Inset shows sampling grids and net current transport vectors (Reed & Schumacher 1986).

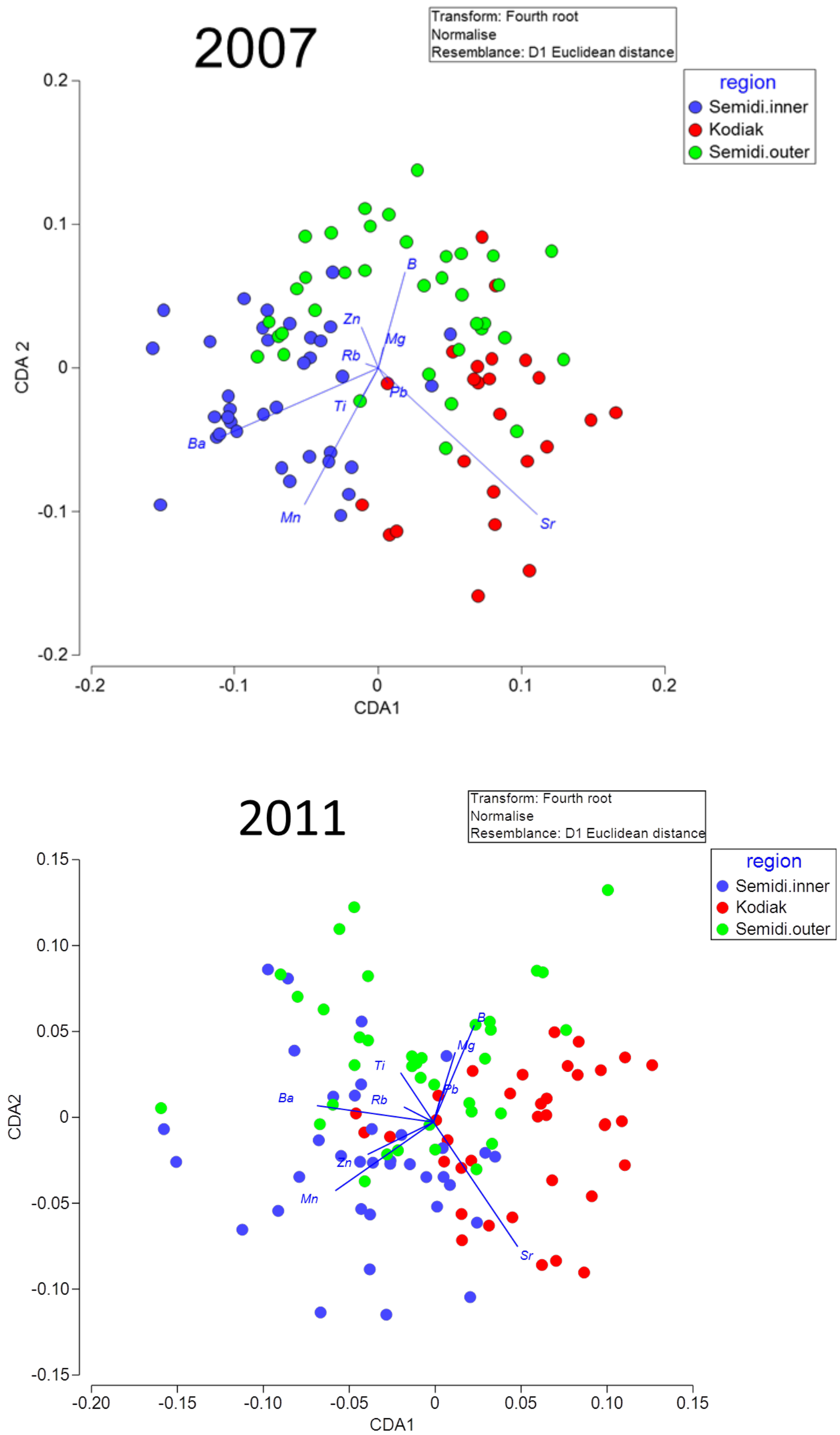

Figure 2. Canonical discriminant analysis (CDA) ordinations of age-0 walleye pollock based on otolith element composition. Fish were collected from 3 regions in the western Gulf of Alaska during September 2007 and October 2011. Vectors indicate correlation between element:Ca ratios and CDA axes.

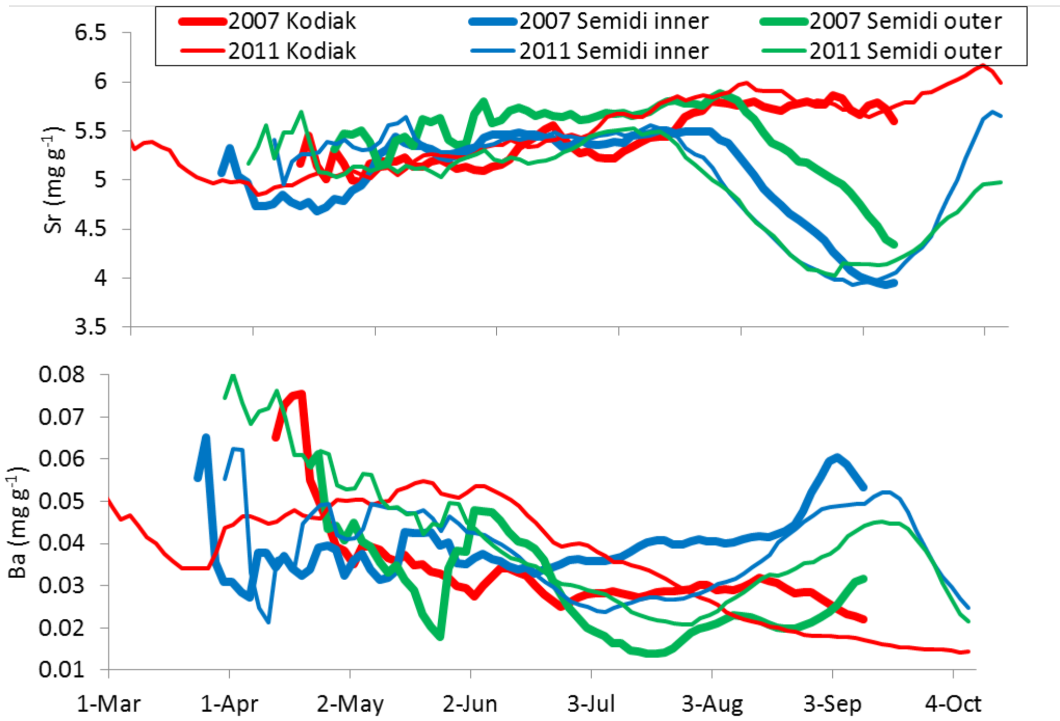

Figure 3. Mean otolith Sr (top) and Ba (bottom) by year and region across 228 age-0 juvenile walleye pollock collected in the western Gulf of Alaska during September 2007 and October 2011. The x-axis, calendar date, was estimated from mean collection date assuming mean daily increment width = 4.5µm (see text).

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

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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*
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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.

<u>References</u>

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

Chang Seung and James Ianelli*
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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.

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2. Stock Assessment

GULF OF ALASKA – REFM
In 1998 the GOA Pollock 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 the unfished level, but declined to 33% by 2016. The spawning stock is projected to increase again in 2017 as the strong 2012 year class starts maturing. The model estimate of female spawning biomass in 2017 is 363,800 t, which is 54.5% of unfished spawning biomass (based on average post-1977 recruitment) and above the $B_{40\%}$ estimate of 267,000 t. The large and unexplained decline in pollock biomass in the 2015 ADFG survey continued in 2016, and thus remains a concern, especially since this time series has shown relatively little variability compared to other indices.

The age-structured assessment model used for GOA W/C/WYAK pollock assessment was modified in the 2016 assessment. The changes included the use of a random effects model for processing the input fishery weight-at-age, and applying a delta-generalized linear model (delta-GLM) to develop a standardized index of abundance from the Alaska Department of Fish & Game (ADFG) trawl survey. The 2016 assessment compared four models to the 2015 model with the new data (Model 15.1a): Model 16.1 as 15.1a but using the random effects model for processing the input fishery weight-at-age, Model 16.2 as 16.1, but applying the delta-GLM to the ADFG survey instead of area-swept biomass, Model 16.3 as 16.2, but with revised Shelikof Strait acoustic survey estimates for net selectivity, and Model 16.4 as 16.2, but with a spatial generalized linear mixed model (GLMM) for the NMFS bottom trawl survey instead of area-swept biomass. Models 16.3 and 16.4 were exploratory at this stage and might be considered as options in future assessments. The authors' recommended final model configuration (16.2) that used the random effects model for processing fishery weight-at-age and the delta-GLM for the ADFG abundance index standardization was used for the 2016 stock assessment.

This year's pollock assessment features the following new data: 1) 2015 total catch and catch-at-age from the fishery, 2) 2016 biomass and age composition from the Shelikof Strait acoustic survey, 3) 2015 biomass and age composition from NMFS bottom trawl survey, 4) 2016 biomass and 2015 age composition from the ADFG crab/groundfish trawl survey, and 5) 2013 and 2015 age compositions from the summer acoustic survey.

Model 16.2 fits to fishery age composition data were reasonable. 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. There were difficulties in fitting the rapid increase in the Shelikof Strait acoustic survey and the NMFS bottom trawl survey in 2013 since an age-structured pollock population cannot increase as rapidly as is indicated by these surveys. The model was unable to fit the extreme low value for the ADFG survey in 2015 and 2016, 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. The addition of the 2016 data point to the age-2 acoustic indices resulted in a large outlier that degraded the fit to the entire time series.

Because the model projection of female spawning biomass in 2017 is above $B_{40\%}$, the W/C/WYAK Gulf of Alaska pollock stock is in Tier 3a. The projected 2017 age-3+ biomass estimate is 1,391,290 t (for the W/C/WYAK areas). Markov Chain Monte Carlo analysis indicated the probability of the stock dropping below $B_{20\%}$ will be negligible in all years. The 2017 ABC for pollock in the Gulf of Alaska west of 140° W longitude (W/C/WYAK) is 203,769 t which is a decrease of 20% from the 2016 ABC. The OFL is 235,807 t for 2017. The 2017 Prince William Sound (PWS) GHL is 5,094 t (2.5% of the ABC). For pollock in southeast Alaska (East Yakutat and Southeastern areas), the ABC for both 2017 and 2018 is 9,920 t and the OFL for both 2017 and 2018 is 13,226 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 1990-2015 bottom trawl survey biomass estimates in Southeast Alaska.

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

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EASTERN BERING SEA - REFM

The female spawning biomass in 2008 was at its lowest level since 1980, but has increased by 152% since then, with a further increase projected for next year, followed by a decreasing trend from projections. The 2008 low was the result of extremely poor recruitments from the 2002-2005 year classes. Recent and projected increases are fueled by recruitment from the very strong 2008 and 2012 year classes (131% and 158% above average, respectively), combined with reductions in average fishing mortality (ages 3-8) from 2009-2010 and 2013-2016. Spawning biomass is projected to be 112% above B_{MSY} in 2017.

New data in this year's assessment include the following:
The 2016 NMFS bottom-trawl survey (BTS) biomass and abundance at age estimates
The 2016 NMFS acoustic-trawl survey (ATS) biomass and abundance at age estimates
Observer data for catch-at-age and average weight-at-age from the 2015 fishery
Updated total catch as reported by NMFS Alaska Regional office 2015 and estimated catch for 2016.

Methodological changes in this year's assessment include the following:
The model was fit to survey biomass rather than survey abundance (numbers of fish)

Sample sizes specified for the robust-multinomial likelihood were revised, based on the "Francis method". The method for estimating current and future year mean body weight at age was improved. For purposes of estimating biological reference points (BRPs) and making projections (but not for estimating historical or current non-BRP parameter values or derived time series), the model was re-run with greater weight given to the prior distribution for the stock-recruitment "steepness" parameter.

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 2.165 million t, up 9% from last year's estimate of 1.984 million t. Projected spawning biomass for 2017 is 4.6 million t, placing EBS walleye pollock in sub-tier "a" of Tier 1. As in recent assessments, 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 0.398, down 1% from last year's value of 0.401. The harvest ratio of 0.398 is multiplied by the geometric mean of the projected fishable biomass for 2017 (7.83 million t) to obtain the maximum permissible ABC for 2017, which is 3.12 million t, up 2% and 13% from the maximum permissible ABCs for 2016 and 2017 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 nine reasons for doing so in the SAFE chapter.

During the period 2010-2013, ABC recommendations were based on the most recent 5-year average fishing mortality rate. Beginning in 2014 it was considered that stock conditions had improved sufficiently warranting an increase in the ABC harvest rate. Specifically, it was recommended the ABC be based on the harvest rate associated with Tier 3, the stock's Tier 1 classification notwithstanding. The Team recommends continuing this approach for setting the 2017 and 2018 ABCs, giving values of 2.800 million t and 2.979 million t, respectively.

The OFL harvest ratio under Tier 1a is 0.526, 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 2017 determines the OFL for 2017, which is 3.640 million t. The current projection for OFL in 2018 given a projected 2017 catch of 1.350 million t is 4.360 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.

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

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 to use for 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 authors 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 biomass estimate based on the average of the three most recent surveys (228,000 t) is used to determine ABC.

The maximum permissible ABC value for 2017 is 97,428 t (assuming M = 0.3 and F_{ABC}= 0.75 x 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.

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F. Pacific Whiting (hake)

G. Rockfish

1. Research

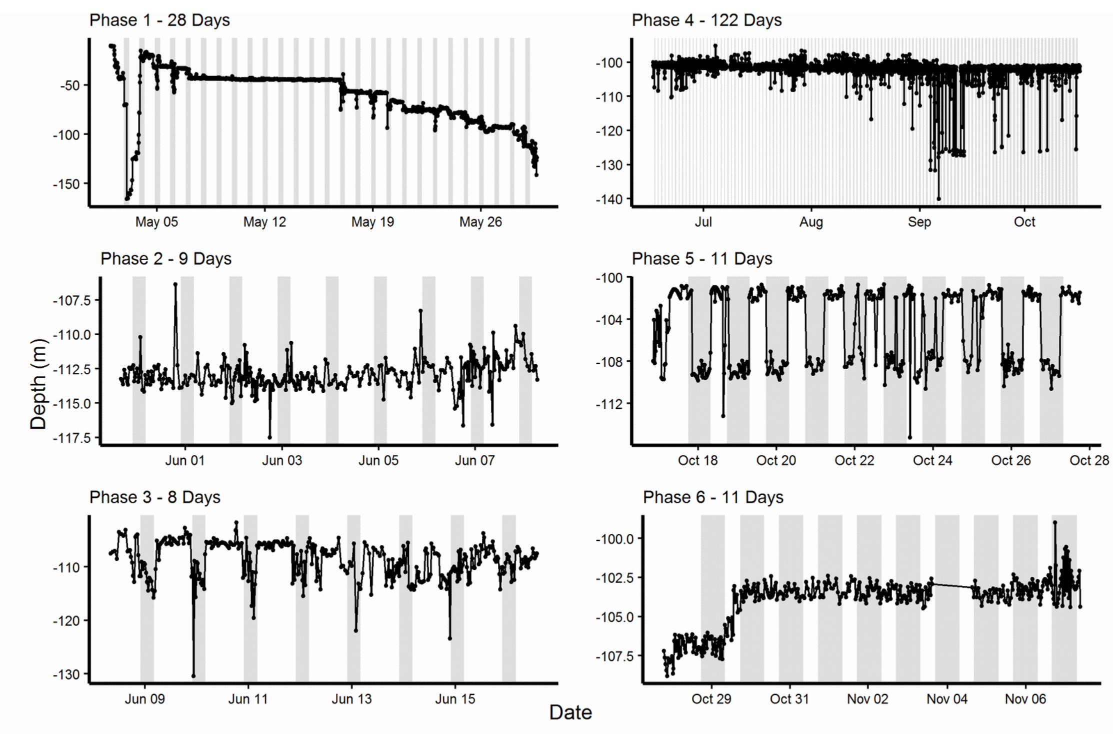
First behavioral observations of a *Sebastes* using pop-up satellite archival tags (PSATs) post

barotrauma – ABL

Pop-up satellite archival tags (PSATs) were deployed on eight blackspotted rockfish (*Sebastes melanostictus*) (37-54 cm fork length) caught at depths from 148-198 m after incurring barotrauma. The six fish released immediately after capture in a weighted cage descended quickly to what was assumed to the bottom depth. Tags ascended to the surface before the preprogrammed pop-up date after only 11-14 days. Two fish were held in captivity for eight months or four years after capture and then released at the surface. One tag came to the surface after only 12 days and a tag deployed on a 37 cm fish was retained for 190 days. Both fish made dives initially and then quickly moved to more shallow depths, indicating that rockfish may require time to acclimate to increased pressure. For the tag that was retained for 190 days, we identified six phases of vertical movement behavior. During the longest phase (123 days) the fish made rapid, 16-39 m dives (sometimes in less than 15 minutes), which were significantly deeper during the day and during high tide. During some of the shorter phases the fish was more sedentary or was deeper at night. Our results show that a Sebastes as small as 37 cm can be tagged with PSATs, if recompression and recovery are allowed to occur in captivity.

For more information contact Cara Rodgveller at (907) 789-6052 or cara.rodgveller@noaa.gov.

Figure: Depth readings from a PSAT deployed on a blackspotted rockfish during six behavioral phases over 190 days. White bars are daytime hours and dark bars encompass the time after sunset and before sunrise.



Alaska rockfish environmental DNA (eDNA) - ABL

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. polyspinus). By collecting water samples in areas of untrawlable habitat, we may be able to identify the presence and absence of rockfish in areas we traditionally cannot sample and ultimately better understand rockfish habitat utilization. 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.

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. Subsequent analyses will determine the concentration of DNA within the water samples and identify individual taxa.

Twenty-eight paired samples (surface and bottom, 56 samples total), 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.

To date, only preliminary laboratory processing has occurred. However, all samples, except for negative controls, contained DNA. The next phase of the analyses will be to identify several broad categories of taxa present in the water samples including phytoplankton, zooplankton, fish, crabs, shrimp, octopus, coral, sponge, otters, and whales, to name a few. Subsequent analyses will further refine the results down to specific species and relate their DNA concentrations to habitat.

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

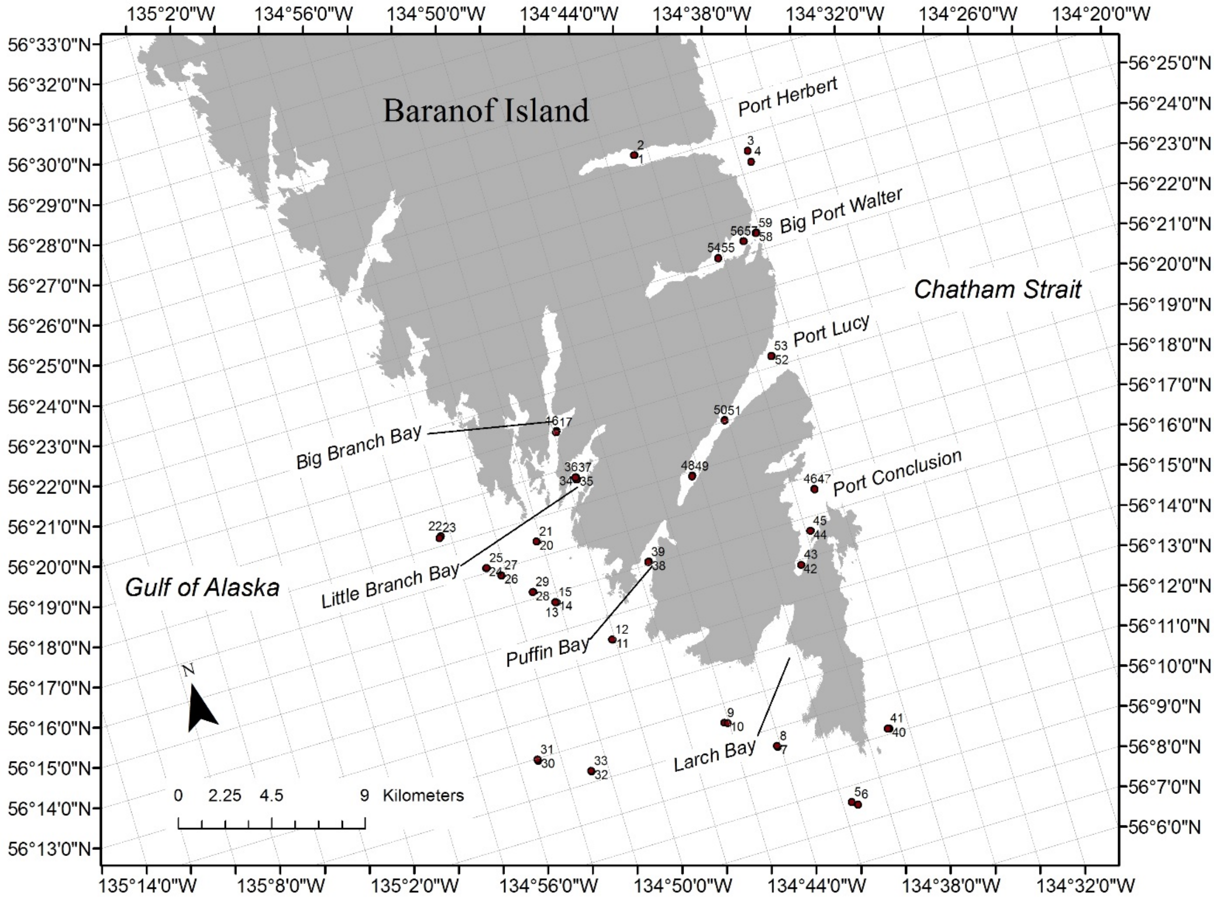


Figure 2. Map of eDNA sampling locations near southern Baranof Island.

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

The contribution of specific habitat types to the productivity of many rockfish species within the Gulf of Alaska remains poorly understood. It is generally accepted that rockfish species in this large marine ecosystem tend to have patchy distributions that frequently occur in rocky, hard, or high relief substrate. The presence of biotic cover (coral and/or sponge) may enhance the value of this habitat and may be particularly vulnerable to fishing gear. Previous rockfish habitat research in the Gulf of Alaska has occurred predominantly within the summer months. This project examined the productivity of the three most commercially important rockfish in the Gulf of Alaska (Pacific ocean perch, *Sebastes alutus*, northern rockfish, *S. polyspinis*, and dusky rockfish, *S. variabilis*) in three different habitat types during three seasons. Low relief, high relief rocky/boulder, and high relief sponge/coral habitats in the Albatross Bank region of the Gulf of Alaska was sampled using both drop camera image analysis and modified bottom trawls. These habitats were sampled at two locations in the Gulf of Alaska during the months of August, May, and December. Differences in density, community structure, prey availability, diet diversity, condition, growth, and reproductive success were examined within the different habitat types. All field work for this project has been completed. Two manuscripts for this project, examining the reproductive productivity and rockfish density and community structure within different habitat types, will be completed within the next year.

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 most commercially important rockfish species including: the rougheye rockfish complex (rougheye and blackspotted rockfish, *S. aleutianus* and *S. melanostictus*), shortraker rockfish, *S. borealis* and other members of the slope complex. 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 2020.

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.

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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.

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2. Assessment

Pacific Ocean Perch (POP) - BERING SEA AND ALEUTIAN ISLANDS - REFM
The survey biomass estimates in the Aleutian Islands were large in 2016 and consistent with the survey biomass estimates in 2010, 2012 and 2014. These continued high survey biomass estimates have contributed to a substantial increase in estimated stock size in recent years. Spawning biomass is projected to be 314,489 t in 2017 and to decline to 307,808 t in 2018. Size composition data continue to show relatively strong recent cohorts.

The current report is a full assessment and contains several important changes to the data and model. The POP assessment had included a fishery CPUE index for the years 1968 - 1977. This index has been removed. The EBS slope survey and associated compositions are now included in the recommended model. Updated data included catch for 2015, estimated catches for 2016 - 2018, 2016 survey biomass estimates for the AI and EBS Slope, and recent age and length compositions. There is also a new recommendation for weighting compositional data.

The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying POP 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 2017 (314,489 t) is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier “a” of Tier 3. The 2017 and 2018 catches associated with the $F_{40\%}$ level of 0.082 are 43,723 t and 42,735 t, respectively, and are the recommended ABCs. The 2017 and 2018 OFLs are 53,152 t and 51,950 t.

ABCs are set regionally based on the proportions in combined survey biomass as follows (values are for 2017): EBS = 11,789 t, Eastern Aleutians (Area 541) = 10,441 t, Central Aleutians (Area 542) = 8,113 t, and Western Aleutians (Area 543) = 13,380 t. The recommended OFLs for 2017 and 2018 are not regionally apportioned. BSAI Pacific ocean perch are not being subjected to overfishing, are not overfished, and are not approaching an overfished condition.

POP - GULF OF ALASKA - ABL

This chapter was presented in executive summary format as a scheduled "off-year" assessment. Full assessments are scheduled to coincide with years when a Gulf of Alaska trawl survey is conducted. Therefore, only the projection model was run, with updated catches. New data in the 2016 assessment included updated 2015 catch and estimated 2016 and 2017 catches. No changes were made to the assessment model.

Spawning biomass was above the *B40%* reference point and projected to be 156,563 t in 2017 and to decrease to 156,444 t in 2018. The SSC has determined that reliable estimates of *B40%, F40%,* and *F35%* exist for this stock, thereby qualifying Pacific ocean perch for management under Tier 3. The current estimates of *B40%, F40%,* and *F35%* are 114,131 t, 0.102, and 0.119, respectively. Spawning biomass for 2017 is projected to exceed *B40%*, thereby placing POP in sub-tier "a" of Tier 3. The 2017 and 2018 catches associated with the *F40%* level of 0.102 are 20,806 t and 20,201 t, respectively, and were the authors' and Plan Team's recommended ABCs. The 2017 and 2018 OFLs are 27,826 t and 27,284 t.

A random effects model was used to set regional ABCs based on the proportions of model-based estimates for 2017: Western GOA = 2,679 t, Central GOA = 16,671 t, and Eastern GOA = 4,568 t. The Eastern GOA is further subdivided into West (called the West Yakutat subarea) and East (called the East Yakutat/Southeast subarea, where trawling is prohibited) of 140° W longitude using a weighting method of the upper 95% confidence of the ratio in biomass between these two areas. For W. Yakutat the ABC in 2017 is 2,786 t and for E. Yakutat/Southeast the ABC in 2017 is 1,782 t. The recommended OFL for 2017 is apportioned between the Western/Central/W. Yakutat area (25,753 t) and the E. Yakutat/Southeast area (2,073 t). Pacific ocean perch is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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GOA Dusky Rockfish Assessment - ABL

Dusky rockfish, *Sebastes variabilis*, have one of the most northerly distributions of all rockfish species in the Pacific. They range from southern British Columbia north to the Bering Sea and west to Hokkaido Is., Japan, but appear to be abundant only in the Gulf of Alaska (GOA).

Rockfish in the GOA are assessed on a biennial stock assessment schedule to coincide with the availability of new AFSC biennial trawl survey data. In 2016, an executive summary assessment was produced as there was no new trawl survey information available. For dusky rockfish, which are assessed using a single-species age-structured model, we run only the projection model with updated catch to determine ABC and the overfishing level (OFL).

For the 2017 GOA fishery, a maximum allowable ABC for dusky rockfish was set at 4,278 t. This ABC is 9% lower than the 2016 ABC but similar to the 2017 projected ABC from 2015. The decrease in ABC is supported by a decline in the trawl survey biomass estimate in 2015 from 2013. A new trawl survey biomass is expected in 2017. The stock is not overfished, nor is it approaching a condition of being overfished.

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Northern Rockfish - BERING SEA AND ALEUTIAN ISLANDS - REFM
Survey biomass was sharply down in 2016 in the Aleutian Islands and slope, but was down from a high biomass estimate in 2014 and more similar to the 2012 survey estimate. Spawning biomass has been increasing slowly and almost continuously since 1977 until recent years, when it appears to be leveling off. Female spawning biomass is projected to be 107,660 t and 106,184 t in 2017 and 2018, respectively. Recent recruitment has generally been below average with few large year classes since 1998.

This chapter is a full assessment as there were surveys conducted in the Aleutian Islands, Bering Sea shelf and slope. The authors explored several different alternative models. Updated data included catch for 2015, estimated catches for 2016 - 2018, a new survey biomass estimate from the AI, and recent age and length compositions. A new approach to weighting the compositional data was also explored.

The SSC has determined that this stock qualifies for management under Tier 3 due to the availability of reliable estimates for $B_{40\%}$ (65,870 t), $F_{40\%}$ (0.065), and $F_{35\%}$ (0.080). Because the projected female spawning biomass of 107,660 t is greater than $B_{40\%}$, sub-tier "a" is applicable, with maximum permissible $F_{ABC} = F_{40\%}$ and $F_{OFL} = F_{35\%}$. Under Tier 3a, the maximum permissible ABC for 2017 is 13,264 t, the value recommended for the 2017 ABC. Under Tier 3a, the 2017 OFL is 16,242 t for the Bering Sea/Aleutian Islands combined. The F_{abc} decreased 7.1% from the 2014 assessment (from 0.070 to 0.065), which is attributed to a 6.1% decrease in the estimate of natural mortality (from 0.049 to 0.046). Management of this stock continues to use a combined BSAI OFL and ABC: 2017 ABC is 13,264 t and the 2017 OFL is 16,242 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
This chapter was presented in executive summary format, as a scheduled "off-year" assessment as full assessments are scheduled to coincide with years when a Gulf of Alaska trawl survey is conducted. Therefore, only the projection model was run, with updated catches. New data in the 2016 assessment included updated 2015 catch and estimated 2016 and 2017 catches. No changes were made to the assessment model.

Spawning biomass is above the *B40%* reference point and projected to be 29,198 t in 2017 and to decrease to 27,344 t in 2018. The SSC has determined that reliable estimates of *B40%, F40%,* and *F35%* exist for this stock, thereby qualifying northern rockfish for management under Tier 3. The current estimates of *B40%, F40%,* and *F35%* are 27,983 t, 0.062, and 0.074, respectively. Spawning biomass for 2017 is projected to exceed *B40%*, thereby placing northern rockfish in sub-tier "a" of Tier 3. The 2017 and 2018 catches associated with the *F40%* level of 0.062 are 3,214 t and 2,923 t, respectively, and were the authors' and Plan Team's recommended ABCs. The recommended 2017 and 2018 OFLs were 4,522 t and 4,175 t.

A random effects model was used to set regional ABCs based on the proportions of model-based estimates for 2017: Western GOA = 432 t, Central GOA = 3,354 t, and Eastern GOA = 4 t (note that the small ABC in the Eastern GOA is included with 'other rockfish' for management purposes). The recommended OFL for 2017 and 2018 is not regionally apportioned. Northern rockfish is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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Shortraker Rockfish - BERING SEA AND ALEUTIAN ISLANDS - REFM
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 survey 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 survey CVs at 0.23 and 0.26, respectively. The random effects model estimate of 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 of biomass estimates 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.

2016 was a full assessment year for this Tier 5 stock; there were no changes in the assessment methodology. 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 2017 biomass estimate was based on the random effects model and ABC was set at the maximum permissible level under Tier 5, where F_{ABC} is 75 percent of *M*. The accepted value of *M* for the shortraker rockfish stock is 0.03, resulting in a *max* F_{ABC} value of 0.0225. This value corresponds to an ABC of 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. A straightforward update of the assessment was presented in an executive summary because the GOA survey was not conducted in

2016. Catch data were updated.

Shortraker rockfish have always been classified into “Tier 5” in the North Pacific Fishery Management Council’s (NPFMC) definitions for ABC and overfishing level, in which a random effects model is applied to the GOA trawl survey biomass estimates from 1984-2015 to estimate exploitable biomass and determine the recommended ABC. For an off-cycle year, there is no new survey information for shortraker rockfish; therefore, the 2015 estimates are rolled over to 2016. Estimated shortraker biomass is 57,175 mt, which is identical to the 2015 assessment biomass estimate. The NPFMC’s Tier 5 ABC definitions state that $F_{ABC} \leq 0.75M$, where M is the natural mortality rate. Using an M of 0.03 and applying this definition to the exploitable biomass of shortraker rockfish results in a recommended ABC of 1,286 t for the 2017 fishery. Gulfwide catch of shortraker rockfish was 578 t in 2015 and estimated at 704 t in 2016. Shortraker rockfish in the GOA are 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.

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Blackspotted/rougheye Rockfish Complex - BERING SEA AND ALEUTIAN ISLANDS - REFM

Spawning biomass for BSAI blackspotted/rougheye rockfish in 2017 is projected to be 7,305 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 Aleutian Islands (2016) increased substantially from the low estimate in 2014, and is more consistent with the level of Aleutian Islands survey estimates since 1991. The 2016 trawl survey biomass estimate from the slope survey is the lowest observed in the time-series since 2002.

The 2016 SAFE report is a full assessment where a Tier 3 age-structured model is applied to the BSAI whereas previously the model was only used for the AI portion of the assessment. The new model includes the EBS Slope survey and associated age and length composition data. New data included updated catch for 2015, estimated catches for 2016 - 2018, a 2016 survey biomass estimate for the AI, and recent length and age composition data. Because some stations could not be surveyed in the 2016 EBS slope survey, the assessment utilizes previous slope surveys, through 2012.

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 2017 of 7,305 t is less than $B_{40\%}$, (8,311 t) the stock qualifies as Tier 3b and the adjusted $F_{ABC} = F_{40\%}$ values for 2017 and 2018 are 0.039 and 0.044, respectively. The maximum permissible ABC for the Aleutian Islands is 501 t, which is the authors’ and Team’s recommendation for the AI portion of the 2017 ABC. The apportionment of 2017 ABC to subareas is 207 t for the Western and Central Aleutian Islands and 294 t for the Eastern Aleutian Islands and Eastern Bering Sea. The overall 2017 ABC of 501 t and a 2017 OFL of 612 t is recommended.

Blackspotted/rougheye Rockfish Complex - GULF OFALASKA - 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. Rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska rockfish in off-cycle years, we usually we present an executive summary to recommend harvest levels for the next two years.

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

There were no changes made to the assessment model or model inputs since this was an off-cycle year. New data added to the projection model included an updated 2015 catch estimate (550 t) and new catch estimates for 2016-2018. The 2016 catch was estimated by calculating an expansion factor and resulted in an estimated catch for 2016 of 628 t. To estimate future catches, we updated the yield ratio to 0.52, which was the average of the ratio of catch to ABC for the last three complete catch years (2013-2015). This yield ratio was multiplied by the projected ABCs from the updated projection model to generate catches of 685 t in 2017 and 668 t in 2018.

For the 2017 fishery, we recommend the maximum allowable ABC of 1,327 t from the updated projection model. This ABC is very similar to last year's ABC of 1,328 t and slightly more than last year's projected 2017 ABC of 1,325 t. The stock is not being subject to overfishing, is not currently overfished, nor is it approaching a condition of being overfished.

Gulfwide catch of rougheye and blackspotted rockfish remains relatively stable in all areas, with some decrease in the longline fisheries and increase in the trawl fisheries in 2016. The majority of the RE/BS rockfish catch remains in the rockfish and sablefish fisheries. The 2016 longline survey abundance estimate (relative population number or RPN) decreased about 22% from the 2015 estimate and is slightly below the long-term mean. Estimates by area were all consistently down with the largest decrease in the East Yakutat/Southeast Outside region.

A full stock assessment document with updated assessment and projection model results will be presented in next year's Stock Assessment and Fishery Evaluation (SAFE) report.

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H. Thornyheads

1. Research

Shortspine Thornyhead Tagging – ABL

The Alaska Fisheries Science Center (AFSC) of the National Marine Fisheries Service (NMFS) has been tagging shortspine thornyhead (*Sebastolobus alascanus*, SST) in offshore waters aboard chartered commercial vessels during the NMFS annual AFSC Longline Survey in Alaska waters since 1992. Tagging of SST first occurred in 1992, but was not consistently done until 1997. Tagging has included conventional anchor tags and internally implanted electronic archival tags.

Since 1992, 13,694 SST have been tagged with conventional anchor tags and a total of 227 tagged SST have been recovered. The majority of recovered tags have been caught using commercial longline gear (160 tags), 38 tags have been recovered on trawl gear, and 1 in a trap. Fifty of the 227 total recovered tags have been caught on research surveys (all on the NMFS annual AFSC Longline Survey). The majority of tag recoveries have been from the Central (75 tags) and Eastern (83 tags) GOA.

The great circle distance traveled by a tagged SST ranges from <1 nm to 990 nm. Of the returned tags with reliable position information, 19% had traveled < 2 nm between tagging and recovery, 36% traveled 2 – 5 nm, 18% traveled 6 - 10 nm, 12% traveled 11 – 50 nm, 4% traveled 51 – 100 nm, and 11% traveled > 100 nm. The average distance traveled was 46 nm, with no apparent difference in travel distance by sex (male = 49 nm and female = 44 nm). It is important to note that an error of up to 5 nm can be expected based on the difference in location between where the AFSC longline survey gear was set (official release location) and where the fish was actually tagged and released.

There appears to be no relationship between fish size at release and movement. The average distance traveled was greatest (95 nm) for the largest size group (>400 mm), but a fish from the smallest size group (<330 mm) traveled the farthest maximum distance (990 nm). Note that these are arbitrary size breaks based on the quantity of data available data by size and size groups were not chosen for biological reasons. All fish tagged are >270 mm and are, therefore, assumed to be mature.

While the majority of tagged SST showed little to no movement (i.e., 73% of tagged recoveries traveled less than 10 nm), there have been some long-distance movements, and some fish crossed management and international boundaries. There appears to be an inclination for a SST to move in an east/southeast direction, and a number of recoveries occurred in British Columbia (BC), Canada, particularly near Queen Charlotte Island. The majority of recovered SST, however, remained within their management area of release. Shortspine thornyhead that were tagged and released in the Eastern GOA were more inclined to move than SST tagged in any other area. Of the 102 recoveries that were released in the Eastern GOA, 76% remained within the Eastern GOA, 18% were recovered in BC, 5% were recovered in the Central GOA, and 1% were recovered on the U.S. West Coast (WC).

Nearly half (48%) of the 153 fish with reliable size information at recovery showed no change in length (39 fish) or a decrease in length (35 fish). These zero growth fish ranged in time at liberty between 33 days and almost 14 years, reiterating that SST exhibit extremely slow growth. It appears that larger fish are more prone to show negative growth; 34 of the 35 fish showing negative growth were >330 mm, and the largest decreases (>100 mm) in length were by fish >400 mm. Additionally, nearly a quarter (23%) of the fish exhibiting negative growth were recovered in BC. Fish with negative growth have been documented by recoveries on NMFS research vessels and by observers on commercial fishing vessels, where accurate length measurements are expected. Ten of the 89 tagged SST recovered on NMFS research vessels or by observers showed a decrease in size.

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2. Stock Assessment

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. A straightforward update of the assessment was presented in an executive summary because the GOA survey was not conducted in 2016. Catch data were updated.

Gulf of Alaska thornyheads (genus *Sebastolobus*) are assessed as a stock complex under Tier 5 criteria in the North Pacific Fishery Management Council's (NPFMC) definitions for allowable biological catch (ABC) and overfishing level (OFL). For thornyheads in the GOA, a random effects model is applied to the GOA trawl survey biomass estimates from 1984-2015 to estimate a time series of exploitable biomass and to determine the recommended ABC. Estimated thornyhead biomass is 87,155 mt. 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 $F_{ABC} \leq 0.75M$, where M is the natural mortality rate. Using an M of 0.03 and applying this definition to the exploitable biomass of thornyhead rockfish results in a recommended ABC of 1,961 t for the 2017 fishery. Gulfwide catch of thornyhead rockfish was 1,033 t in 2015 and estimated at 984 t in 2016. Thornyhead rockfish in the GOA are not being subjected to overfishing. It is not possible to determine whether this complex is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

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I. Sablefish

1. Research

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 2016. Total sablefish tag recoveries for the year were around 800. Twenty-four percent of the recovered tags in 2016 were at liberty for over 10 years. About 36 percent of the total 2016 recoveries were recovered within 100 nautical miles (nm; great circle distance) from their release location, 35 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 37 years, and the greatest distance traveled of a 2016 recovered sablefish tag was 2,364 nm. Three adult sablefish and nine juvenile sablefish tagged with archival tags were recovered in 2016. Data from these electronic archival tags, which will provide information on the depth and temperature experienced by the fish, are still being analyzed.

Tags from shortspine thornyheads, Greenland turbot, Pacific sleeper sharks, lingcod, spiny dogfish, and rougheye rockfish are also maintained in the Sablefish Tag Database. Twenty-two thornyhead and 3 Greenland turbot (one conventional and two archival tags) were recovered in 2016.

Releases in 2016 on the groundfish longline survey totaled 3,364 adult sablefish, 766 shortspine thornyheads, and 2 Greenland turbot. Pop-up satellite tags (PSAT) were implanted on 13 sablefish.

An additional 961 juvenile sablefish were tagged during an additional cruise in 2016.

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Juvenile Sablefish Studies – ABL

Juvenile sablefish studies have been conducted by the Auke Bay Laboratories in Alaska since 1984 and were continued in 2016. A total of 972 juvenile sablefish were caught, tagged, and released in St. John Baptist Bay and Silver Bay, near Sitka, AK, over 4 days (July 13th – July 16th) with 100 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 9.72 sablefish per rod hour fished. This was up significantly from 2015 (4.91), and higher than the recent high catch in 2011 (7.63). The mean length of sablefish was considerably smaller in 2016 compared to the recent time period despite being a fairly similar time of the year for sampling and we noted the fish seemed undernourished.

In addition to the annual juvenile sablefish tagging near Sitka, two days (9/1 – 9/2/2016) were spent sampling various bays around Kodiak Island. This tagging cruise in the Central Gulf of Alaska (CGOA) was conducted as follow up to compare with the highly successful 2015 CGOA juvenile tagging. Rare reports Gulfwide of juvenile sablefish catches in the summer of 2015 led to two days sampling off Kodiak Island (8/24 – 8/25/2015) that resulted in one of the highest seen CPUEs in the time series of juvenile sablefish tagging. No juvenile sablefish were caught during the 2016 sampling. This result is interesting, as numerous reports of large juvenile sablefish catches were reported in the Eastern Gulf of Alaska in both 2015 and 2016, but only in the CGOA in 2015.

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Sablefish Archival Tagging Study - ABL

During the 1998, 2000, 2001, and 2002 AFSC longline survey, 600 sablefish were implanted and released with electronic archival tags that recorded depth and temperature. These archival tags provide direct insight into the vertical movements and occupied thermal habitat of a fish. 127 of these tags have been recovered and reported from commercial fishing operations in Alaskan and Canadian waters. Analysis of these data began in 2011 continued in 2012 and 104 of these tags have been analyzed to date. Temporal resolution of depth and temperature data ranged from 15 minutes to one hour, and data streams for an individual fish ranged from less than a month to greater than five years. After a hiatus during 2013-2015, data analysis resumed in 2016. A manuscript is anticipated for 2017.

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Sablefish Satellite Tagging - ABL

The fifth year of extensive tagging of sablefish with pop-up satellite tags (PSATs) was conducted on the AFSC annual longline (LL) survey in 2016. Pop-off satellite tags were deployed on 13 sablefish throughout the Gulf of Alaska (GOA) and the Aleutian Islands (AI) to study daily and large-scale movements. These tags were programmed to release from the fish 1 January 2017 and 1 February 2017, in hopes of determining spawning locations and ultimately areas which may be used to help assess recruitment. Data from these tags will also provide an improved picture of the daily movements and behavior patterns of sablefish. The 2016 released tags join the 78 tags that were released in the GOA, AI, and Bering Sea (BS) on the LL Survey during 2012 -2015. This work is still in the early stages of analysis, it is still too early to determine if there is any directed movement by sablefish for spawning purposes. Admittedly, tags should be programmed to remain on the fish for an entire year in order to determine if sablefish are exhibiting any homing behavior for spawning purposes. Ideally, the fish would be tagged just before the spawning season in the winter and programmed to release the following winter during the spawning season. However, having the release location of the tag and the pop up location (location of the fish when the tag released) has provided great insight into (relatively) short term and winter behavior of sablefish.

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Can future spawning of female sablefish be determined in the summer in the Gulf of Alaska? – ABL

It is preferable to gauge maturity when fish that will spawn have oocytes in advanced stages of vitellogenesis. For sablefish the spawning season is estimated to peak in February or March. However, typical sampling platforms, such as the NMFS bottom trawl and longline surveys in Alaska, are available only June through August. This encompasses the time in the reproductive cycle when fish are either resting or beginning to develop. Macroscopic evaluations of sablefish ovarian development have been collected on NMFS longline surveys in Alaska since 1996. Thus far, maturity data have not been validated using histology and have not been used for assessment.

In 2015, 588 female sablefish were collected on the longline survey in the central and eastern Gulf of Alaska (Figure 1) in July and August. All sablefish were aged, livers weights were collected, maturity was classified at-sea, and ovarian tissues were prepped for a microscopic evaluation. Ovaries containing oocytes in advanced cortical alveoli (CA) stage or in vitellogenesis were considered to be maturating towards spawning in the coming season. Microscopically, fish that were predicted to skip spawning lacked developing oocytes, had a thick ovarian wall, thick tissue within the ovary, and veins within the ovary. (The advanced CA stage was chosen a cut-off because fish previously sampled in December that would skip spawning contained oocytes that were in earlier stages of development [perinucleolar or early CA]).

We found that ovaries were at a wide variety of developmental stages, indicating some ovaries that were just beginning to develop and some may not have initiated development yet. Even though I have concerns about the accuracy of maturity classifications of immature and skip spawning fish in the summer months, we examined age at maturity curves for a comparison of methodology and geographic areas (survey leg). The discrepancies in age at maturity between macroscopic and microscopic methodology varied on each survey leg (Figures 1 and 2). In addition, when using only one method for maturity classification, age at maturity curves varied by leg (Figure 2). The results indicate that 1) summer data may not provide accurate results even if microscopic methods are employed and 2) that there may be variation in maturity throughout the Gulf of Alaska, which deserves further study in the future.

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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.

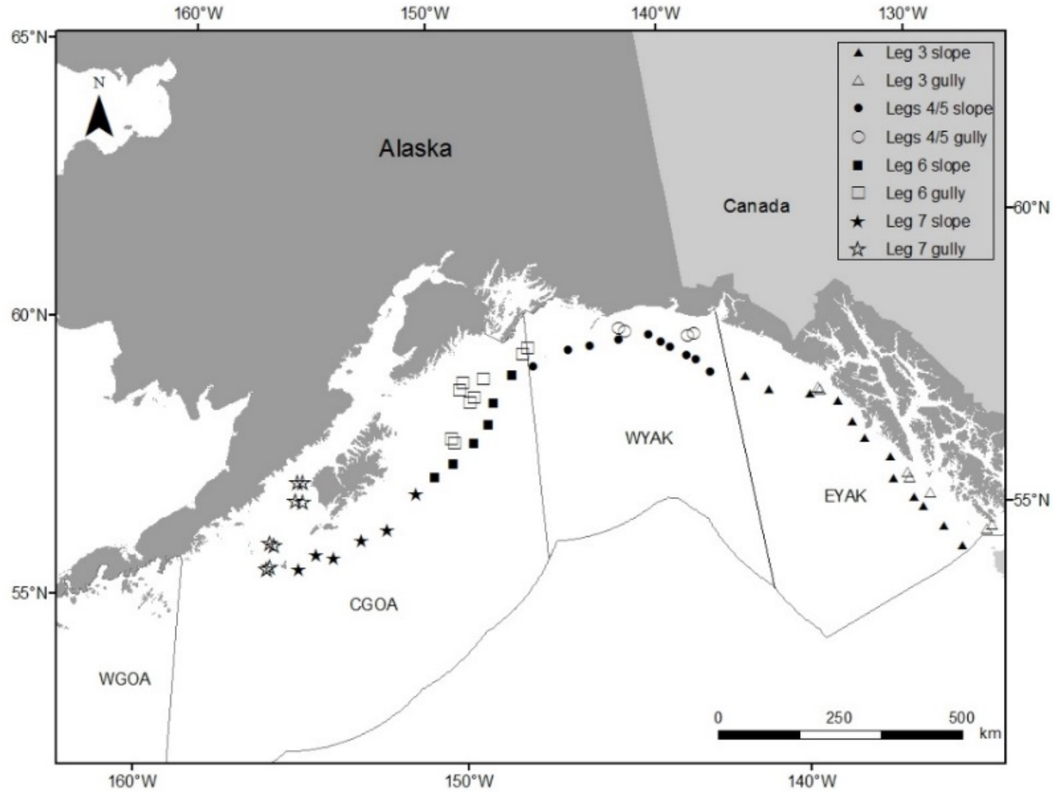
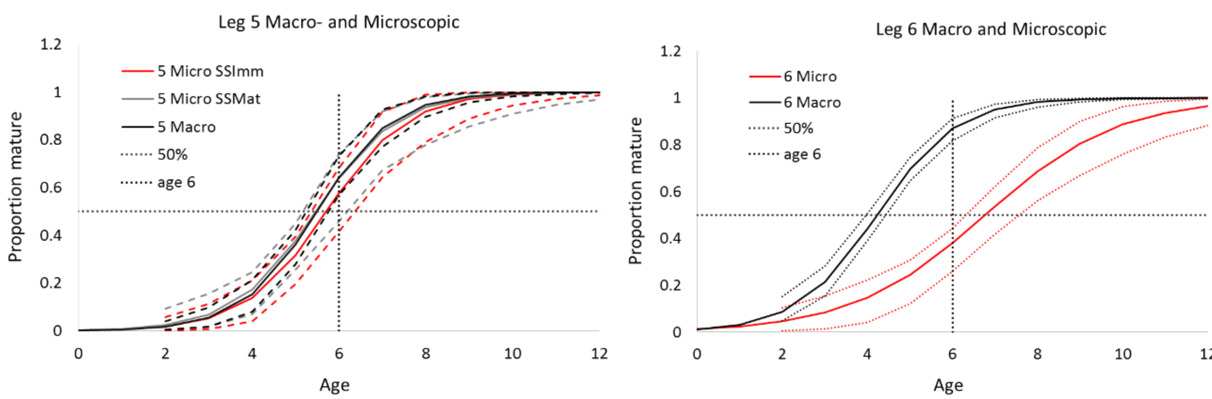


Figure 2. Age at maturity on legs 5 or 6 when maturity was determined with either macroscopic or microscopic methods. Fish that were assumed to skip spawning were either classified as immature (SSImm) or mature (SSMat); no skip spawning fish were identified on leg 6. The lines at age 6 and 50% maturity are included as points of reference.



A second year of sampling sablefish in the central Gulf of Alaska prior to spawning – ABL
Female sablefish were sampled in December of 2011 for a study of age at maturity immediately before the spawning season near Kodiak Island, which is near the center of their Alaska distribution. Skipped spawning was documented in sablefish for the first time. Skip spawning fish could be identified on histology slides by the combination having only immature oocytes, a much thicker ovarian wall than immature fish, a thick tissue (stroma) separating oocytes, and veins within the ovarian tissue. In 2015 nearby locations and some of the same sites were sampled for the second

time for a measure of skipped spawning rate and age at maturity. There were many fewer skip spawning fish in 2015, even in cross-shelf gullies where they were most prevalent in 2011. In 2015, sablefish were absent at these locations. This may indicate that skip spawning fish aggregate in gullies and spawning fish aggregate on the continental slope. In age at maturity curves skipped spawning fish were either included as "immature" or "mature", creating two separate curves in each year. This is not the only way to model skip spawning in age at maturity curves, but the method was chosen until more data on skip spawning rates by age are available. In 2011, when skipped spawning was more prevalent, classifying them as immature increased the A_{50} substantially compared to when they were considered mature. In 2015 the two curves were virtually identical due to a small number of skipped spawning fish. It is likely that skip spawning rates vary by year depending on the environment and fish condition. The age at maturity will vary depending on the prevalence of skip spawning and its relationship with age.

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	A_{50}	
	Skip Spawn Immature	**Skip Spawn Mature**
2011	9.9	6.8
2015	7.5	7.3

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

Description of indicator: Biophysical indices from surveys and fisheries in 2014 and 2015 were used to predict the recruitment of sablefish to age-2 in 2016 and 2017 (Yasumiishi et al. 2015a). The southeast coastal monitoring project has an annual survey of oceanography and fish in inside and outside waters of northern southeast Alaska (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 (NOAA ABL). 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: Based on a low chlorophyll *a* value in 2014 (3.73) and 2015 (1.12) we expect an abundance of 19.7 million age-2 sablefish in 2016 and below average at 3.8 million age-2 sablefish in 2017. We modeled age-2 sablefish recruitment estimates from 2001 to 2015 (Hanselman et al. 2015) as a function of sea temperature, chlorophyll *a*, and pink salmon productivity during the age-0 stage for sablefish. The model with the lowest Bayesian information critierion (112) described the stock assessment estimates of recruitment of sablefish to age-2 as a function of late August chlorophyll *a* during the age-0 stage (Figure 1; Table 1). A regression model indicated that chlorophyll *a* during the age-0 phase was positively and signficantly correlated with sablefish recruitment (R^2 = 0.59; p-value = 0.0008). Sea temperature and pink salmon productivity fell out of the model with the addition of 4 years of data to the 2016 model compared to the 2015 model

(Yasumiishi et al. 2015b).

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: Late summer chlorophyll *a* in 2014 and 2015 was used to predict the recruitment of Alaska sablefish to age-2 in 2016 and 2017. The model predicts 19.7 million age-2 sablefish in 2016 (average) and below average recruitment of sablefish to age-2 at 3.8 million in 2017.

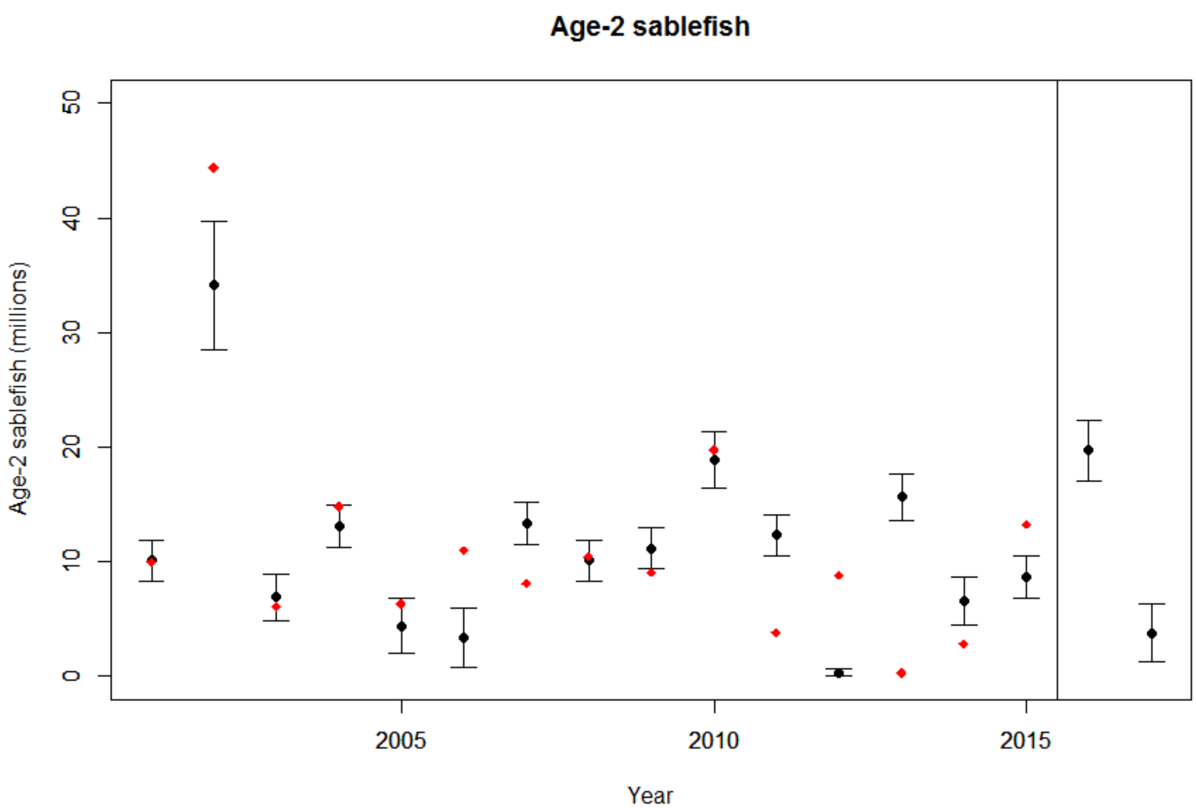

Figure 1. Stock assessment estimates (red), model estimates (black), and the 2016 and 2017 prediction for age-2 Alaska sablefish. Stock assessment estimates of age-2 sablefish were modeled as a function of late August chlorophyll *a* levels in the waters of Icy Strait in northern southeast Alaska during the age-0 stage (*t*-2).

Research conducted by Ellen Yasumiishi, Kalei Shotwell, Dana Hanselman, Joe Orsi, Emily Fergusson.

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Table 1. Nearshore survey data fit to the stock assessment estimates of age-2 sablefish (millions of fish) from Hanselman et al. (2015). Table shows the 2016 model fitted (2001-2015), forecast (2016 and 2017) estimates and standard errors for age-2 sablefish, and the predictor variable (1999-2013).

Year	Stock assessment Estimates Sablefish (t)	Model Fitted and forecast Estimates	Standard error	Predictor variable Chlorophyll a (t-2)
2001	9.98	9.96	2.24	2.15
2002	44.39	33.48	5.14	6.08
2003	6.07	6.85	1.81	1.63
2004	14.83	12.89	1.82	2.64
2005	6.33	4.4	2.1	1.22
200	10.97	3.38	2.55	1.05

6				
2007	8.09	13.13	2.61	2.68
2008	10.44	9.96	1.59	2.15
2009	9.09	11.04	2.46	2.33
2010	19.76	18.58	2.08	3.59
2011	3.84	12.18	2.01	2.52
2012	8.82	0.386	0.386	0.55
2013	0.29	15.4	2.21	3.06
2014	2.82	6.55	4.17	1.58
2015	13.26	8.86	1.7	1.92
2016		19.7	2.64	3.73
2017		3.79	2.49	1.12

Pilot Study of Sablefish (*Anoplopoma fimbria*) Larval Rearing at AFSC-RPP

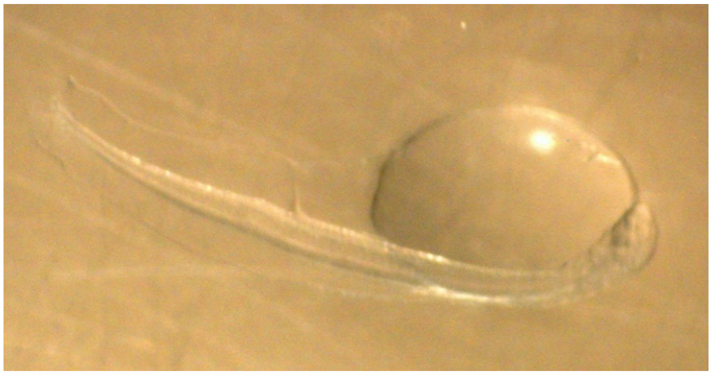
We conducted a pilot study of sablefish larval rearing with the following objectives:

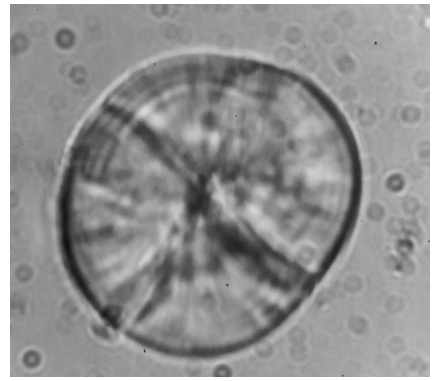
1. Validate daily increment formation in otoliths using alizarin complexone (ALC) staining so that field-collected larvae may be correctly aged for growth studies.
2. Evaluate a cell-cycle based method for assessing condition.
3. Early-life development information (note when specific developmental traits 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 Laboratory at Manchester, WA provided unfertilized eggs from two females (Groups A and B) and milt from three males caught off the coast of Washington. We fertilized the eggs in our lab and kept them in the dark at 5.7°C. Group B eggs died soon after fertilization. The surviving group was reared at 5.7°C until first feeding at which time the temperature was raised to 6.9°C to emulate larvae rising into the surface water. At hatching, a 16 hour light: 8 hour dark light cycle was started and light level was kept low (< 1 µmol photon $m^{-2}s^{-1}$) by using black screen tank covers. Light level was gradually increased between hatching and first feeding by reducing the number of screens covering the tanks. Larvae were on the bottom of the tanks during the time from hatching to shortly after first feeding at which time they rose off the bottom and swam up to the surface. At that time all screens were removed (light level = 10 μmol photon $m^{-2}s^{-1}$).

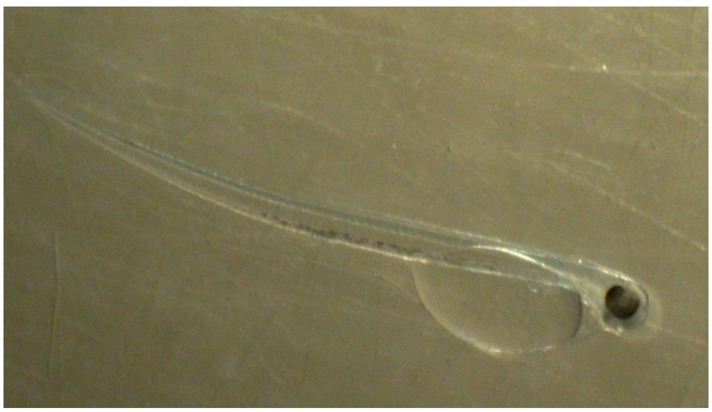
Development at 5.7°C
Fertilization to hatch = 13 days. Approximate size at hatch = 5.00 mm.
Hatch to first feeding = 27 days. Approximate size at first feeding = 8.00 mm.

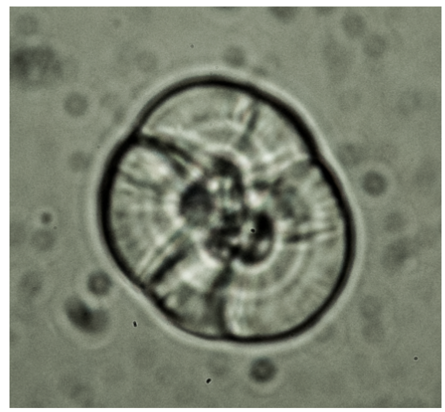
Developmental observations
Hatch: very large yolk, no body or eye pigment, and mouth was not formed, hatch mark formed on otoliths
8 days after hatch: eyes pigmentation starts, larvae were reactive to touch and short bursts of swimming observed, gut was apparent
11 days after hatch: liver forming
12 days after hatch: eye approximately 70% pigmented, anus open
14 days after hatch: dorsal gut pigmentation begins
16 days after hatch: eyes fully pigmented (eyes may be functional at this time)
22 days after hatch: mouth is apparent but not functional
27 days after hatch: first feeding, yolk was still present
30 days after hatch: larvae attracted to light and swim to the surface of the rearing tanks
38 days after hatch: yolk depleted



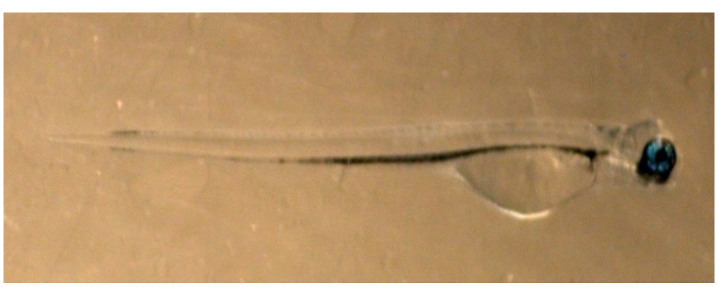


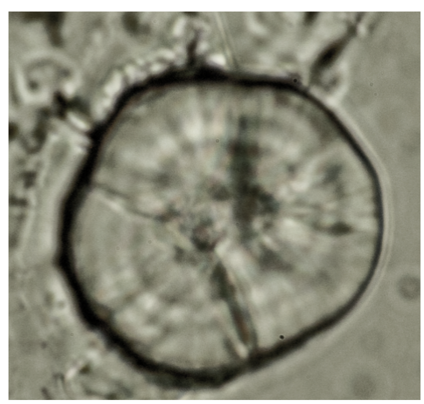
6 days after hatch Otolith Diameter
= 22 µm
SL = 5.85 mm SL = 5.82 mm



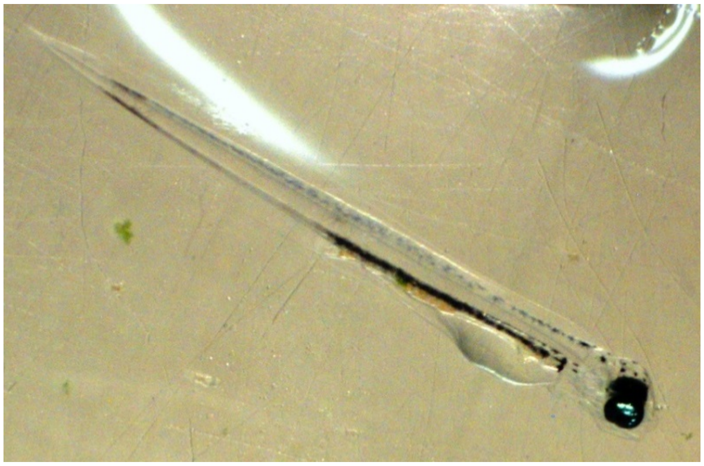


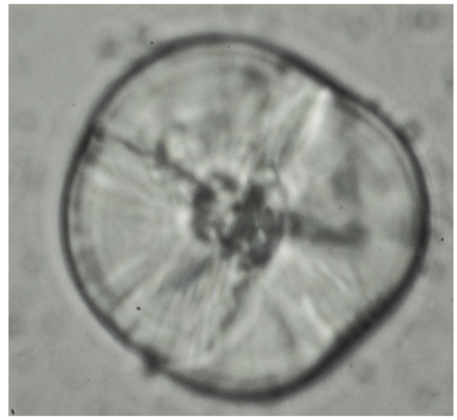
14 days after hatch Otolith Diameter
= 25µm
SL = 7.19 mm SL = 7.11 mm



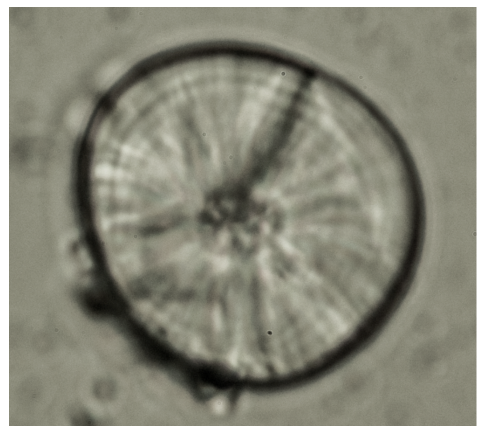


22 days after hatch Otolith Diameter
= 31 µm
SL = 8.03 mm SL = 7.84 mm





28 days after hatch Otolith Diameter = 36 µm
1 day after first feeding SL = 8.65 mm
SL = 7.93 mm



31 days after hatch Otolith Diameter = 34 µm

For further information contact Annette Dougherty and Steve Porter

2. Stock Assessment

BERING SEA, ALEUTIAN ISLANDS, AND GULF OF ALASKA - ABL

A full sablefish stock assessment was produced for the 2017 fishery. We added relative abundance and length data from the 2016 AFSC longline survey, relative abundance and length data from the 2015 longline and trawl fisheries, age data from the 2015 longline survey and 2015 fixed gear fishery, updated 2015 catch, and estimated catches for 2016-2018.

In addition to these usual new data updates, the following substantive new changes were made to the data inputs:

1) New analytical variance calculations for the domestic longline survey abundance index

2) New area sizes for the domestic longline survey abundance index
3) Domestic longline survey estimates corrected for sperm whale depredation
4) Estimates of killer and sperm whale depredation in the fishery

The longline survey abundance index increased 34% from 2015 to 2016 following a 21% decrease from 2014 to 2015 which was the lowest point of the time series. The fishery abundance index decreased 12% from 2014 to 2015 and is the time series low (the 2016 data are not available yet). There was no Gulf of Alaska (GOA) trawl survey in 2016. Spawning biomass is projected to decrease slightly from 2017 to 2019, 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.

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.

Projected 2017 spawning biomass is 35% of unfished spawning biomass. Spawning biomass had increased from a low of 33% of unfished biomass in 2001 to 42% in 2009 and has now stabilized near 35% of unfished biomass projected for 2017. The 1997 year class has been an important contributor to the population; however, it has been reduced and is predicted to comprise 5% of the 2017 spawning biomass. The last two above-average year classes, 2000 and 2008, each comprise 13% and 15% of the projected 2017 spawning biomass, respectively. The 2008 year class will be about 85% mature in 2017.

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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.

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. 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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Coastwide data comparison for sablefish – ABL
Sablefish stock assessments are conducted independently for the US West Coast (California-Oregon-Washington), Canada, and both Alaska State and 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. A data and model comparison effort is underway that will document the differences in the assessment models and available data for each management area. Where possible, estimated recruitment, indices of abundance, and age-specific demographic data such as maturation, length, and weight will be compared across areas. 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 to the review. We hope this project will help foster communication and collaboration across management areas.

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J. Lingcod

K. Atka Mackerel

1. Research

Developing a stereo camera system to survey nearshore Steller sea lion prey fields in the

central and western Aleutian Islands--GAP
RACE groundfish scientists continued research of fish distribution in nearshore Steller sea lion prey fields in untrawlable habitat by conducting underwater surveys using a low cost stereo underwater camera built at the AFSC. Scientists conducted an opportunistic assessment of nearshore fishes during the Steller sea lion count survey aboard the R/V *Tigilax*. Forty-six transects were conducted in three depth strata. Habitat, species composition and size distribution were assessed using the AFSC developed SEBASTES software. All species that were present in the sea lion diets were observed in the camera transects except Pacific salmon and squid. Survey trawl estimates and camera transect estimates seemed compatible at this spatial scale which is the first step in developing this tool as a survey tool for fish in untrawlable grounds.

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

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).

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2. Stock Assessment

Spawning biomass reached a peak in 2005, then decreased continuously through 2016 (a decline of 56%), and is projected to decrease further, at least through 2018. The 1998-2001 year classes were all very strong, but since then, the 2006 and 2007 year classes were the only ones that were above average. In particular, the 2011 year class, which was estimated to be above average in last year’s assessment, is now estimated to be below average. However, the projected female spawning biomass for 2017 (145,258 t) is still above $B_{40\%}$ (125,288 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 2015 year-end catch was updated, and the projected total catch for 2016 was set equal to the 2016 TAC. The 2015 fishery age composition data were added and the biomass estimate from the 2016 AI bottom trawl survey was added. Methodological changes included the following:
In the assessment model: Input sample sizes for compositional data were set proportional to the

number of sampled hauls containing Atka mackerel, rather than the number of sampled Atka mackerel. The average sample sizes (across years) were held constant at the values used in last year's assessment, however. In the projection model the selectivity schedule was set equal to the average of the most recent five years for which model estimates are available, rather than the most recent five years (with the current year set equal to the previous year).

Catches for 2017 and 2018 were assumed to equal 62% of the BSAI-wide ABC, based on an analysis of the effect of the revised Steller Sea Lion Reasonable and Prudent Alternatives that were implemented in 2015, rather than the 80% rate that was used 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 2017 yield (ABC) at $F_{40\%}$ = 0.34 is 87,200 t, down 3% from the 2016 ABC and up 2% from last year's projected ABC for 2017. The projected 2017 overfishing level at $F_{35\%}$ = 0.40 is 102,700 t, down 2% from the 2016 OFL and up 3% from last year's projected OFL for 2017. 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 2017 are 34,890 t for Area 541 and the southern Bering Sea region (a 13 % increase), 30,330 t for Area 542 (and 11 percent increase), and 21,980 t for Area 543 (a 32 % decrease from the 2016 level of 32,292).

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

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L. Flatfish

1. Research

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

This study investigates mechanisms responsible for significant shifts of annual yellowfin sole biomass estimates in the eastern Bering Sea, and provides evidence that temperature-mediated changes in spatial availability (i.e., to the bottom trawl survey) is a major contributor. Yellowfin sole (*Limanda aspera*) distributions in the eastern Bering Sea are known to extend into waters shallower (<30 m) than the bottom trawl assessment survey, where potentially large portions of the biomass are not sampled due to high concentrations of adult fish that are spawning in inshore waters at the time of the survey (June-July). The spawning period is preceded by annual spring migration of adults from deeper shelf waters (>100 m) to nearshore areas of Bristol and Kuskokwim bays (Wakabayashi, 1989).

A portion of the annual variability in annual biomass estimates is explained by a linear relationship with bottom temperature (Nichol, 1997), where biomass has increased with annual temperature. While stock assessment models have incorporated the effect (Wilderbuer et al., 2016), the mechanism has been unclear. Two potential mechanisms behind the temperature effect have been suggested. One is temperature-mediated survey catchability, when under colder conditions, fish escapement under the trawl footrope increases and/or herding by the bridals decreases. The other involves a change in fish availability where temperature affects the timing of inshore spawning migration. In this scenario, during warmer years, the migration occurs earlier in the spring, and spawning is more progressed at the time the survey is conducted. This results in higher percentages of spent adults that have rotated out of unavailable nearshore areas, increasing the overall percentage available to the survey. This research is focused on the latter mechanism.

To test the hypothesis that distributions, and subsequently survey biomass estimates, were affected by the timing of spawning, several analyses were performed. First, we used the 35 year EBS bottom trawl survey time series (Lauth and Nichol, 2013) to plot the summer spatial distributions of yellowfin sole during representative “warm” and “cold” years, doing so separately for immature and mature males and females (maturity based on length). Overall distributions were expected to be shifted farther offshore during warmer years. Second, we examined 8 years of trawl survey CPUE data during which common stations (20 to 34) in Bristol Bay were sampled twice within the same year, once in early June and again in late July. The logic here is that if the timing of spawning affects yellowfin sole availability to the survey, with greater availability when spawning is more complete, then we should observe increases in abundance when stations are sampled later in the season. Furthermore, if males remain on the spawning grounds longer than females, as for other flatfishes (Solmundsson et al., 2003; Hirosi and Minami, 2007), we should observe increased numbers of mature females relative to mature males (e.g., sex-ratio) during the later sampling, owing to higher percentages of spent females that have migrated out of the spawning grounds.

Shifts in distributions between warm and cold years were most prominent among mature females, with concentrations much deeper (>50 m) during the warmer years. Mature males on the other hand were similarly distributed with largest concentrations at the nearshore survey edge both in warm and cold years. Immature males and females were also similarly distributed between warm and cold years. Yellowfin sole were more concentrated during the later July sampling period in all 8 years sampled. These increases included immature and mature males and females, although the largest increases occurred for mature females, both by percent and raw CPUE. In addition, mature females abundance increased at a greater proportion than mature males between early and late samplings in all but one of the eight years.

Further analyses will include the testing of various measures of temperature (i.e., bottom, surface) and winter ice extent to see which measures have the greatest effect on sex-ratio (or female proportion) and estimates of biomass.

For further information, contact Dan Nichol, (206)526-4538, Dan.Nichol@noaa.gov.

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Acoustic characterization of sea floor habitats of northern rock sole using video groundtruthing--GAP

Echoview's bottom classification module was used to analyze 38 kHz Simrad ES60 echosounder data. Random Forest was used to compare the results of the bottom classification to the visual categorization of the same trawl path using camera data. Unfortunately, the majority of samples are a single bottom type which makes results from machine learning techniques suspect. The acoustic data, especially for deeper stations, suffers from substantial interference from a second sounder that was left on during sampling; quantifying or removing the interference will be required before moving forward with the project.

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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 habitat of juvenile yellowfin sole (*Limanda aspera*; YFS) and northern rock sole (*Lepidopsetta polyxystra*; NRS).

The objective of the project in 2016 was to examine latitudinal differences in habitat quality and in the growth and condition of the juvenile flatfishes. In general, the distribution of the juveniles in the EBS ranged from the Alaska Peninsula in the south to Nunivak Island in the north, in inner-shelf waters ≤50 m deep. 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 the population appeared to have shifted south towards Bristol Bay ("south" habitat). It is unknown whether YFS juveniles followed a similar pattern. During the 2016 bottom trawl survey, a 3-m beam trawl was used to sample juvenile flatfish (≤17 cm TL) and a 0.1 m^2 van-Veen-type benthic grab was used to sample the infauna prey and sediments at selected shallow, coastal stations in the north and south habitats.

Based on the composition of the main prey taxa and their respective caloric values, the north habitat had generally lower energy available to juvenile flatfish than the south. Juvenile diets were similar interspecifically and between north and south habitats, and all showed high electivity for prey and spatial mismatch with prey composition that suggested that prey availability was not limiting

(Yeung and Yang, 2017). The distribution and body condition of the juveniles were not spatially correlated with the prey field, and condition was not significantly different between north and south. The putative age-0 fish were mostly found in the south, and juveniles were significantly larger at age in the south than in the north. These preliminary results showed that the north and south habitats had similarly suitable prey environment, arguing for physical environmental conditions, most prominently temperature and currents being the principal drivers of juvenile distribution.

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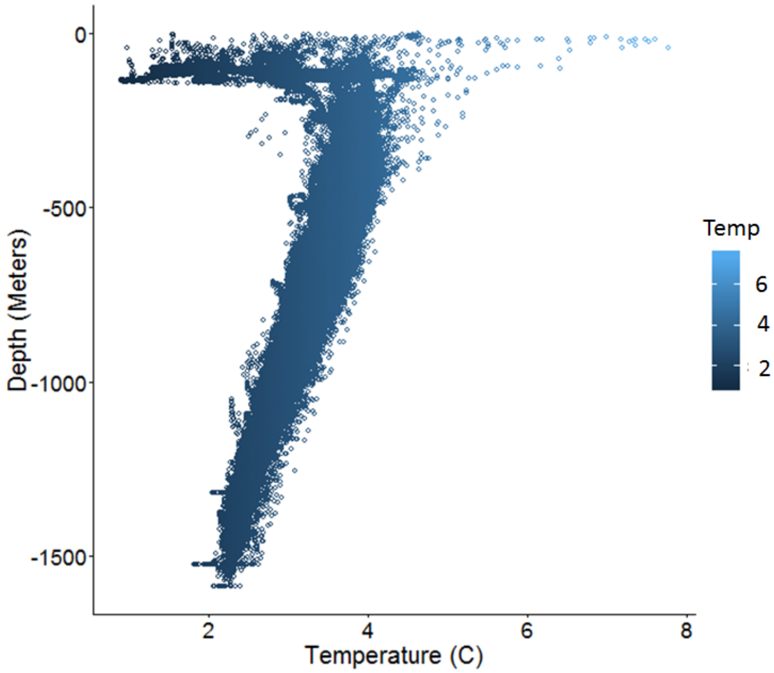
Yeung, C., Yang, M.-S., 2017. Habitat quality of the coastal southeastern Bering Sea for juvenile flatfishes from the relationships between diet, body condition and prey availability. Journal of Sea Research 119, 17-27.

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.



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2. Assessment

Yellowfin sole Stock Assessment - BERING SEA - REFM
The 2016 EBS bottom trawl survey resulted in a biomass estimate of 2.66 million t, compared to the 2015 survey biomass of 1.93 million t (an increase of 10 percent). 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 (1.8 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 as strong as any observed since 1983 and the 2006 is also an above average contributor to the reservoir of female spawners. The 2016 catch of 130,500 t represents the largest flatfish fishery in the world and the five-year average exploitation rate has been 6% for this stock (consistently less than the ABC).

Changes to the input data include:
2015 fishery age composition, 2015 survey age composition, 2016 trawl survey biomass point estimate and standard error, estimate of the discarded and retained portions of the 2015 catch, And an estimate of the total catch made through the end of 2016. A catch of 150,000 t was assumed for 2017 and the 2018 projection.
Changes to the assessment methodology: Changes were made to the fishery weight-at-age where the average of the fishery aged samples from 2008-2014 were used for 2008-2016, replacing previous values that were time-invariant.

The SSC has determined that 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 424,000 t, and projected female spawning biomass for 2017 is 778,600 t, indicating 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 biomasses) 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 0.114. The current value of the OFL harvest ratio (the arithmetic mean of the F_{MSY} ratio) is 0.125. The product of the maximum permissible ABC harvest ratio and the geometric mean of the 2017 biomass estimate produced the 2017 ABC of 260,800 t, and the corresponding product using the OFL harvest ratio produces the 2017 OFL of 287,000 t. For 2018, the corresponding quantities are 250,800 t and 276,000 t, respectively.

Yellowfin sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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 2016 bottom trawl survey resulted in a biomass estimate of 1.46 million t, a 4% increase from the 2015 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 stock assessment model indicates that the stock declined in the late 1990s and early 2000s due to poor recruitment during the 1990s but is now at a high level and is projected to decline in the near future due to the lack of good observed recruitment since 2005. The stock is currently estimated at over twice the B_{MSY} level.

Changes to input data in the 2006 analysis include: Estimates of catch (t) and discards for 2015-2016, 2015 fishery age composition, 2015 survey age composition and the 2016 trawl survey biomass point estimates and standard errors. The chapter contains summaries for several assessment models that examined different states of nature by varying estimates of male and female natural mortality and catchability. Model 15.1, the model that has been used for the last several years was chosen as the preferred model again for 2017.

The SSC has determined that northern rock sole qualifies for management under Tier 1. Spawning biomass for 2017 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 2017 ABC harvest recommendation is 155,100 t (F_{ABC} = 0.155) and the 2017 OFL is 159,700 t (F_{OFL} = 0.160). The 2018 ABC and OFL values are 143,100 t and 147,300 t, respectively. Recommended ABCs correspond to the maximum permissible levels.

This is a stable fishery that lightly exploits the stock because it is constrained by PSC limits and the BSAI optimum yield cap. Usually the average catch/biomass ratio is about 3-4 percent 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.

Northern Rock Sole - GULF OF ALASKA Shallow Water Complex - REFM

Shallow-water and deep-water flatfish are assessed on a biennial schedule to coincide with the timing of survey data. Since no GOA survey was conducted in 2016, a partial assessment is prepared for the 2016 off year to project the estimates of the stock status forward. An executive summary for shallow water flatfish was presented that included updated 2015 catch and the partial 2016 catch as well as 2016 catch projections for northern and southern rock sole. Projected catch to the end of 2016 is calculated as the average fraction of catch to October 13 from the last 10 years (83.4%). The projected 2017 catch is set equal to the projected 2016 catch. This is a change from previous assessments which assumed maximum permissible ABC as the catch for the upcoming year. Last year's projected 2017 biomass, OFL and ABC estimates for the shallow-water complex from the 2015 assessment used catch assumptions that were considerably higher than current estimates. This resulted in lower biomass projections than the current update. Otherwise there were no changes to the assessment methodology. The random effects model was used to estimate 2015 biomass for the Tier 5 calculations.

The rock sole assessment model estimates are used for trend and spawning biomass estimates whereas the remaining species in this complex are based solely on the NMFS bottom trawl surveys. Biomass, OFL and ABC values for 2017 and 2018 for northern and southern rock sole are estimated using projections from the 2015 assessment model with catches updated for 2015 and 2016.

Northern and southern rock sole are in Tier 3a while the other species in the complex are in Tier 5. The recommended ABC for the shallow water flatfish complex is equivalent to the 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 44,514 t and OFL of 54,583 t for 2017.

The northern and southern rock sole component of the complex represents 78% of catch in 2016. Most recently, the catch has been less than 15% of the ABC. Northern and southern rock sole are not being subjected to overfishing and are neither overfished nor approaching an overfished condition. Information is insufficient to determine stock status relative to overfished criteria for the rest of the shallow water flatfish stock complex. Catch levels for this complex remain well below the TAC and below levels where overfishing would be a concern. The GOA northern and southern rock sole stocks are not being subjected to overfishing and are neither overfished nor approaching an overfished condition.

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 2016 shelf trawl biomass estimate increased 13% from 2015 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.

This assessment was changed to a bi-ennial cycle beginning with the 2014 assessment; this is a full assessment year. Changes to the input data in this analysis include:

2016 catch biomass was added to the model
2015 catch biomass was updated to reflect October – December 2015 catches
2013-2015 fishery age composition data were added

2015-2016 fishery length composition data were added to the model.
2015-2016 Eastern Bering Sea (EBS) shelf survey biomass and 2016 Aleutian Islands (AI) survey biomass were added to the linear regression used to determine estimates of AI survey biomass in years when no AI survey occurred; a new survey biomass index was added to the assessment model for 1982-2016 based on updated linear regression results.
2015-2016 survey bottom temperatures were added to the model.
2014-2015 survey age composition data were added to the model.
2015-2016 survey length composition data were added to the model.
Estimates of the length-at-age, length-weight, and weight-at-age relationships, and the length-at-age transition matrices were updated by adding data from 2001 to 2015. Growth estimates therefore include data from 1985, 1992-1995, and 2000-2015.

All age- and length-composition data were weighted using methods described in McAllister and Ianelli (1997) to approximate effective sample size for each year and data type. The harmonic mean over years was used to approximate the effective sample size for each data type and the assessment model was iteratively tuned such that input and effective sample sizes were approximately equal.

The SSC has determined that 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 2017 (223,469 t) is above $B_{40\%}$, flathead sole is in Tier 3a. The authors and Team recommend setting ABCs for 2017 and 2018 at the maximum permissible values under Tier 3a, which are 68,278 t and 66,164 t, respectively. The 2017 and 2018 OFLs under Tier 3a are 81,654 t and 79,136 t, respectively.

Flathead sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

Flathead Sole - GULF OF ALASKA - REFM
The 2017 spawning biomass estimate (82,819 t) is above $B_{40\%}$ (36,866 t) and projected to be stable through 2018. Total biomass (3+) for 2017 is 269,638 t and is projected to slightly increase in 2018. Flathead sole remain lightly exploited in the GOA.

The flathead sole stock is assessed on a biennial schedule to coincide with the timing of survey data. This year is an off-year thus an executive summary of the assessment was compiled. The projection model was run using updated 2015 catch and new estimated total year catches for 2016-2017 to calculate the 2017 and 2018 ABC and OFL.

Flathead sole are determined to be in Tier 3a. For 2017 the maximum permissible ABC of 35,243 t was determined from the updated projection. The F_{OFL} is set at $F_{35\%}$ (0.40) which corresponds to an OFL of 43,128 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 2017 and 2018 are based on the random effects model applied to GOA bottom trawl survey biomass in each area.

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Greenland Halibut (Turbot)

The projected 2017 female spawning biomass is 50,461 t, which is a 63% increase from last year's 2016 estimate of 31,028 t. Female spawning biomass is projected to increase to 55,347 t in 2018. 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 2017 and onward predict an increase in spawning biomass as these year classes grow and mature.

Changes to the input data include:

- Updated 2015 and projected 2016 catch data
- 2016 EBS shelf trawl survey estimates
- 2016 EBS slope trawl survey estimates
- 2016 ABL longline survey estimates
- 2016 EBS shelf survey, slope survey, and ABL longline length composition estimates
- 2015 EBS shelf survey age composition
- Updated fishery catch-at-length data for 2016

There were no changes made to the base model which has the same configuration as model 15.1 from the 2015 assessment except the addition of catch and size composition data from both the longline and trawl fisheries for 2016 as well as the addition of the 2016 Slope trawl survey index value and size composition data.

The 2016 accepted model (16.4) had a number of modifications from the base model:

To better fit the size composition data, the size bins for males and females were combined for composition lengths shorter than 52 cm. Residuals for the 2012 and 2016 Slope survey composition data also were problematic. In addition, longline fishery data had substantial residual patterns with overestimates of larger fish than what was observed. To better fit these data a new block was created for 2011 through 2016 for the Slope survey species composition data and the longline fishery data were allowed to be dome-shaped. To simplify data conflicts, the ABL longline size composition data were removed. These data were aggregated by sex and fit poorly, likely due to the high degree of sexual dimorphism found in this species (bimodal size distribution when aggregated).

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 2017 female spawning biomass was at 50,461 t, well above the estimate of $B_{40\%}$ (41,239 t). Because the projected spawning biomass in year 2017 is above B40%, Greenland turbot ABC and OFL levels will be determined at Tier 3a of Amendment 56. The maximum permissible value of F_{ABC} under this tier translates into an OFL of 11,615 t for 2017 and 12,831 t for 2018 and a maximum permissible ABC of 9,825 t for 2017 and 10,864 t for 2018. However, the author suggested a more conservative maximum permissible ABC of 7,000 t for both 2017 and 2018 due to the likelihood that this stock will continue to have poor recruitment for the foreseeable future. The Plan Team disagreed with the author's ABC choice as it was subjective and not supported by the model and recommended that the ABCs for 2017 and 2018 be set at maximum permissible.

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 recommended 2017 and 2018 ABCs in the EBS are 8,577 and 9,484 t. The 2017 and 2018 ABCs for the AI are 1,248 t and 1,380 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.

Arrowtooth Flounder - BERING SEA AND ALEUTIAN ISLANDS- REFM
The projected age 1+ total biomass for 2017 is 779,195 t, a decrease from the value of 920,920 t projected for 2017 in last year's stock assessment. The projected female spawning biomass for 2017 is 485,802 t, a decrease from the 534,347 t estimated from the 2016 SAFE report. The stock has remained at a high level for the past 20 years and is subject to light exploitation.

New information incorporated into the assessment model for this report include: Survey size compositions from the 2015 and 2016 Eastern Bering Sea shelf survey, 2016 Eastern Bering Sea slope survey, and 2016 Aleutian Islands survey. Biomass point-estimates and standard errors from the 2015 and 2016 Eastern Bering Sea shelf surveys, 2016 Eastern Bering Sea slope survey, and 2016 Aleutian Islands survey. Fishery size compositions for 2015 and 2016 and estimates of catch through October 26, 2016 were also included as well as age data from the 1993, 1994, 2012, 2014, and 2015 Bering Sea shelf and 2014 Aleutian Islands surveys, and also the 2012 Eastern Bering Sea slope survey.

The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock. Arrowtooth flounder therefore 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 above $B_{40\%}$, so ABC and OFL recommendations for 2017 were calculated under sub-tier "a" of Tier 3. The authors and Team recommend setting F_{ABC} at the $F_{40\%}$ level, which is the maximum permissible level under Tier 3a, resulting in 2017 and 2018 ABCs of 65,371 t and 58,633 t, respectively, and 2017 and 2018 OFLs of 76,100 t and 67,023 t. Arrowtooth flounder is a largely unexploited stock in the BSAI. Arrowtooth flounder is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

Ecosystem Considerations
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 are derived from a projection model in even years when there is no trawl survey and are very similar to those estimated in the last full assessment in 2015. The projection model estimate of total (age 1+) biomass shows a slight decrease to 2,103,090 t in 2017. Female spawning biomass in 2017 was estimated at 1,174,400 t, well-above $B_{40\%}$, and is essentially equivalent (0.5% decrease) to the 2016 estimate in last year's assessment.

There were no changes in assessment methodology since this was an off-cycle year. Parameter values from the previous year's assessment model, projected catch for 2016, and updated 2015 catch were used to make projections for ABC and OFL estimates. Arrowtooth flounder are determined to be in Tier 3a.

This arrowtooth flounder stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

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.

This assemblage is not being subjected to overfishing. It is not possible to determine whether this assemblage is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

Deep-water flatfish - REFM GULF OF ALASKA
The deepwater flatfish complex is comprised of Dover sole, Greenland turbot, and deepsea sole. . This year is an off-year thus an executive summary of the assessment was presented and there were no changes in assessment methodology. New information available to update the Dover sole projection model consisted of updated 2015 catch and catch estimates for 2016 and 2017.

Dover sole is a Tier 3 stock which is assessed using an age-structured model. A single species projection model was run using parameter values from the accepted 2015 Dover sole assessment model. Both Greenland turbot and deepsea sole are in Tier 6. The 2017 Dover sole ABC is 9,109 t. The Tier 3a calculations for Dover sole result in 2017 OFL of 10,938 t. The 2017 Tier 6 calculation of ABC for the other species in the complex is 183 t and OFL is 244 t. The GOA Plan Team agrees with the authors' recommendation to use the combined species' ABCs and OFLs for the deep-water flatfish complex for 2017. This equates to a 2017 maximum permissible ABC of 9,292 t and OFL of 11,182 t for the deep-water flatfish complex.

Based on the results of the updated assessment, 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 deep-water flatfish complex the species is 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.

Greenland turbot and deepsea sole fall under Tier 6. ABCs and OFLs for Tier 6 species are based on historical catch levels and therefore these quantities are not updated. ABCs and OFLs for the individual species in the deepwater flatfish complex are determined as an intermediate step and then summed for calculating complex-level OFLs and ABCs. Dover sole apportionment was computed using the random effects model and included the 2015 NMFS bottom trawl survey biomass distributions. Greenland turbot and deepsea sole apportionments were computed using historical survey biomass distributions of both species.

The model estimate of 2016 spawning stock biomass for Dover sole is 49,179 t, which is well above $B_{40\%}$ (22,692 t). Spawning stock biomass and total biomass are expected to remain stable through 2017. Stock trends for Greenland turbot and deepsea sole are unknown.

Apportionment for the deepwater flatfish complex was done using the random effects model to fill in depth and area gaps in the survey biomass by area for Dover sole. The resulting proportion of predicted survey biomass in each area formed the basis for apportionment of the Dover sole portion of the deep-water complex. The Greenland turbot and deepsea sole portion was based on the proportion of survey biomass for each species in each area, averaged over the years 2005-2015. The ABC by area for the deep-water flatfish complex is then the sum of the species-specific portions of the ABC.

M. Pacific halibut

1. Research

Halibut Excluders-RACE MACE Conservation Engineering
In 2016, CE scientists, in collaboration with a Bycatch Reduction Engineering Program (BREP) project led by FishNext Research (Dr. Craig Rose), executed a cooperative fishing gear research charter on the F/V *Marathon* in the Gulf of Alaska to test the use of selective herding lines in front of the trawl footrope as a bycatch reduction device for halibut. The hope was that this bycatch reduction device (BRD) would separate halibut from target species in the mouth of the net, as opposed to just in front of the codend, where most current BRD's are located. This excluder concept is based on CE observations that show halibut swimming ahead of the trawl for longer periods than smaller flatfish. The purpose of the selective herding lines is to allow halibut to escape over the

wing extensions before they enter the trawl, causing less stress on escaping fish compared to an excluder just forward of the codend.

Thorough video analysis is still needed, but initial findings from fishing tows conducted with a closed codend encountered poor fishing production. There could be several reasons for low fishing productivity, including 1) low density of target species during the experiment, 2) while the selective herding lines seemingly encouraged halibut to escape over the wings, they may have also increased escape of target species, and 3) poor water quality/visibility. While plenty of halibut were encountered, the mixture of trawl-catchable fish species was different than expected. Fewer small soles were caught, replaced by more pollock, arrowtooth flounder and rockfish.

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N. Other Groundfish Species

CONSERVATION ENGINEERING (CE)

Develop alternative trawl designs to effectively capture pollock concentrated against the seafloor while reducing bycatch and damage to benthic fauna--CE

The Alaska pollock fishery requires the use of pelagic trawls for all tows targeting that species. During some periods of the pollock fishery, these fish concentrate against the seafloor and, to capture them, fishermen have to put nets designed for midwater capture onto the seafloor. We are developing footropes raised slightly off of the seafloor in order to have less effect on seafloor habitats than the continuous, heavy footropes (generally chains) currently required on pelagic trawls. We have held several workshops with 20+ participants, including captains of pollock trawlers and industry representatives, as well as federal and university scientists to come up with ideas for alternative footropes to test. In May 2014 we began exploring these possibilities with experiments to compare the seafloor effects of the different alternative footropes. Preliminary results show that we reduced footrope contact with the seafloor by at least 90%. This research was funded through an award to NOAA-AFSC and Alaska Pacific University (APU) from the North Pacific Research Board, and the final report of that project is now available on the web (http://projects.nprb.org/#metadata/01f771ea-b802-41cb-b468-281ab28c8475/project). In order to better understand benthic habitat effects of current pollock trawl footropes, collaborators from APU will join a 2017 research cruise with the CE group. They will examine how the bottom contact varies along the chain footropes used by the pollock fishery under different deployment conditions.

Provide underwater video systems to fishermen and other researchers to facilitate development of fishing gear improvements --CE

We have 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. Either way, the goal of better understanding fishing gear operation and quicker development of improvements is being realized. The current systems have been in use for about 5 years now and have proven to be very easy to use, durable and flexible. All camera system components are enclosed in a single 8.9 cm (3.5 inch) diameter acrylic tube mounted on a plastic plate. The entire system measures 53.3 x 22.9 x 12.7 cm (21 x 9 x 5 inches) and is of nearly neutral buoyancy in water. The CE group now has six of these systems for both our use and for use as loaner systems. While this design is so inexpensive and functional that many vessels have acquired their own systems, there is still a need for loaner systems. In 2016, we ruggedized the existing loaner camera system design by replacing the acrylic tube with a titanium tube. This new system was successfully field tested through our loaner camera program. Representatives from the pollock fishery used four loaner cameras (one of which was the new ruggedized system) in 2016 to do their own field tests to examine if the use of light on existing salmon excluders could enhance salmon escapement during fishing.

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

GROUNDFISH ASSESSMENT PROGRAM

Combining data from bottom trawl and acoustic surveys to estimate an index of abundance for semipelagic species --GAP

Fishery-independent surveys are useful for estimating abundance of fish populations and their spatial distribution. It is necessary in the case of semipelagic species to perform acoustic-trawl (AT) and bottom-trawl (BT) surveys to assure that sampling encompasses both midwater and demersal components of the population. Abundance estimates from both survey types are negatively biased because of the blind zones associated with fish vertical distribution. These biases can vary spatially and temporally, resulting in confounded trends and additional variation in abundance estimates. To improve abundance estimates for semipelagic species we propose a new method for combining BT and AT survey data using environmental variables to predict the vertical overlap. On an example of pollock AT and BT surveys in the eastern Bering Sea we show that combined estimates provide more reliable whole water column and spatial distribution estimates than either survey can by itself. Although the combined estimates are still relative they account for the uncertainty in the bias ratio between two survey methods and uncertainty associated with the extent of the water column sampled by both surveys. Our method of combining BT and AT data can be extended to other semipelagic species.

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

Determination of Parameters for an Underwater Camera System that Maximizes Available Light for Analysis While Minimizing Visual Detection by Demersal Rockfishes in Southern California--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. 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) necessitating the addition of a color component to aid in species identification. To develop an underwater camera and lighting system for assessing southern California demersal rockfish 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 should be addressed: (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?

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.

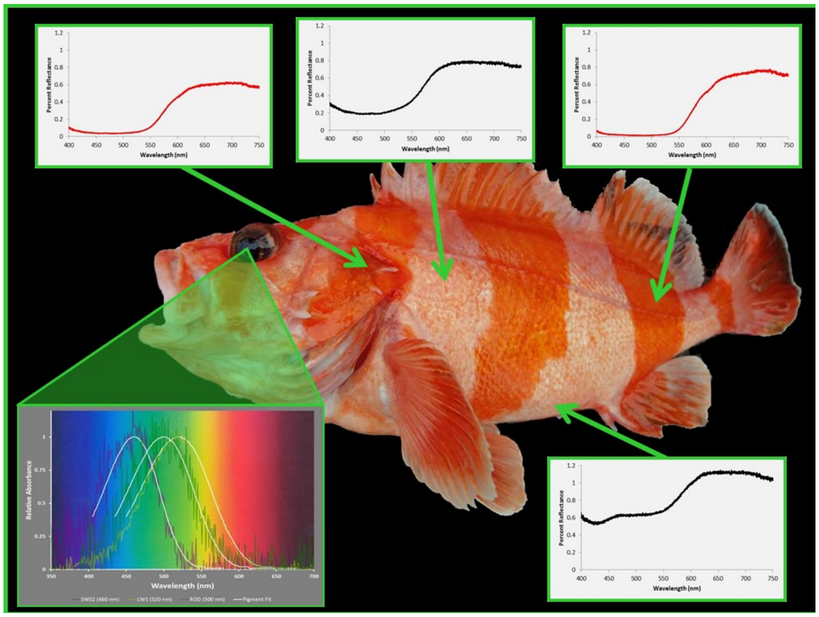
The optical properties of deep water reefs near Santa Barbara, CA, where the specimens for this study were collected are being modelled using a customized software package that we created for determining target contrast ratios at depth. This work is being combined with the third objective of this study 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 ongoing.

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.

Combining bottom trawls and acoustics in a diverse semipelagic environment: What is the contribution of walleye pollock (Gadus chalcogrammus) to near-bottom acoustic backscatter in the eastern Bering Sea?--GAP

The abundance of walleye pollock (Gadus chalcogrammus) in the eastern Bering Sea (EBS) is estimated in part through fisheries-independent acoustic trawl (AT) surveys, which currently use acoustic backscatter data down to 3 m above the bottom. A large portion of adult pollock are demersal and these estimates will become more accurate if the survey is extended closer to bottom. The purpose of this project was to assess the feasibility of extending the AT survey closer to the bottom by estimating the contributions of each demersal fish species to observed acoustic backscatter in the highly diverse near-bottom region. This was accomplished by fitting a regression model to simultaneously collected acoustic backscatter and bottom trawl (BT) catch data. Pollock were the dominant source of acoustic backscatter among demersal species accounting for 85.9 ± 4.8 % of acoustic backscatter (mean ± standard deviation). A method was developed to extend the AT survey to within 0.5 m of the bottom and applied to the 1994-2014 surveys, pollock biomass increased by an average of 35 ± 12 %.

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

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Differences in sampling efficiency between two bottom trawls used in Arctic surveys of bottom fishes, crabs and other demersal macrofauna--GAP

This study compares two different research bottom trawls used in legacy surveys in the Alaska high-artic. Results from this study will provide scientists and mangers context for assessing and interpreting historical survey results as well as provide a framework for considering the ‘how’ and ‘what’ for articulating research priorities and choosing the most appropriate gear(s) and method(s) for long-term monitoring of the high-arctic benthic ecosystem. The two research bottom trawls investigated in this study were the 3-m plumb-staff beam trawl (PSBT; Norcross et al. 2013) and the 83-112 Eastern bottom trawl (EBT; Stauffer 2004). The PSBT is a small, fine-meshed trawl that has been used throughout the Chukchi Sea and Beaufort Sea since 2007 for smaller scale ecosystem surveys of oil lease sites and multidisciplinary studies (Logerwell et al. 2015, Norcross et al. 2013, Norcross et al. 2010, Norcross and Holladay 2010). The EBT is a commercial-sized large-mesh trawl that has been used for conducting a large-scale annual standardized fishery-independent survey of the eastern Bering Sea shelf for fishery stock assessment since 1976 (Pereyra et al. 1976, Conner and Lauth 2016) and a triennial red king crab survey in the northern Bering Sea from 1977 to 1991 (Soong and Banducci 2008). The same gear and methods have also been used for large-scale ecosystem surveys in the eastern Chukchi Sea in 2012 (Goddard et al. 2014), the southeastern Chukchi Sea and Norton Sound in 1976 (Wolotira et al. 1977), the northeastern Chukchi Sea in 1990 (Barber et al. 1997), the Beaufort Sea in 2008 (Rand and Logerwell 2011), and the northern Bering Sea in 2010 (Lauth 2011).

This study used a paired comparison experiment to examine the differences in sampling efficiency between the EBT and PSBT. Indices compared included taxa number and type, abundance by weight and number, and size composition. In addition, a size-selectivity ratio function (Kotwicki et al. 2017) for the PSBT and EBT was derived for snow crab, Arctic cod and five other taxonomic groups.

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

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At-sea backdeck electronic data entry--GAP

The RACE groundfish group has been working on an effort to digitally record their survey data, as it is collected on the back deck. This new method will eventually replace the original method of recording biological sampling data on paper forms (which then needed to be transcribed to a digital format at a later time).

This effort has involved the development of in-house Android applications. These applications are deployed on off-the-shelf Android tablets. The first application developed was a length recording app, which replaced the obsolete and unsustainable "polycorder" devices already in use. The length application is now used on all groundfish surveys.

Last summer, a specimen collection app was tested on one of the groundfish surveys. This application will be deployed on all groundfish surveys in the summer of 2017.

A prototype catch weight recording application is scheduled to be tested in the summer of 2017.

Future plans include establishing two-way communication between the tablets and a wheelhouse database computer, so all collected biological data can be fully integrated into a centralized database.

This effort aims to allow us to collect more, and more accurate, biological data, in a more efficient way.

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2Systematics Program - RACE GAP

Several projects on the systematics of fishes of the North Pacific have been completed or were underway during 2016. 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 Pacific. Similarly, they are collaborating on a study of capelin and its taxonomic status in the North Pacific. 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 partial revision of the lumpsucker genus *Eumicrotremus* (Stevenson, with Mecklenburg and Kai); and a study of the developmental osteology of the bathymasterid *Ronquilus jordani* (Stevenson, with Hilton and Matarese). Work on the molecular phylogenetics and morphology of the pectoral girdle of snailfishes (Orr, Stevenson, Spies, with UW) is underway. A description and naming of two new species of snailfishes from the Aleutian Islands has been published (Orr, 2016), and descriptions of other new species from Alaska continues.

In addition to taxonomic revisions, descriptions of new taxa, and guides, RACE systematists have published work in collaboration with molecular biologists at the University of Washington and within AFSC to identify snailfish eggs parasitizing king crabs (Gardner, Orr, Stevenson, Somerton, and Spies, 2016). The description and naming of a new snailfish, discovered during this project 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), *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). Stevenson recently completed a section on manefishes for the FAO guide to the living marine resources of the Eastern Central Atlantic (Stevenson, Kenaley, and Britz, 2016), as well as documents summarizing species identification procedures in the North Pacific Observer Program (Stevenson et al., 2016) and species enumeration and quantification on the eastern Bering Sea shelf trawl survey (Stevenson, Weinberg, and Lauth, 2016).

Orr and Stevenson have also conducted work with invertebrates. With the support of NPRB and JISAO and in collaboration with specialists at the UW and the California Academy of Sciences, a comprehensive annotated checklist of the marine macroinvertebrates of Alaska, comprising over 3500 species, has now been published (Drumm et al., 2016). 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 2016:

Drumm, D. T., K. P. Maslenikov, R. Van Syoc, J. W. Orr, R. R. Lauth, D. E. Stevenson, and T. W. Pietsch. 2016. An annotated checklist of the marine macroinvertebrates of Alaska. *NOAA Professional Paper NMFS 19*, 289 pp.

Gardner, J. R., J. W. Orr, D. E. Stevenson, I. Spies, and D. A. Somerton. 2016. Reproductive parasitism between distant phyla: molecular identification of snailfish (Liparidae) egg

masses in the gill cavities of king crabs (Lithodidae). *Copeia* 104:645–657.
Orr, J. W. 2016. Two new species of *Careproctus* (Liparidae) from the Aleutian Islands. *Copeia* 104:890–896.
Stevenson, D. E., C. P. Kenaley, and R. Britz. 2016. Caristiidae: Manefishes, p. 2519–2525. In: *The Living Marine Resources of the Eastern Central Atlantic*, Vol. 4: Bony fishes part 2 (Perciformes to Tetraodontiformes) and Sea turtles. K. E. Carpenter and N. DeAngelis (eds.), Food and Agriculture Organization of the United Nations.
Stevenson, D. E., K. L. Weinberg, and R. R. Lauth. 2016. Estimating confidence in trawl efficiency and catch quantification for the eastern Bering Sea shelf survey. *U.S. Department of Commerce, NOAA Technical Memorandum NMFS-AFSC-335*, 51 p.
Stevenson, D. E., M. Moon, M. Rickett, and M. Vechter. 2016. Species identification in the North Pacific Observer Program: training, protocols, and data monitoring. *Alaska Fisheries Science Center Processed Report 2016-04*, 37 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.

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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Andrews, A.G., III, W.W. Strasburger, E.V. Farley, Jr., J.M. Murphy, and K.O. Coyle. 2015. Effects of warm and cold climate conditions on capelin (*Mallotus villosus*) and Pacific herring (*Clupea pallasii*) in the eastern Bering Sea. Deep-Sea Res. II http://dx.doi.org/10.1016/j.dsr2.2015.10.008i

Mecklenburg, C.W., T.A. Mecklenburg, and L.K. Thorsteinson. 2002. Pacific herring. In: Fishes of Alaska. American Fisheries Society, Bethesda, p. 134.

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

Tojo, N., G.H. Kruse, and F.C. Funk. 2007. Migration dynamics of Pacific herring (*Clupea pallasii*) and response to spring environmental variability in the southeastern Bering Sea. Deep Sea Research Part II: Topical Studies in Oceanography 54(23):2832-2848.

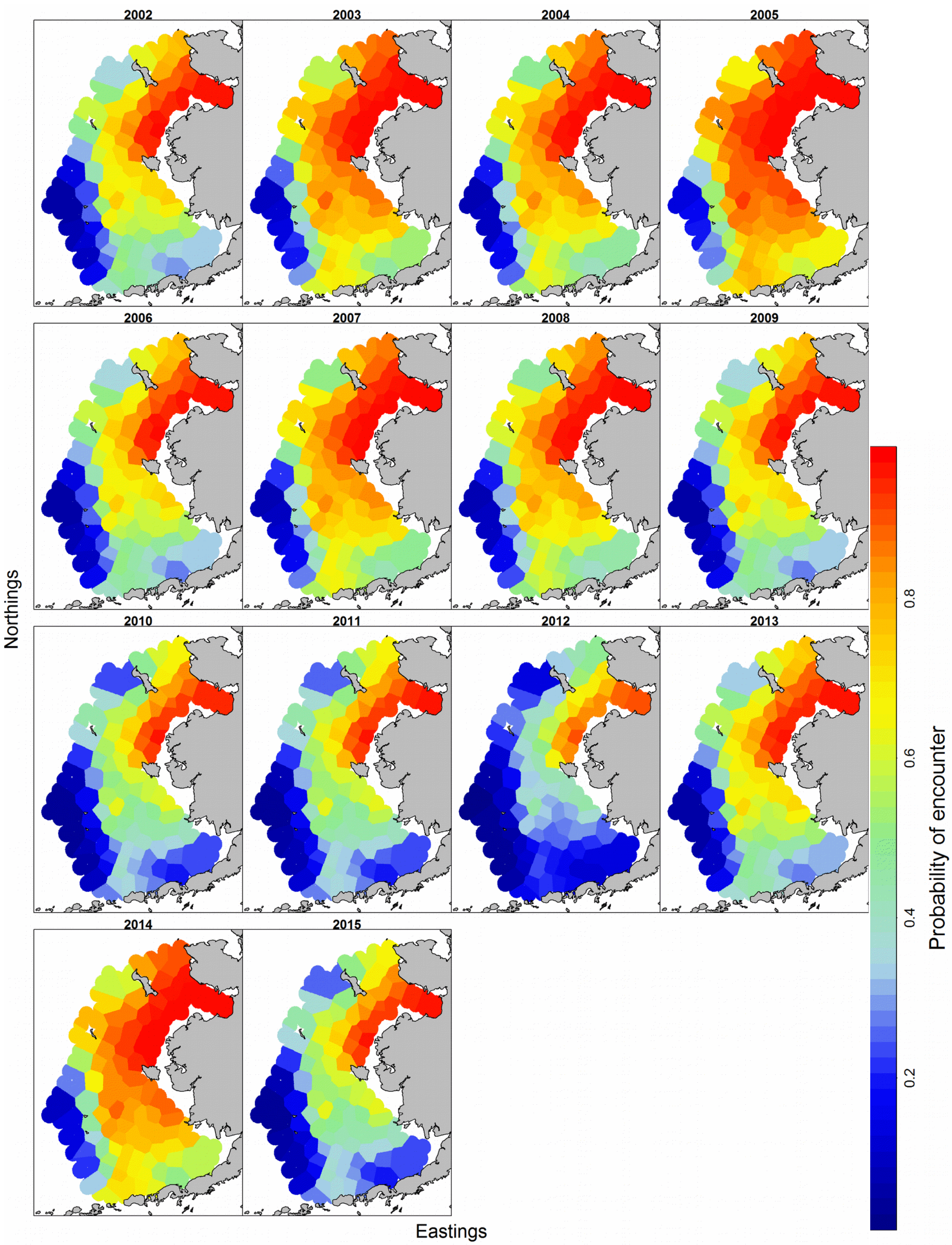

Figure 1. Density of Pacific herring in the eastern Bering Sea during late summer, 2002-2015. Densities were estimated using the geostatistical delta-generalized linear mixed model from Thorson et al. (2015).

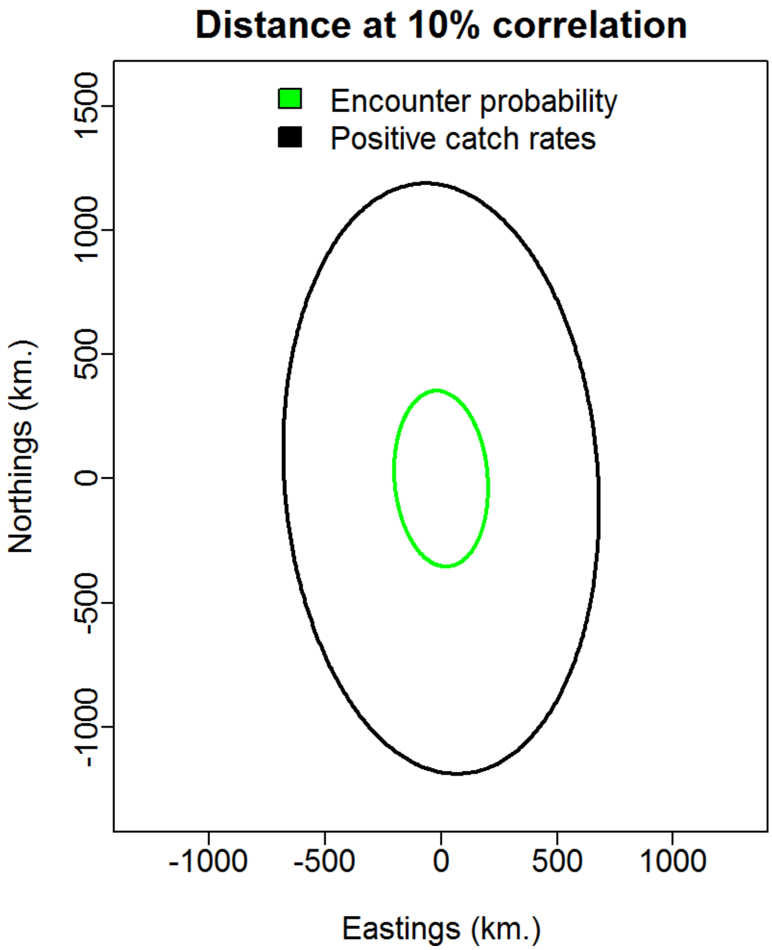

Figure 2. Geometric anisotropy plots for encounter probability of Pacific herring on the eastern Bering Sea shelf during late summer, 2002-2015.

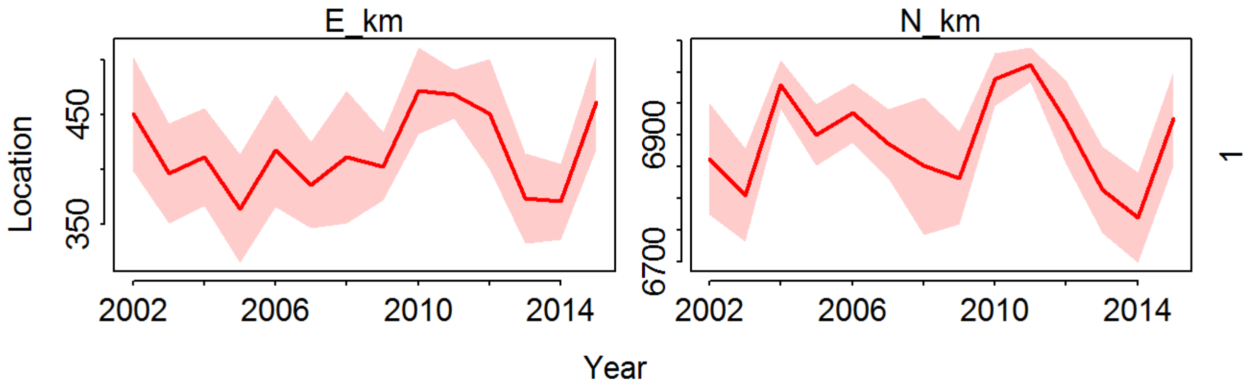

Figure 3. Northward and eastward center of gravity (distribution) in units of km for Pacific herring on the eastern Bering Sea during late summer, 2002-2015.

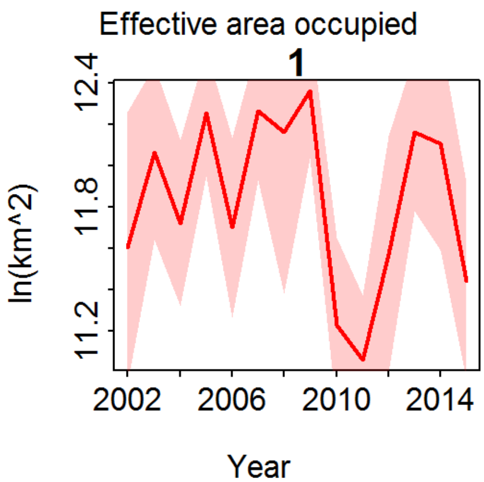

Figure 4. The effective area (ln(km^2)) occupied by Pacific herring on the eastern Bering Sea shelf during late summer, 2002-2015.

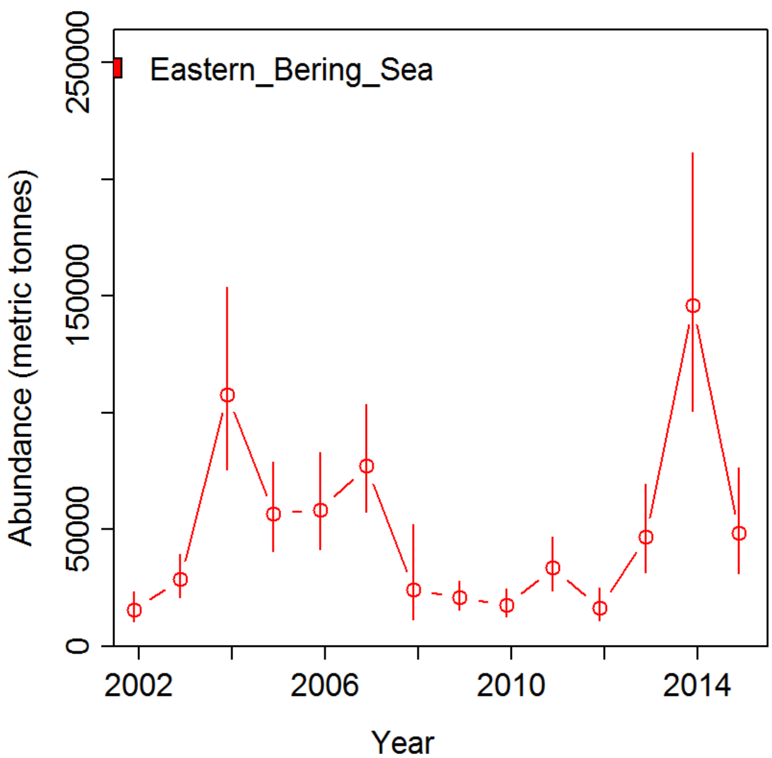

Figure 5. Estimated index of abundance with 95% confidence intervals for Pacific herring in the eastern Bering Sea during late summer, 2002-2015. Abundance was estimated using the geostatistical delta-generalized linear mixed model from Thorson et al. (2015).

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

Otolith shape variation and body growth differences in giant grenadier – ABL

Fish stocks can be defined by differences in their distribution, life history, and genetics. Managing fish based on stock structure is integral to successful management of a species because fishing may affect stocks disproportionately. Genetic and environmental differences can affect the shape and growth of otoliths and these differences may be indicative of stock structure. We quantified the shape of female giant grenadier, *Albatrossia pectoralis*, otoliths and compared body growth rates for fish with the three otolith shapes; shape types were classified visually by an experienced giant grenadier age reader, and were not defined by known distribution or life history differences. We found extreme variation in shape; however, the shapes were a gradation and not clearly defined into three groups. The two more extreme shapes, visually defined as “hatchet” and “comb”, were discernable based on principal component analysis (PCA) values of elliptical Fourier coefficients, and the “mixed” shape overlapped both of the extreme shapes. Body size of fish with hatchet-shaped otoliths grew faster than fish with a comb-shaped otoliths. A genetic test (the COI gene sequence data used by the Fish Barcode of Life Initiative) showed almost no variability among samples, indicating that the samples were all from one species. The lack of young specimens makes it difficult to link otolith shape and growth difference to life history. In addition, shape cannot be correlated with adult movement patterns because giant grenadiers experience 100% mortality after capture and, therefore, cannot be tagged and released. Despite these limitations, the link between body growth and otolith shape indicates measureable differences that deserve more study.

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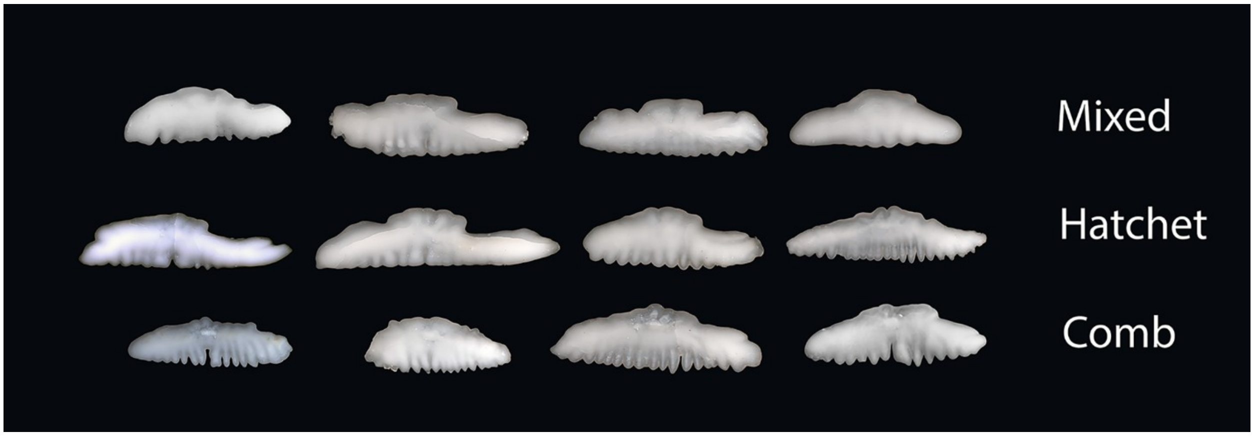

V. Ecosystem Studies

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.

Species Profiles and Ecosystem Considerations (SPEC) – ABL
Over the past several years, a new framework has been proposed to start the process of integrating ecosystem and socioeconomic information directly into the Alaska groundfish stock assessments (Shotwell et al. 2016). These stock profiles and ecosystem considerations (SPECs) 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. The new SPEC process creates ecosystem baselines to be included in the stock assessment fishery evaluation (SAFE) reports utilizing national initiative data currently being collected for all assessed stocks across the county. There are four primary baseline SPEC elements for a given stock or stock complex. First, an overall ecosystem status rating summarizes the results from the national initiatives to provide immediate and succinct context for the priorities of the stock or stock complex. The rating should include subjects relevant to the particular fishery management plan of the stock (e.g., data classification, prioritization, and vulnerability assessment). The rating is based on four categories of low (L), moderate (M), high (H), and very high (VH). These ratings indicate whether this particular factor is of low to high importance for the stock (e.g., a low habitat prioritization implies that more habitat research would have low impact for improvement of this stock assessment). The second element starts as an informal life history conceptual model that provides the relevant information on the stock life history stages and potential survival bottlenecks between stages. The third element, is a qualitative stock profile that follows the format of the overall rating but further identifies strengths and weaknesses over a suite of response categories (e.g., stock status, economics, biology). Finally, the first three elements are used in concert to develop a list of potential ecosystem or socioeconomic indicators that are then compiled for monitoring as time series in a graphical report card. These baselines can then be enhanced with new information from process studies (e.g. IERPs, FATE) or continued ecosystem monitoring (e.g. standard surveys, remote sensing). The SPECs 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., D.H. Hanselman, S. Zador, and K. Aydin. 2016. Stock-specific Profiles and Ecosystem Considerations (SPEC) for Alaska groundfish fishery management plans. Report to Joint Groundfish Plan Team, September 2016. 15 pp.

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

Benthic Habitat Research – Gulf of Alaska - ABL

The primary goal of the Gulf of Alaska (GOA) benthic habitat research project was to characterize the preferred early juvenile life stage settlement habitat for the five focal groundfish species (sablefish, pollock, Pacific cod, Pacific ocean perch, and arrowtooth flounder) specified by the GOA Integrated Ecosystem Research Project (IERP). The Final Report to the NPRB (100+pgs) included the following information for the five focal species: 1) extensive literature review of habitat preferences with life stage tables, 2) methods and maps of the high resolution suite of benthic habitat variables, 3) methods and database of the field observations for the early juvenile stages, 4) methods and maps for the literature based habitat suitability, 5) methods, model selection, model results, and final maps for the model-based habitat suitability 6) regional based habitat suitability estimates, and 7) extensive discussion of the project. A manuscript by led by J. Pirtle was accepted for the special issue of Deep-Sea Research II describing the work on the early juvenile stage habitat suitability models for the five species. The follow up Essential Fish Habitat (EFH) project (also led by J. Pirtle, HCD with C. Rooper, RACE) used the baseline habitat suitability framework from the GOA-IERP and extended this work to include new biophysical habitat metrics (e.g. production, temperature, corals) and apply the methods to a variety of groundfish species from the early juvenile life stage through adults (including the five focal species). The results from this project were included in the 2016 EFH update which was reviewed and accepted by the council process. A NOAA Technical Memorandum is currently in development to summarize the EFH project. The whole life cycle EFH results are also planned for inclusion where relevant in the new species profiles and ecosystem considerations (SPEC) sections of the stock assessment fishery evaluation (SAFE) process and may assist fishery managers in future decisions regarding survey planning and habitat assessment. During the final phase of the GOA Project Synthesis, the baseline habitat suitability models will be combined with individual based models (IBMs) in a novel approach to delineating survival trajectories for understanding recruitment of groundfish. The case studies for this approach will be Alaska sablefish and GOA arrowtooth flounder.

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Alaska Coral and Sponge Initiative – RACE & ABL

Deep-sea coral and sponge ecosystems are widespread throughout most of Alaska’s marine waters. In some places, such as the western Aleutian Islands, these may be the most diverse and abundant deep-sea coral and sponge communities in the world. Deep-sea coral and sponge communities are associated with many different species of fishes and invertebrates in Alaska. Because of their biology, these benthic invertebrates are potentially vulnerable to the effects of commercial fishing, climate change and ocean acidification. Since little is known of the biology and distribution of these communities, it is difficult to manage human activities and climate impacts that may affect deep-sea coral and sponge ecosystems.

Beginning in FY2012 the NOAA Deep Sea Coral Research and Technology Program (DSCRTP) initiated a field research program in the Alaska region for three years (FY2012-2015) to better understand the location, distribution, ecosystem role, and status of deep-sea coral and sponge habitats. The research priorities of this initiative include:

- Determine the distribution, abundance and diversity of sponge and deep-sea coral in Alaska;
- Compile and interpret habitat and substrate maps for the Alaska region;
- Determine deep-sea coral and sponge associations with FMP species and their contribution to fisheries production;
- Determine impacts of fishing by gear type and testing gear modifications to reduce any impacts;
- Determine recovery rates of deep-sea coral and sponge communities from disturbance; and,
- Establish a monitoring program for the impacts of climate change and ocean acidification on deep-coral and sponge ecosystems.

Fieldwork for the AKCSI project was completed in FY15 with a remotely operated vehicle cruise in Southeast Alaska to examine Primnoa thickets at two study sites. The important accomplishments of this project included; the production of model-based maps of coral and sponge habitat for all of Alaska, analysis of seasonal patterns of rockfish use of coral habitat, and a number of studies examining the growth and reproduction of Primnoa corals in southeast Alaska. A final report for this project was completed in December 2016 and will be available as a NOAA Technical Memorandum at some point in 2018. Results of this project were delivered at the International Coral Symposium in Boston, MA in September 2016.

Contact: Chris Rooper (chris.rooper@noaa.gov)

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.

AFSC pilot study using TriggerCams to assess rockfish density on Footprint Bank, Channel Islands-RACE MACE & GAP

Williams, K, Rooper, C, Tuttle, V, Boldt J, Laidig T, Jones, D

This pilot project was to develop a stationary camera survey for rockfish in untrawlable habitats. Its primary objective was to test the overall survey design, deployment methods, and gear performance ahead of the Untrawlable Habitat Strategic Initiative (UHSI) efforts in FY17. This study involved 4 vessel days aboard the NOAA Channel Islands Sanctuary vessel R/V Shearwater in September 2016. A total of 26 camera drops were made using 7 camera units, resulting in sufficient data to characterize the baseline density of rockfish by species within the 150 m isobath at Footprint Bank in the Channel Islands National Marine Sanctuary. The data analyses is ongoing for this project.

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

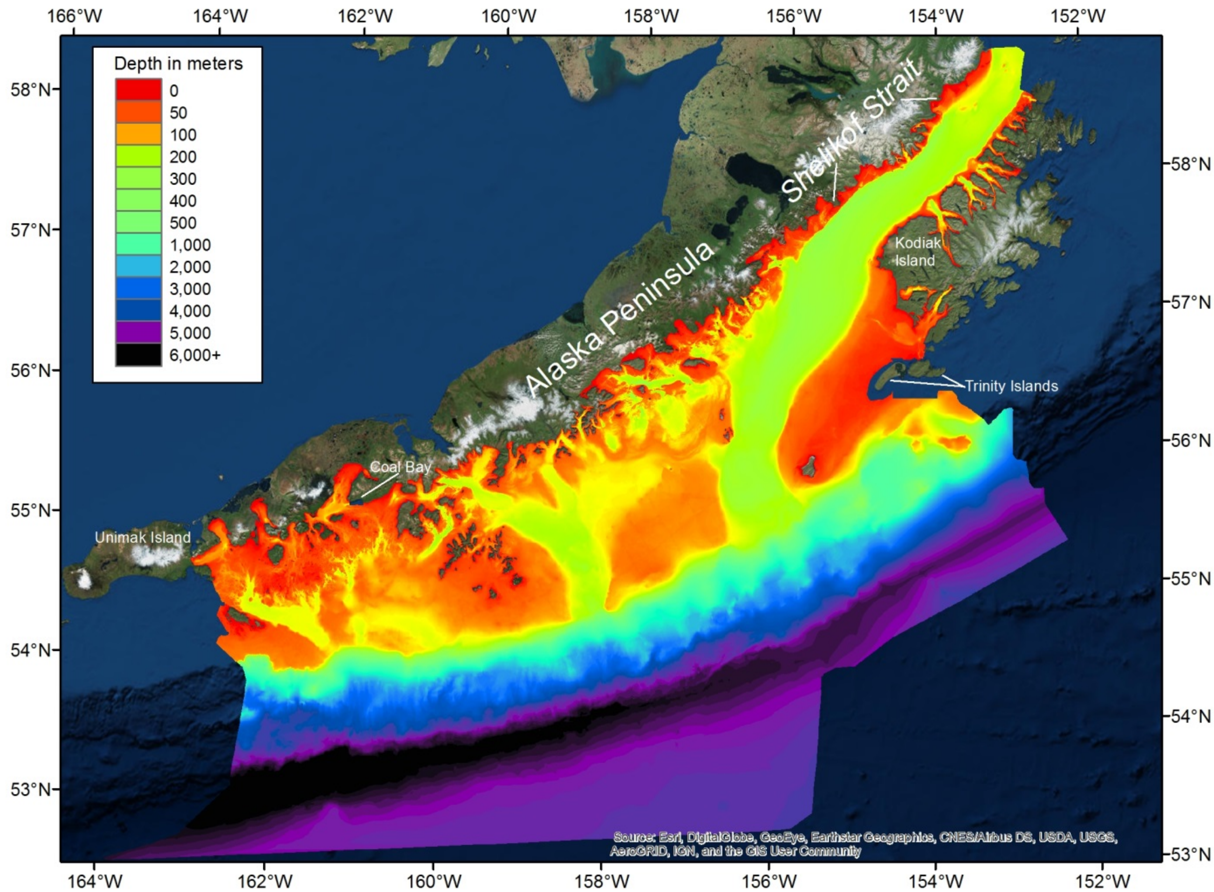
Stienessen, S, Jones, D, Rooper, C, Pirtle, J, Wilson, C, Weber, T

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.

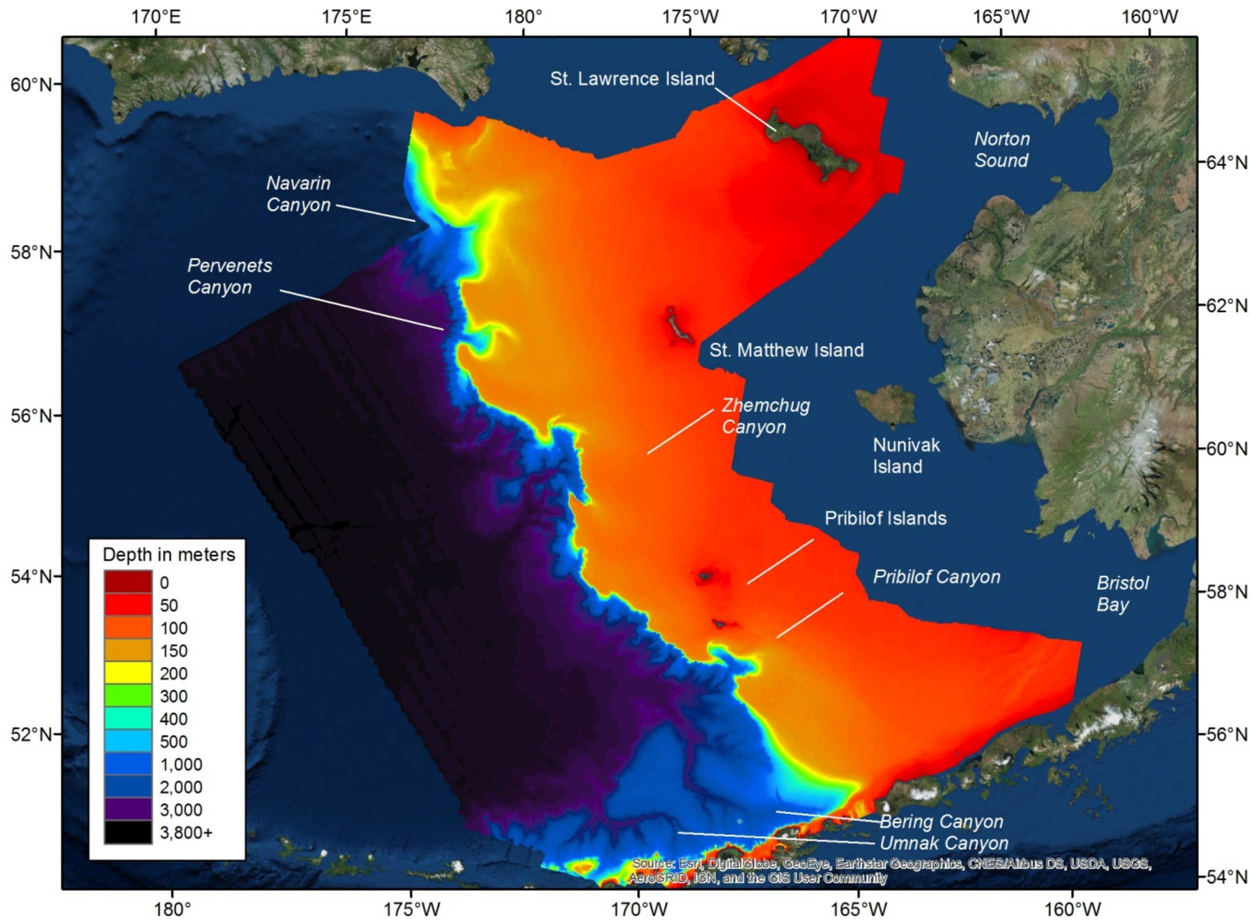
Bathymetry of the western Gulf of Alaska and eastern Bering Sea slope - RACE GAP

As a continuation of work in Alaskan waters (http://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/default.htm), scientists with the AFSC's Groundfish Assessment Program (GAP) are in the process of publishing bathymetry for the western Gulf of Alaska (wGOA) and eastern Bering Sea slope (EBSS), Alaska. This work is part of a project using smooth sheets and other sources to provide better seafloor information for fisheries research.

The western Gulf of Alaska project ranged from Unimak Island on the west, along the south side of the Alaska Peninsula to Kodiak Island and through Shelikof Strait on the east. Coal Bay, on the south side of the peninsula near the western extent of this region, has never been surveyed and was therefore left blank. The area around the Trinity islands is scheduled to be mapped this summer. This wGOA compilation connects to our previously bathymetry compilations of the Aleutian Islands (https://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/Aleutians.htm), the central Gulf of Alaska (https://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/CentralGOA_1.htm), and Cook Inlet (https://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/Cook_Inlet_1.htm).



The eastern Bering Sea slope compilation ranged from Umnak and Bering canyons in the south and up to Navarin Canyon and St. Lawrence Island in the north. This EBSS compilation connects to our previously bathymetry compilations of Norton Sound (https://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/Norton_Sound.htm) and the Aleutian Islands (https://www.afsc.noaa.gov/RACE/groundfish/Bathymetry/Aleutians.htm).



Funding from the NMFS Alaska Regional Office's Essential Fish Habitat (AKR EFH: http://www.afsc.noaa.gov/HEPR/docs/Sigler_et_al_2012_Alaska_Essential_Fish_Habitat_Research_Plan.pdf) made this work possible. These bathymetry compilations are part of a GAP (Groundfish Assessment Program) effort to create more detailed bathymetry and sediment maps in order to provide a better understanding of how studied animals interact with their environment.

Contact Mark.Zimmermann@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 objectives of this project are; 1) to identify potential spawning areas for rockfish in the western Gulf of Alaska (Figure 2), 2) to collect underwater stereo imagery to identify the substrate types and species and sizes of benthic invertebrates associated with spawning activity and 3) to sample larvae in situ from spawning habitats using a newly developed plankton pump (Figure 3).

This research will be conducted on Leg 1 of the 2017 Gulf of Alaska bottom trawl survey, which is anticipated to begin in late May 2017. Objective 1 will be addressed by examining all bottom trawl survey catches for spawning or mature fish. Based on previous experience, we typically capture rockfish during Leg 1 of the bottom trawl survey that are mature or in spawning (parturition) condition. These are usually northern rockfish (Sebastes polyspinis), dusky rockfish (S. variabilis) and Pacific Ocean perch (S. alutus). The proportion of the regular length sample of females of each rockfish species that are in spawning condition will be recorded and expanded to the overall size of the catch. The trawl survey catches containing rockfish species that are spawning or mature will be recorded and the occurrence will trigger additional sampling at the station. Based on previous experiences during the bottom trawl survey, it is anticipated that about 10 individual stations will have spawning rockfish present and will trigger additional sampling. The additional sampling will consist of conducting one camera transect along the track of the bottom trawl path and two transects parallel to the path where the spawning fish were collected. These 3 transects will be five minutes in duration and will be used to identify substrate types and document the presence (and size) or absence of benthic invertebrates on and around the bottom trawl track. Next an autonomous plankton pump with a separate stereo camera (Kilburn et al. 2010, Madurell et al. 2012) will be deployed on each camera transect using crab line and a float. The plankton pump will collect samples of zooplankton and larvae in the water column at specific locations, as well as provide images of the substrate where the plankton sample was taken.

In addition to camera tow data, an autonomous plankton pump with a stereo camera (Kilburn et al. 2010, Madurell et al. 2012) will be deployed on each transect using crab line and a float. The plankton pump consists of a motor, pump, 75 and 200 micron mesh, flow meter , and a codend (Figure 3). Once the pump assembly comes to rest on the substrate the camera will record the surroundings for several minutes to identify coral, sponge, or bare habitat. The lights will then be turned off for 5 minutes to prevent attraction or visual avoidance of larval fish. A timed trigger will activate the pump to run for 10 minutes and the flowmeter will document flow rate. The lights will be turned back on after 10 minutes to assess location and record any movement. All samples will be preserved at sea in 95% ethanol for later analysis in Seattle. Larval fish will undergo genetic analysis as well to obtain accurate identification. The sample size for plankton collections will be approximately 30, given that about 10 bottom trawl hauls should contain spawning rockfish and would thus trigger additional sampling.

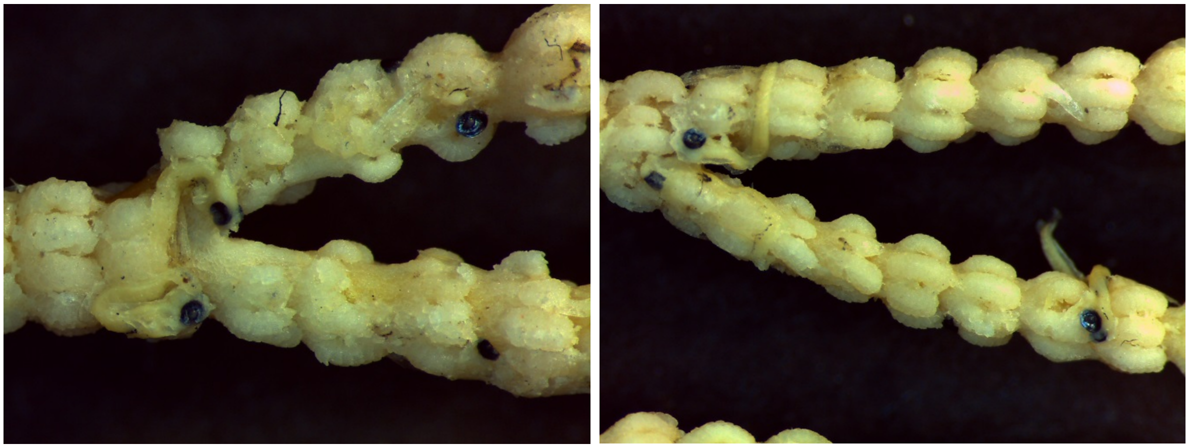


Figure 1.Fish larvae on a Fanellia gorgonian.

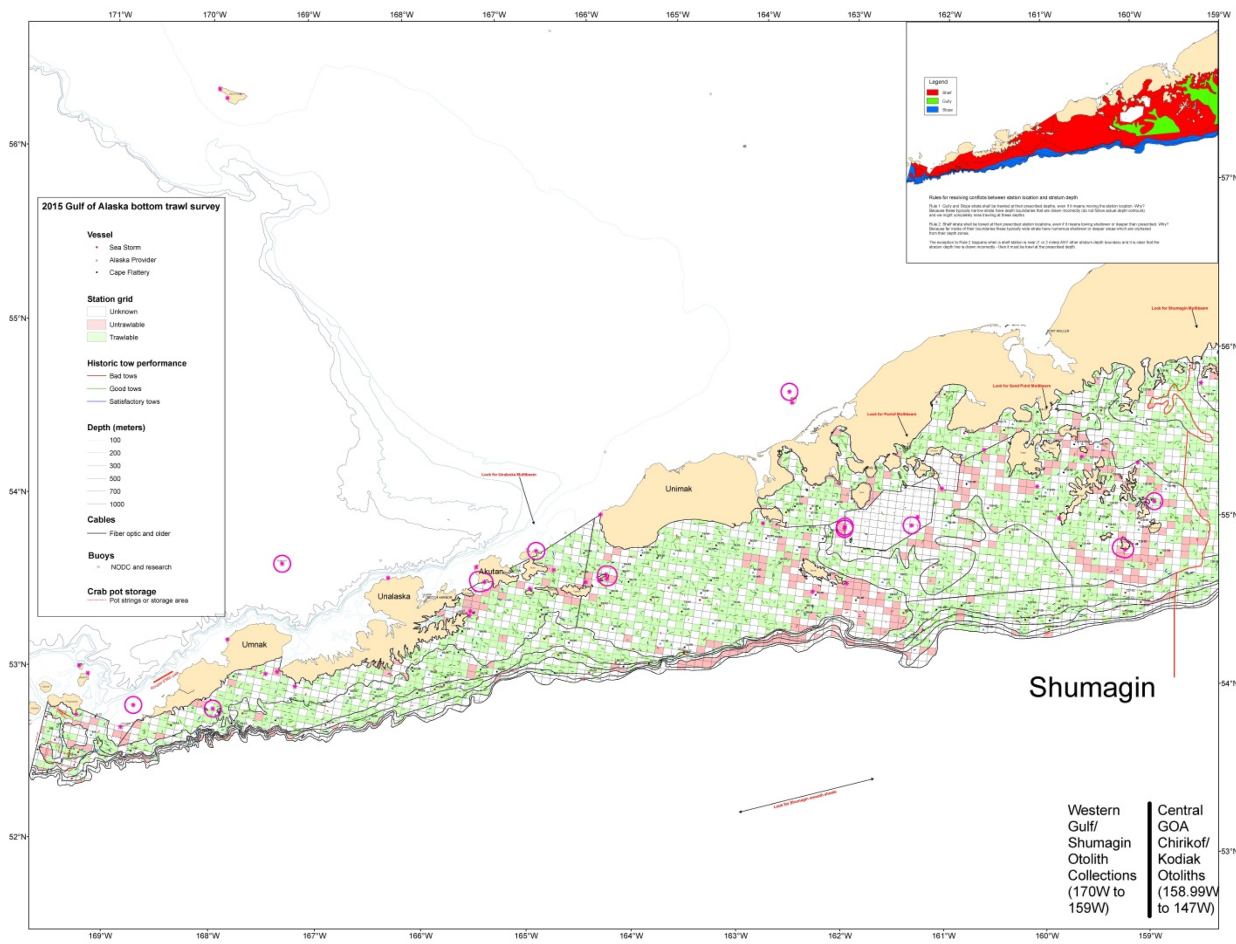


Figure 2. Map of 2015 western Gulf of Alaska bottom trawl survey stations from the Islands of Four Mountains to the Shumagin Islands as an example of the station pattern for the study. One of the survey vessels will conduct the study at its assigned stations.

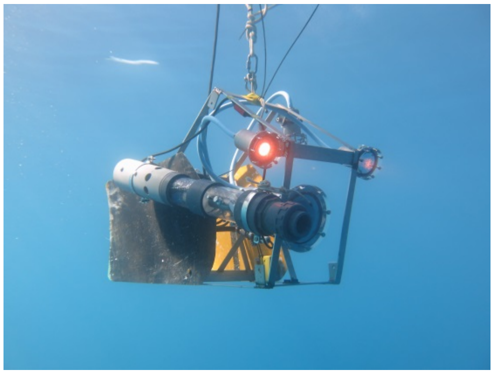
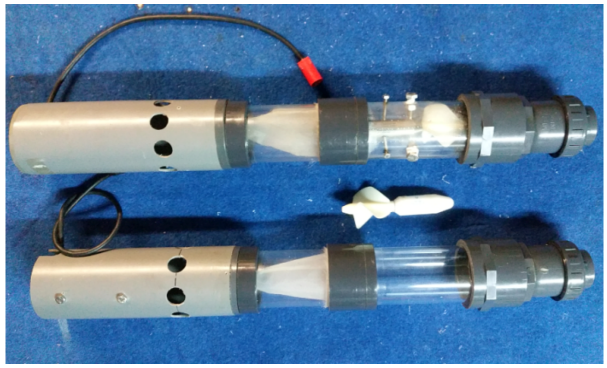
 

Figure 3. Plankton pump and deployment system with camera and lights. Images courtesy of ShelfReCover

RACE Recruitment Processes (RPP)

The Recruitment Processes Program's (RPP) overall goal is to understand the mechanisms that determine whether or not marine organisms survive to the age of "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 that we study, we attempt to learn what biotic and abiotic factors cause or contribute to the observed 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 applied by us and by others at the Alaska Fisheries Science Center to better manage and conserve the living marine resources for which NOAA is the steward. Below are research activities focusing on multiple species and ecosystem effects.

Contact: Janet Duffy-Anderson

ARCTIC

Ichthyoplankton Assemblages and Distribution in the Chukchi Sea 2012-2013 - RPP

There is significant interest in the effects of climate change on the Pacific Arctic ecosystem, and in determining influences on resident biota. In summer 2012 and 2013, large-scale fisheries oceanographic surveys that included ichthyoplankton tows were conducted in the northern Bering and eastern Chukchi Seas as part of the Arctic Ecosystem Integrated Survey (Arctic Eis). Analyses are currently underway to examine the environmental drivers of larval fish distribution, and whether those drivers vary interannually as large-scale atmospheric and oceanographic forcing varies. Arctic cod were associated with two water masses, Chukchi Winter Water and a water mass made of a combination of Anadyr Water, Bering Shelf Water, and Chukchi Shelf Water. Both of these water masses are expected to be relatively high in nutrients and zooplankton prey advected from either the Chukchi Shelf or from the Bering Sea. Yellowfin sole were associated with Alaska Coastal Water. This is a water mass that is advected from the south along the coast in the Alaska Coastal Current and is expected to be relatively low in nutrients. Yellowfin sole spawn in coastal waters in the Bering Sea, so it is not surprising that they would be advected into the Chukchi Sea in this water mass. Further analyses will examine the phytoplankton and zooplankton distributions relative to larval fish distributions. A multivariate model will be constructed to quantify the effects of year, location, water mass, phytoplankton and zooplankton on larval fish distribution.

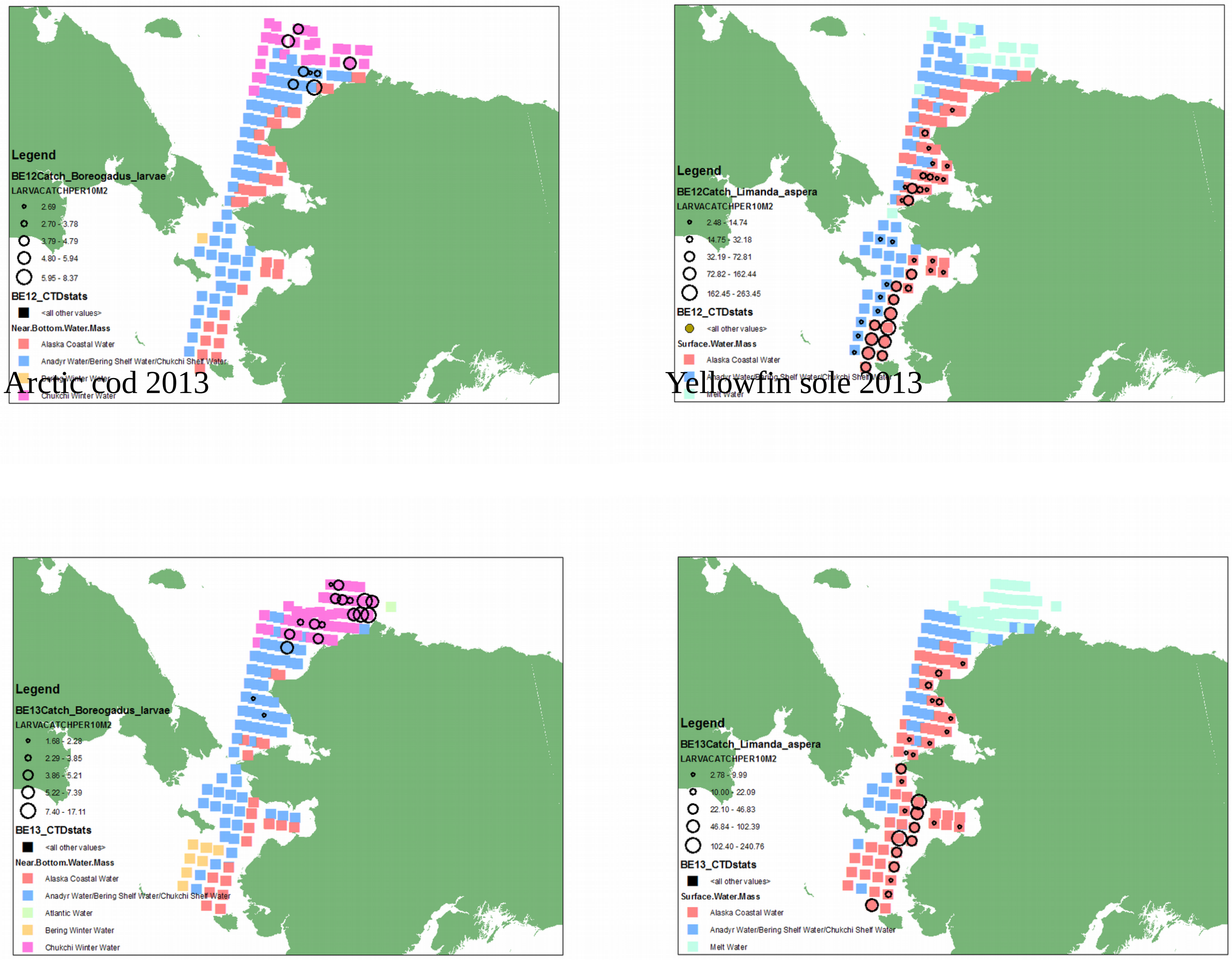
Figure 1.

Arctic cod 2012

Yellowfin sole 2012

Arctic cod 2013

Yellowfin sole 2013



Libby Logerwell, Morgan Busby and Janet Duffy-Anderson

BERING SEA

Copepod dynamics across warm and cold periods in the eastern Bering Sea: implications for walleye pollock (*Gadus chalcogrammus*) and the Oscillating Control Hypothesis--RPP

Differences in zooplankton populations in relation to climate have been explored extensively on the southeastern Bering Sea shelf, specifically in relation to recruitment of the commercially important species walleye pollock (*Gadus chalcogrammus*). We hypothesized that warm and cold periods would show differences in copepod life history stage abundance and estimated secondary production rates. Data on numerically dominant copepod species across 3 months (May, July, September) during a period of warmer water temperatures (2001-2005) and a period of colder water temperatures (2007-2011) were compared. For most copepod species, warmer conditions resulted in increased abundances in May; the opposite was observed in colder conditions (data not shown). Abundances of smaller sized copepod species did not differ significantly between the warm and cold periods whereas abundances of larger sized *Calanus* spp. increased during the cold period during July and September. Estimated secondary production rates in the warm period were highest in May for smaller sized copepods; production in the cold period was dominated by the larger sized *Calanus* spp. in July and September (Figure 1). We hypothesize that these observed patterns are a function of temperature-driven changes in phenology combined with shifts in size-based trophic relationships with primary producers. Based on this hypothesis, we present a conceptual model that builds upon the Oscillating Control Hypothesis to explain how variability in copepod production links to pollock variability (Figure 2). Specifically, fluctuations in spring sea-ice drive regime-dependent copepod production over the southeastern Bering Sea, but greatest impacts to upper trophic levels are driven by cascading July/September differences in copepod production.

David G. Kimmel, Lisa B. Eisner, Matthew T. Wilson, Janet T. Duffy-Anderson

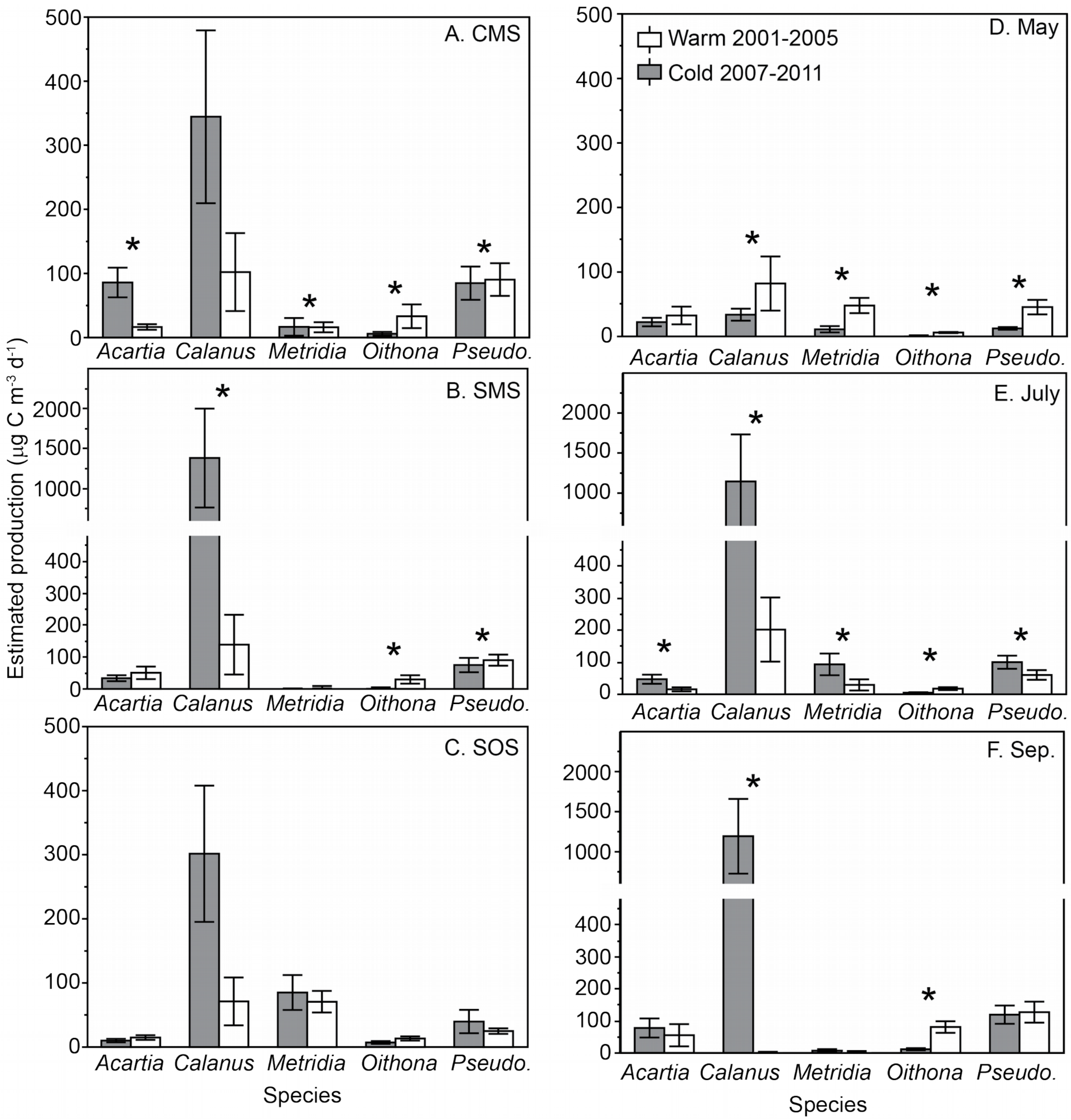


Figure 1. Copepod estimated secondary production rates (µg C m^{-3} d^{-1}) for each species (*Pseudo* is *Pseudocalanus* spp.) during cold (2007-2011) and warm (2001-2005) periods by region (all months combined): Central Middle Shelf (CMS) (A), South Middle Shelf (SMS) (B), and South Outer Shelf (SOS) (C) of the Bering Sea and by month (all regions combined): May (D), July (E), and September (F). Asterisks indicate statistical differences (ANOVA, Tukey HSD post-hoc test p < 0.05) between warm and cold period.

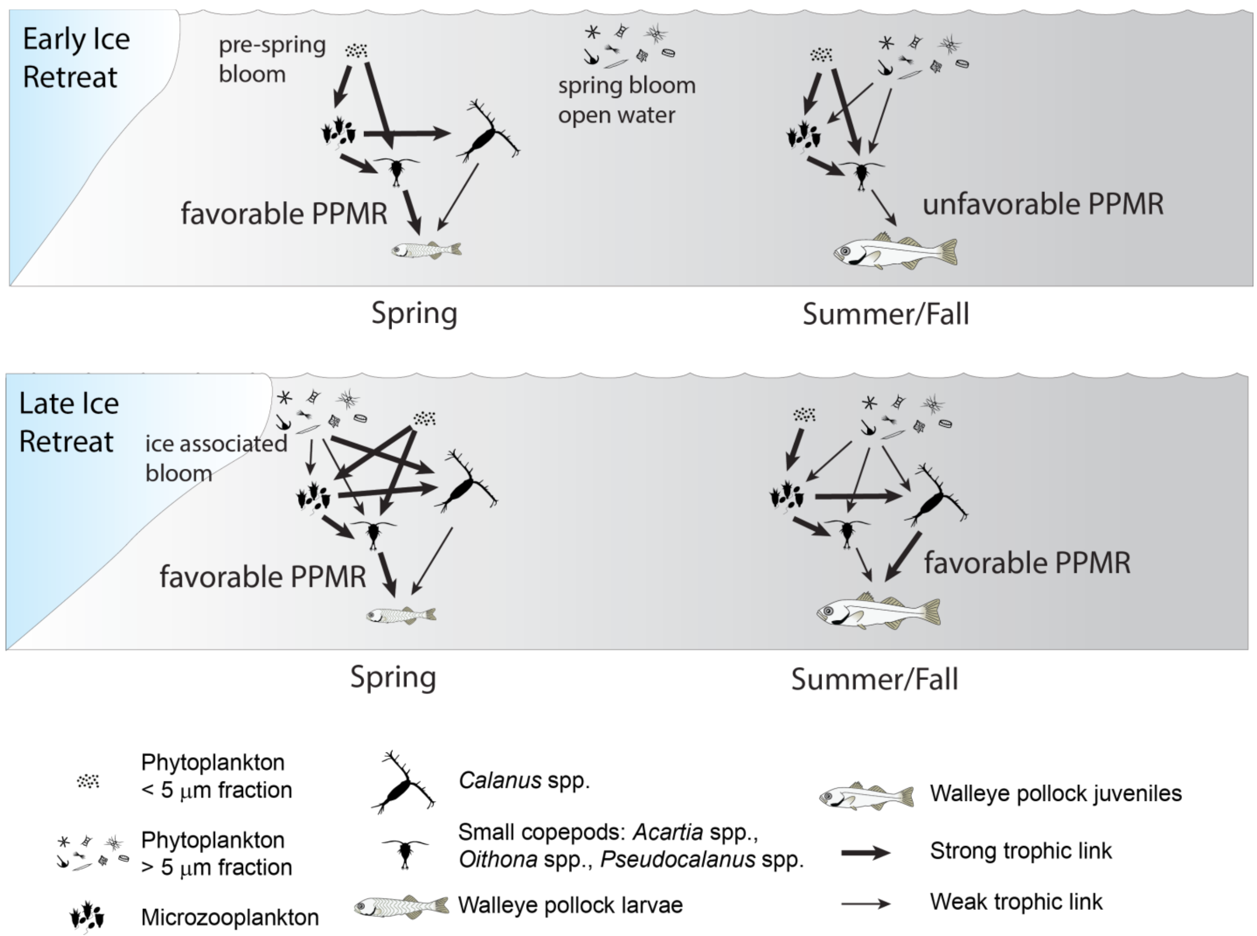


Figure 2. Conceptual model of the trophic interactions in the southeastern Bering Sea. During a year with early ice retreat (top panel) small phytoplankton cells are preyed upon by microzooplankton, small copepods, and early stages of *Calanus* spp. Warm temperatures result in higher copepod production rates and trophic transfer is high because larval walleye pollock have a favorable predator-prey mass ratio (PPMR) with their copepod prey. In the summer/fall, both large and small phytoplankton cells are present, but large copepods have disappeared from the southeastern shelf, resulting in high abundances of smaller-bodied copepods. These prey are too small to sustain the larger walleye pollock, resulting in an unfavorable PPMR and poor trophic transfer. During a year with late ice retreat (bottom panel), the spring phytoplankton bloom occurs in the marginal ice zone and in the wake of sea-ice retreat. The bloom is made up of larger sized phytoplankton cells (primarily diatoms) and is preyed upon by *Calanus* spp. early life stages; however, these prey are too large to be eaten by walleye pollock. Large phytoplankton cells are also preyed upon by microzooplankton and smaller bodied copepods that in turn provide a source of prey for walleye pollock larvae. Overall production rates are lower due to colder temperatures, but PPMR are favorable for efficient trophic transfer. In the summer/fall, *Calanus* spp. prey predominately on microzooplankton that are fueled by productive small phytoplankton cells. The larger, lipid rich *Calanus* spp. provide a favorable PPMR for walleye pollock that have switched from growth to energy provisioning in order to overwinter.

Assessing environmental DNA (eDNA) methods for use in fisheries surveys - RPP

Overall Objective:

Evaluate the performances of quantitative PCR (qPCR) and next-generation sequencing (NGS) methods for screening environmental DNA (eDNA) for species composition and relative abundances for three fish taxa (pollock, capelin and Pacific Ocean perch) that are difficult to distinguish via acoustic signatures.

Specific objectives:

1. Compare species composition and relative abundance estimates from qPCR and eDNA methods with those derived from trawling at the same sampling sites for adult walleye pollock and Pacific Ocean perch.
2. Compare species composition and relative abundance estimates from qPCR and eDNA methods with those derived from trawling at the same sampling sites for age-1 walleye pollock and capelin.
3. Evaluate the accuracy and precision of estimates from qPCR and eDNA methods using replicate samples taken from two depths in proximity to a shoal of fishes detected acoustically and subsequently sampled by trawling.

eDNA sampling and extraction

Seawater sample were collected on three dates from late June to mid-July, 2016 during a MACE hydroacoustics survey in the eastern Bering Sea. Three replicate seawater samples were taken at two discrete depths (in shoal and 10 m above shoal) on a CTD cast with 7 L Niskin bottles following the trawl. We requested that the CTD be paired as closely in time and location to the center of the trawl path as survey shipboard operations would allow. This resulted in eDNA sampling being conducted, on average, approximately 1.3 km from the center of the path with times between trawl and CTD cast ranging from 1.3 – 6.0 h (Table 1).

Table 1. eDNA collection data. Distance and time of CTD cast from center of tow path and time of trawl, respectively.

CTD date	CTD lat	CTD long	distance (km)	time (H:min)
21-Jun-16	55.2772	165.1188	1.29	1:20
1-Jul-16	55.902	168.7457	1.24	6:02
31-Jul-16	57.2945	173.8748	1.36	2:39

Filters frozen at -80 °C were thawed and incubated overnight at 65 °C in 900 µl of Longmire’s solution followed by bead beating of filters. eDNA was extracted using a phenol/chloroform protocol modified from Renshaw et al. (2015). Samples were resuspended in 30-50 µL of reagent grade water prior to qPCR trials.

qPCR probe and primer design/optimization

To date, we have developed primer/probe combinations for all three target species in the project, walleye pollock, capelin and Pacific Ocean perch (Table 2). Primer pairs and FAM-labeled probes were designed using Allele ID v. 7.0 (Premier Biosoft, Palo Alto, CA).

Initial qPCR reactions consisted of 4.32 µl of reagent grade water, 6 µl of Master mix, 0.22 µl each forward and reverse primers (50 µM), 0.22 µl probe (10 µM) and 1.0 µl of template DNA. The thermocycling profile for qPCR assays consisted of denaturation at 95 °C for 10 minutes, followed by 40 cycles of: 92 °C for 15 s, 60 °C for 1 mi. qPCR assays were conducted on an ABI7900, Applied Biosystems.

qPCR protocol optimization is still in progress. Initial results from the pollock probe produced unexpectedly low estimates of pollock eDNA (discussed below). We switched from GTX Mastermix to Environmental Mastermix (Applied Biosystems) to improve assay sensitivity. The Environmental Mastermix did improve qPCR amplification in pollock, but also produced weak, late-cycle amplification in Pacific cod, Saffron cod and Arctic cod. We are currently adjusting primer concentrations to eliminate those signals while retaining optimal sensitivity for pollock eDNA.

Table 2. Species-specific qPCR primers and probes. Size refers to number of base pairs in PCR amplicon.

species	size	F primer	R primer	probe
Walleye pollock	119	CCCTATTTGTTTGAGCAG	GTCAGTTAGAAGTATTGTGA	AGCCGTGCTTCTACTTCTA
capelin	74	CCCTCTTTCCTTCTCCTCTTA	GGCGGGTAAACTGTTCAG	TAGAAGCAGGAGCCG
Pacific Ocean perch	175	GGTGAAGGGCTATAACTAG	ACCTCATTATTTGGTTGATC	CCCCTGTAAGTACA

Walleye pollock

Primer and probe development/testing for quantitative PCR (qPCR) began in late winter-early spring, 2016. The pollock assay was optimized to provide species-specific amplification for pollock (versus four other gadid species) Standard qPCR curves for pollock exhibit 96-100% amplification efficiency in the range of 0.00025 – 10.0 ng μl^{-1} of pollock genomic DNA (Fig. 1).

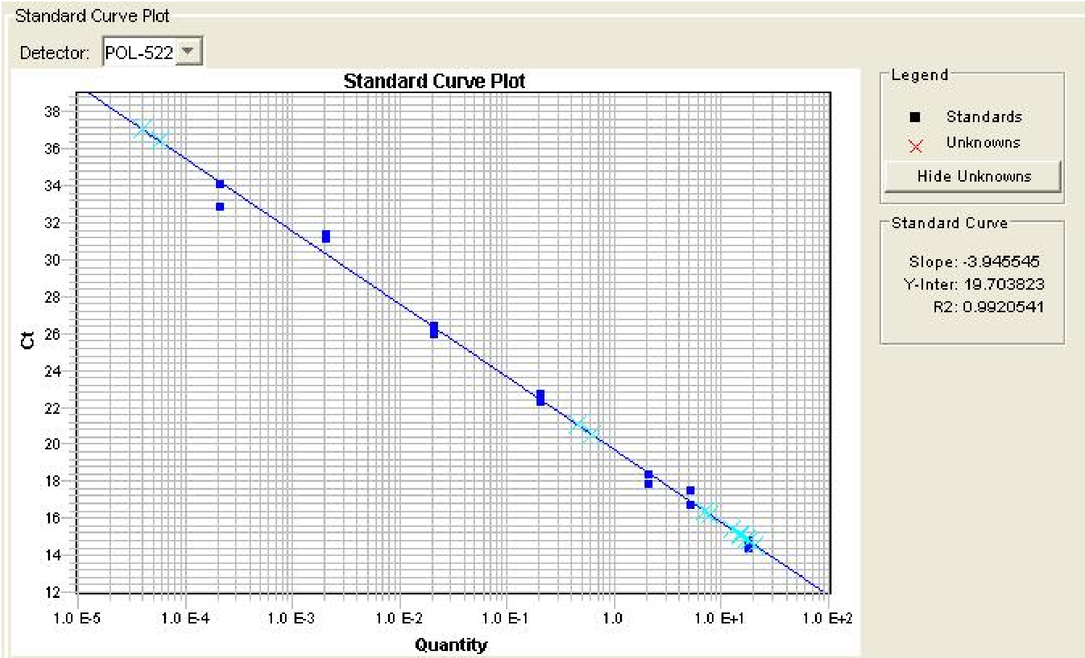
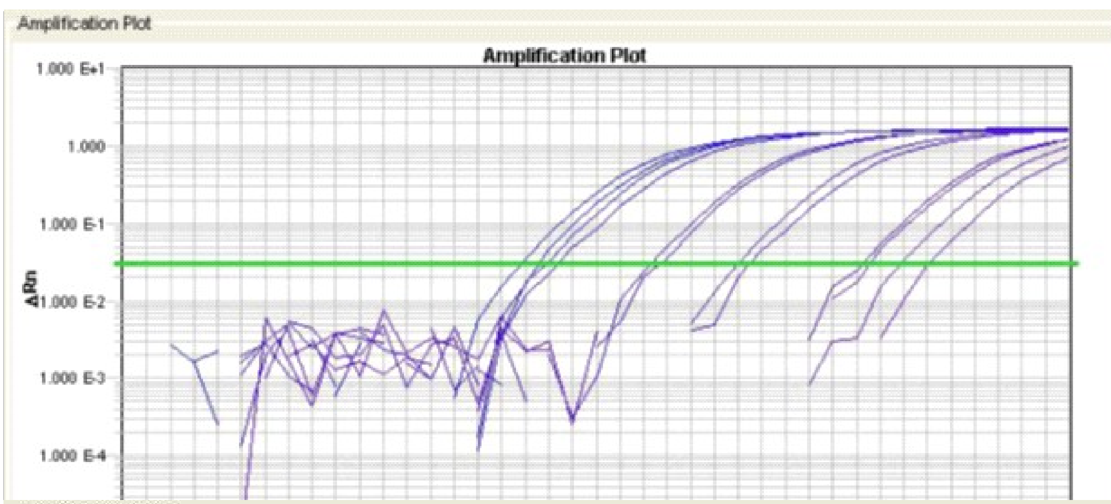
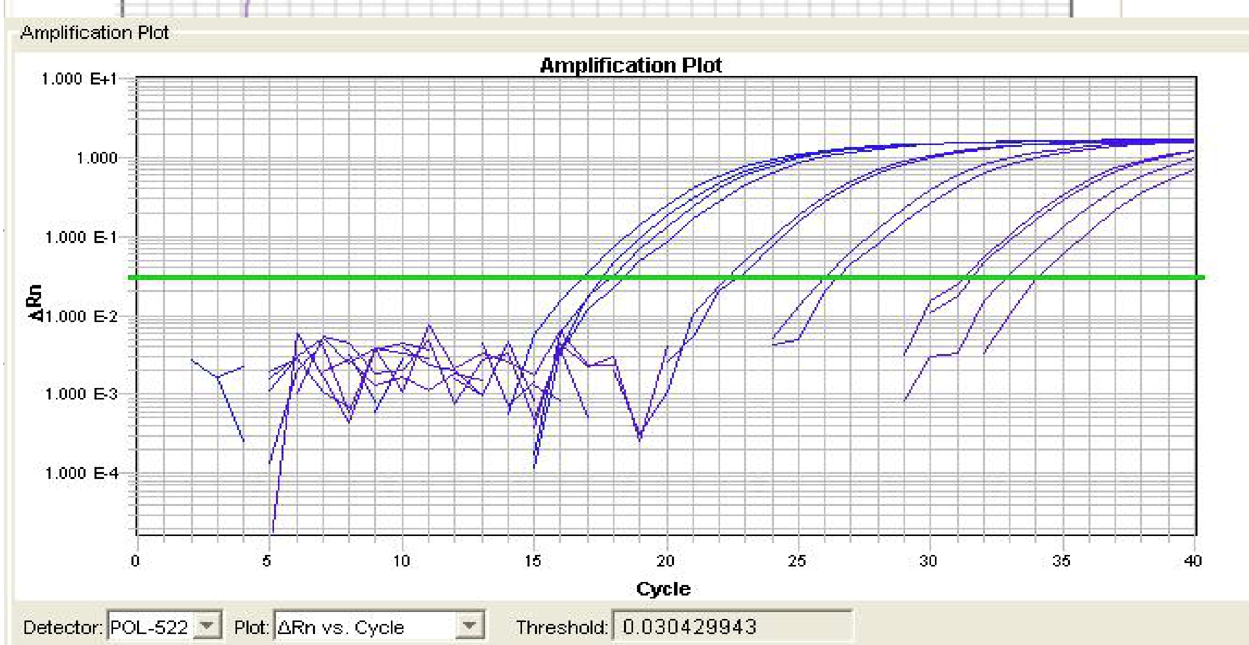


Figure 1. qPCR standard curves for walleye pollock. Replicate standard concentrations (blue boxes) range from 0.00025 – 10.0 ng ul^{-1}.





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close proximity in time and space (Table 3). Echogram screen shots (not shown) at the locations where water was sampled show considerable fish sign, which we assume are mostly pollock.

CTD #	Depth (m)	eDNA (ng µl^{-1})	# pollock in tow
36	51		1493
	81	0.0002	
74	91	0.0001	538
	152	0.0003	
129	221	na	16
	232	0.0001	

Table 3. Sampling depths, estimated pollock eDNA concentrations and number of pollock recorded in associated trawl near that location.

Capelin

Tests of the qPCR primers/probe combination developed for a 74 bp fragment of the *COI* gene in capelin showed similar amplification efficiency and sensitivity, but showed weak amplification with some eulachon and longfin smelt samples. Unfortunately, no capelin were recorded in the three trawls associated with the eDNA samples and only 23 individuals were captured during the entire survey. We do not expect to find capelin eDNA in the samples but have not tested the probe yet as we are optimizing the assay for high sensitivity.

Pacific Ocean perch (POP)

Primers and probe were designed to amplify a 175 bp fragment of the mitochondrial *ND4* gene in POP (Table 2). A diagnostic SNP to distinguish POP from other rockfishes was previously identified in NPRB Project #1219 (Lyon et al. 2016). Preliminary results indicate high probe efficiency and amplification in the range of 0.005 – 5.0 ng ul^{-1} genomic DNA concentration. Most importantly, seven other rockfish species in the ascertainment panel (Rougheye, Northern, Dusky, Redbanded, Harlequin, Black-spotted, Shortraker), chosen from recorded rockfish species in eastern Bering Sea shelf and slope surveys, failed to amplify with the primers/probe combination. Three of 14 POP genomic DNA samples also failed to amplify, although two of those failing have also not amplified with other mtDNA primers. We suspect that DNA degradation or potential misidentification of voucher specimens may be an issue. Only one of the three CTD stations sampled (#129) reported POP in the trawl catch. The CTD cast was taken 1.36 km from and 2.65 h after the trawl (Table 1), which recorded a catch of 122 individuals.

CTD #	depth (m)	replicate	eDNA (ng µl-1)	mean	std. dev.
129	221	1	0.0002	0.0006	0.0004
		2	0.0012		
		3	0.0003		
129	232*	1	0.0001	0.0002	0.0002
		2	0.0001		
		3	0.0005		

Table 4. eDNA sampling depths, estimated POP eDNA concentrations, and mean and standard deviations for replicate samples. * denotes sample compromised during extraction protocol.

Next generation sequencing (NGS)

NGS has not yet been conducted on eDNA samples. We are attempting to concentrate yields prior to library construction, which is expected to occur in February – March, 2017.

For further information contact Mike Canino at mike.canino@noaa.gov

Preliminary results of 2016 spring Bering Sea ichthyoplankton survey--RPP

The primary objective of the 2016 Eco-FOCI/EMA spring ichthyoplankton survey was to assess the abundance and spatial distribution pattern of Walleye Pollock *Gadus chalcogrammus* larvae over the southeastern Bering Sea shelf. An expanded sampling grid designed to determine the extent of the distribution of Walleye Pollock larvae and take into account differences in larval distribution between warm and cold years in the southeastern Bering Sea was used for the first time (Fig. 1). It consisted of a core grid of 145 stations that are always occupied, and 282 adaptive sampling stations located around the core grid that are occupied depending on at-sea counts of larval pollock. (Fig. 1). If at-sea counts are above a threshold, sampling continues to the next adaptive station along a transect line. If at-sea counts are equal to or below a threshold, indicating the edge of the distribution has been reached, then sampling moves to the next transect line.

The survey was conducted from May 18 to June 8, and 212 stations were completed, including all core stations and 67 adaptive sampling stations. Zooplankton and ichthyoplankton were sampled using a paired 20 and 60-cm bongo array with 153µm and 505µm mesh nets respectively. Tows were conducted to 10 meters off bottom or 300 meters maximum depth. A Sea-Bird FastCat CTD was mounted above the bongo array to acquire gear depth, temperature, and salinity profiles. A preliminary assessment of the pattern of larval abundance was determined at sea by counting the number of pollock larvae collected at each station by a bongo tow. These at-sea counts also determined which adaptative stations were sampled.

Larvae were abundant on the eastern side of the sampling grid consistent with previous observations of warm years in the Bering Sea (Fig. 2). All of the near-shore adaptive sampling stations were occupied. That area had not been previously surveyed for Walleye Pollock larvae and it showed that larvae were located further inshore than previously thought. In the north, abundance was greatest between approximately 50 and 100 m depth, and between 30 and 70 m in the south (Fig. 2). Zooplankton collected in bongo tows at selected stations were examined to determine the spatial distribution of the proportions of small (< 2 mm) and large (> 2 mm) copepod taxa, euphausiids, chaetognaths, and other zooplankton (Fig. 3). In the most general terms, large copepod taxa were dominant on the outer shelf, small copepod taxa dominated the middle and inner shelves, and the inner shelf had the greatest diversity of species (Fig. 3).

Conclusion: The new survey grid was successful in locating both the eastern and western extent of the larval distribution (Fig. 2). Large copepod species are lipid rich and therefore may be a more nutritious source of prey for fish than smaller species. Pollock larvae do not feed directly on the adult stage copepods described in this report, however characterization of the adult taxa provides an indication of the production and availability of earlier stages (microzooplankton) that are potentially available as prey to larvae. Comparing the distributions of larvae and zooplankton (Figs. 2 and 3) showed that larvae were most likely feeding on the early stages of the less nutritious small copepod species and this may have consequences for survival of later stages of pollock.

For further information contact: Steven Porter, Lauren A. Rogers, Kathryn Mier

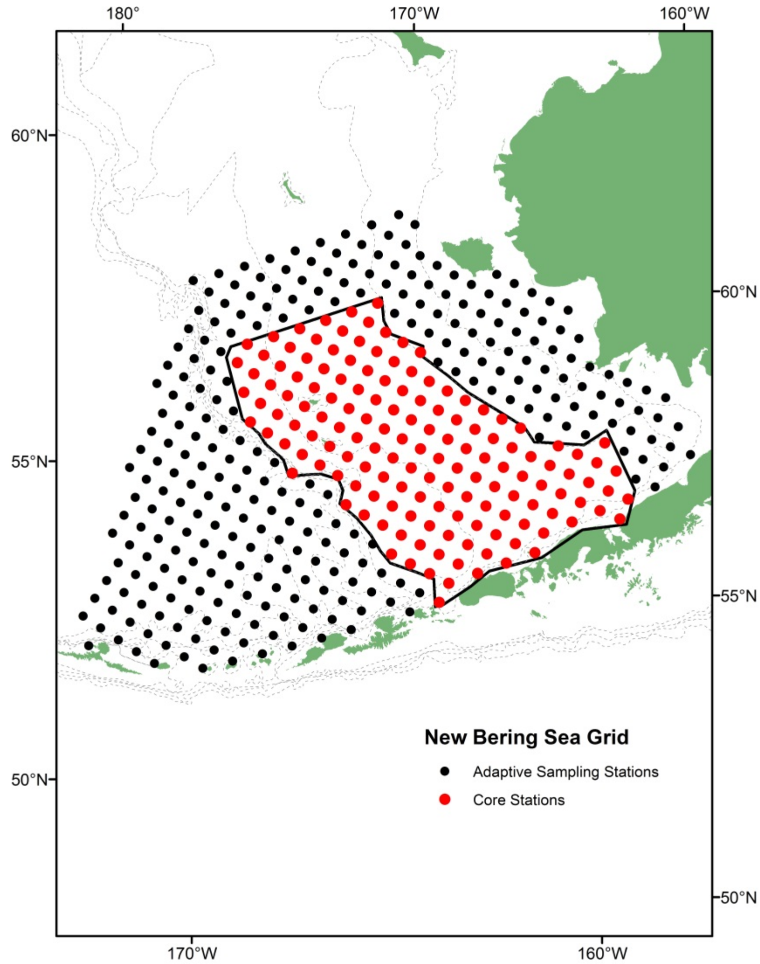

Figure 1. The new Bering Sea spring ichthyoplankton survey grid. A core grid of 145 stations is always occupied. Adaptive sampling stations are used to determine the extent of the larval distribution, and their occupation is dependent upon at sea counts of Walleye Pollock larvae.

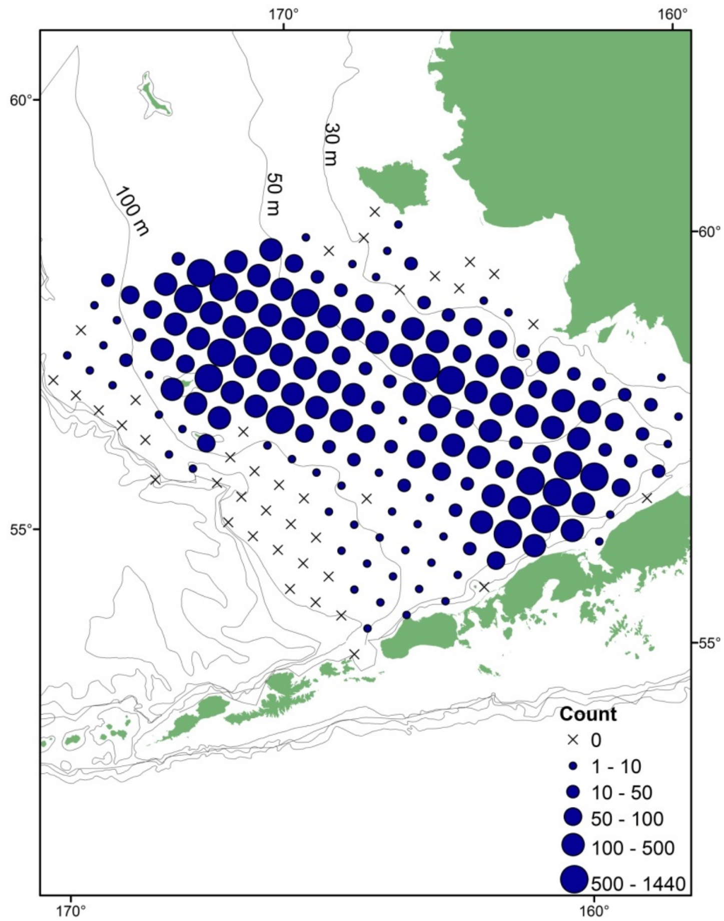

Figure 2. Abundance of Walleye Pollock larvae based on number of larvae counted at sea from bongo tows. Data are preliminary and will be verified at the AFSC.

Return of warm conditions in the southeastern Bering Sea: phytoplankton – fish--RPP
In 2014, the Bering Sea shifted back to warmer ocean temperatures (+2 ºC above average), bringing concern for the potential for a new warm stanza and broad biological and ecological cascading effects. In 2015 and 2016 dedicated surveys were executed to study the progression of ocean heating and ecosystem response. We describe ecosystem response to multiple, consecutive years of ocean warming and offer perspective on the broader impacts. Ecosystem changes observed include reduced spring phytoplankton biomass over the southeast Bering Sea shelf relative to the north, lower abundances of large-bodied crustacean zooplankton taxa, and degraded feeding and body condition of age-0 walleye pollock. This suggests poor ecosystem conditions for young pollock production and the risk of significant decline in the number of pollock available to the pollock fishery in 2-3 years. However, we also noted that high quality prey, large copepods and euphausiids, and lower temperatures in north may have provided a refuge from poor conditions over the southern shelf, potentially buffering the impact of a sequential year warm stanza on the Bering Sea pollock population.

We offer the hypothesis that juvenile (age-0, age-1) pollock may buffer deleterious warm stanza effects by either utilizing high productivity waters associated with the strong, northerly Cold Pool, as a refuge from the warm, low production areas of the southern shelf or by exploiting alternative prey over the southern shelf when access to Cold Pool waters is limited. We show that in 2015, the ocean waters influenced by spring sea ice (the Cold Pool) supported robust phytoplankton biomass (spring) comprised of centric diatom chains, a crustacean copepod community comprised of large-bodied taxa (spring, summer), and a large aggregation of midwater fishes, potentially young pollock. In this manner, the Cold Pool may have acted as a trophic refuge in that year. In 2016 however, a retracted Cold Pool precluded significant refuging in the north, though pollock foraging on available euphausiids over the southern shelf may have mitigated the effect of warm waters and reduced large zooplankton prey availability. This work presents the hypothesis that, in the short term, juvenile pollock can mitigate the drastic impacts of sustained warming. This short-term buffering, combined with recent observations (2017) of renewed sea ice presence over southeast Bering Sea shelf and a potential return to average or at least cooler ecosystem conditions, suggests that recent warm year stanza (2014-2016) effects to the pollock population and fishery may be mitigated.

For further information contact Janet T. Duffy-Anderson, Phyllis J. Stabeno, Elizabeth C. Siddon, Alex Andrews, Daniel W. Cooper, Lisa B. Eisner, Edward V. Farley, Colleen E. Harpold, Ron A. Heintz, David G. Kimmel, Fletcher Sewall, Adam Spear, Ellen Yasumishii

Figure 1. Acoustic backscatter (Nautical Area Scattering Coefficient, m^2/nmi^2) estimates in 2015 indicate higher backscatter (age-0, age-1 and mixed schools including jellyfish) in the Cold Pool relative to the shelf.

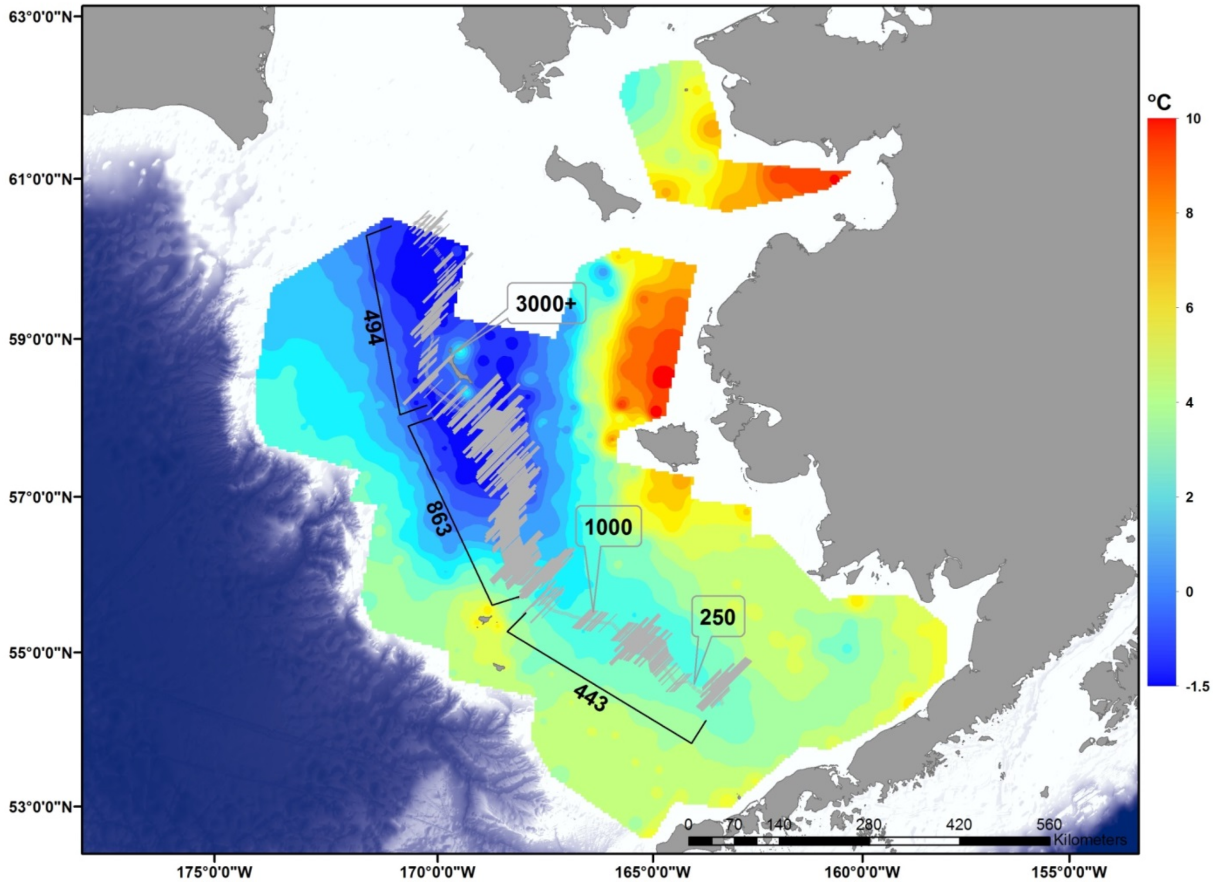

Figure 2. Mean abundance (estimated number m^{-3}) of small copepods < 2 mm (A), large copepods > 2 mm (B), and euphausiids < 5 mm (C) in the northern Bering Sea and southern Bering Sea shelf during spring and fall of 2015-2016. Error bars represent ± standard error of the mean.

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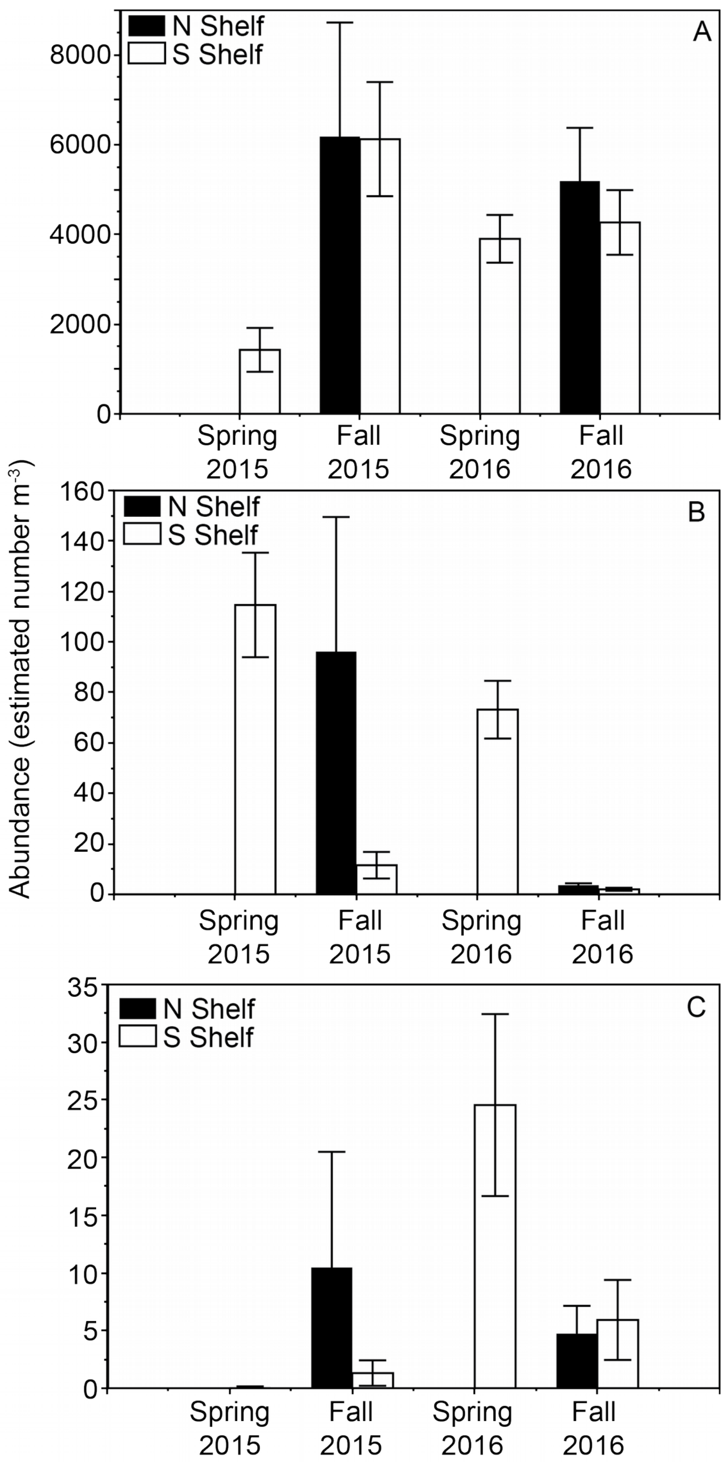

A
N Shelf
S Shelf
8000
6000
4000
2000
0
Spring 2015
Fall 2015
Spring 2016
Fall 2016
B
160
140
120
100
80
60
40
20
0
C
35
30
25
20
15
10
5
Abundance (estimated number m-3)

GULF OF ALASKA

Larval Groundfish Survey in the Western Gulf of Alaska--RPP

The objectives of this project are to conduct an ichthyoplankton survey and process studies in the region between Unimak Pass and Shelikof Strait so that we may estimate the abundance, transport, and other factors influencing the survival of young walleye pollock larvae and other species such as sablefish. Sampling with the Sameoto neuston will be used to specifically target sablefish in the surface layer. We will also occupy Line 8 to continue our 29-year time series of environmental and biological conditions in Shelikof Strait. Sampling will begin near Unimak Pass and continue up through Shelikof Strait along the Kenai Peninsula, and then along the east side of Kodiak Island as time permits. In addition to this sampling, stations have been selected from the main grid for monitoring nutrients, salts, and oxygen for PMEL scientists. Satellite tracked drifters provided by PMEL may be released in areas of high larval walleye pollock abundance. Line 8 sampling will include 20-cm and 60-cm bongos and conductivity, temperature, and depth (CTD) profiles with Niskin bottle samples for chlorophyll, microzooplankton, and nutrients. Additional CTD profiles without firing the Niskin bottles may be requested throughout the survey for calibration purposes.

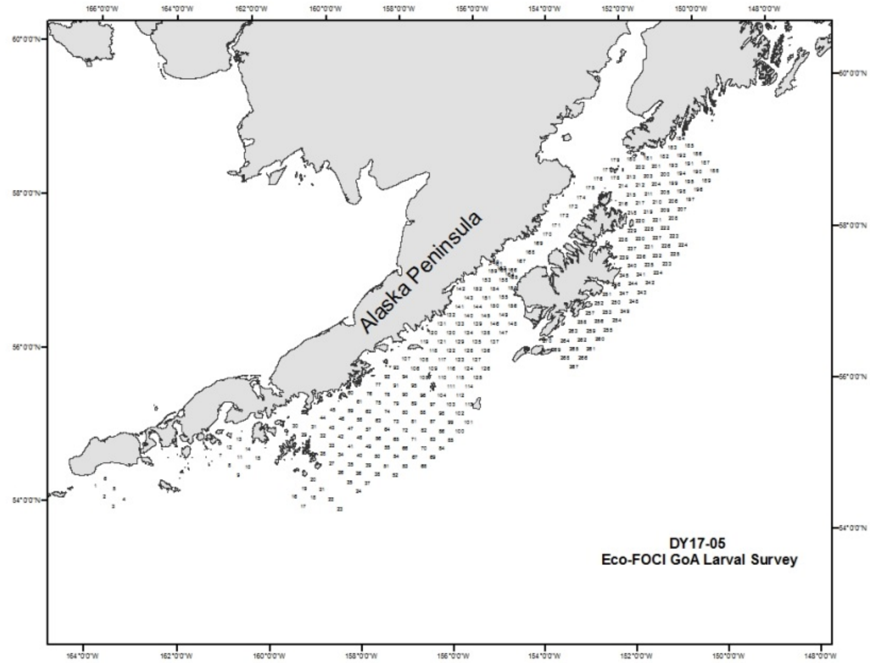
The survey will be conducted along the grid from the Gulf side of Unimak Pass to the Shumagin Islands, through Shelikof Strait, to the Kenai Peninsula and along NE Kodiak. A total of 270 stations have been planned, but all stations may not be occupied. The standard gear for this survey will be a 60-cm bongo array with 0.505-mm mesh netting. The 20-cm bongo net (0.333-mm mesh netting) will be added to the wire for sampling on alternate cross-shelf survey lines. A rapid zooplankton assessment (RZA) will be conducted to determine abundance of prey species available to larval fish at stations when the 20/60 bongo array is fished. A FastCat will be mounted above the bongo array to provide depth, temperature, and salinity data. Tows will be to 100 meters or 10 meters off the bottom, whichever is shallower.

Live tows may be conducted with the CalVET to examine larval walleye pollock condition if larvae ≤ 8 mm are found. If larvae are collected for the pollock condition study, a CalVET tow (with 53 µm mesh) to 70 meters will be conducted to collect small zooplankton. The CalVET is a vertical tow and will be deployed and retrieved at a rate of 45 - 60 m/min. The FastCat will be mounted above the CalVET.

A total of 40 Neuston tows will be conducted along the shelf break and other known areas of larval sablefish abundance to acquire specimens for special studies. The net mesh will be 505 µm and fished at a ship speed of 1.5 to 2.0 knots for 10 minutes. The ship will be standby for a rough count of sablefish larvae to determine if another Neuston tow will be conducted at that station to obtain samples for special studies (age and growth, condition, diet). The first Neuston sample conducted at each station will be a quantitative sample and preserved in 1.5% formaldehyde. The second Neuston sample will be sorted for larvae and preserved in 100% ethanol or frozen. Current laboratory rearing experiments conducted at AFSC to validate daily growth will be compared to WGoA field collected sablefish.

For further information contact Annette Dougherty and Alison Deary

Figure 1. Survey area in the western Gulf of Alaska



Gulf of Alaska Ichthyoplankton Abundance Indices 1981-2015--RPP
The Alaska Fisheries Science Center's (AFSC) Ecosystems and Fisheries Oceanography Coordinated Investigations Program (EcoFOCI) has been sampling ichthyoplankton in the Gulf of Alaska (GOA) from 1972 to the present, with annual sampling from 1981–2011 and biennial sampling thereafter. The primary sampling gear used for these collections is a 60-cm bongo sampler fitted with 333 or 505-μm mesh nets. Oblique tows are carried out mostly from 100 m depth to the surface or from 10 m off bottom in shallower water. Historical distribution of sampling effort extends from the coastal area to the east of Prince William Sound southwestwards along the Alaska Peninsula to Umnak Island, covering coastal, shelf and adjacent deep water, but has been most intense in the vicinity of Shelikof Strait and Sea Valley during mid-May through early June (Fig. 1). From this area and time, a subset of data has been developed into time-series of ichthyoplankton species abundance for 12 larval taxa in the GOA, including species of groundfish (Fig. 2).

In relation to the previous three decades of observations, 2015 was an anomalous year for most species. For walleye pollock, larval abundance was the lowest ever observed, following a very high positive anomaly in 2013. Pacific cod, flathead sole, northern rock sole, and Pacific sand lance also had record low abundances in 2015, and starry flounder and Pacific halibut showed strong negative anomalies. Only two taxa showed positive anomalies in 2015: northern lampfish and rockfish. Rockfish, which aren't identified to species, continued their steep upward trend, which started in 2007 and accelerated in 2011 and 2013.

The warm anomaly in the Gulf of Alaska in 2014 and 2015 appears to have had wide-ranging consequences for the marine ecosystem. Our data suggest that the anomalous warm conditions corresponded to extreme low abundances of larvae for many species, although the mechanism underlying such a response is still being investigated. Possibilities include a mismatch of prey availability with the period of larval first-feeding, low quality prey resources, advection of larvae out of preferred shelf habitats, or thermal stress. Investigation into these mechanisms is continuing. Icthyoplankton surveys can provide early-warning indicators for ecosystem conditions and recruitment patterns in marine fishes. While mortality during later life stages is clearly important, poor conditions during the first few weeks and months of life can already determine the potential for a large year class, emphasizing the importance of studying processes affecting mortality and abundance of early life history stages.

For further information contact Lauren A. Rogers and Kathryn Mier

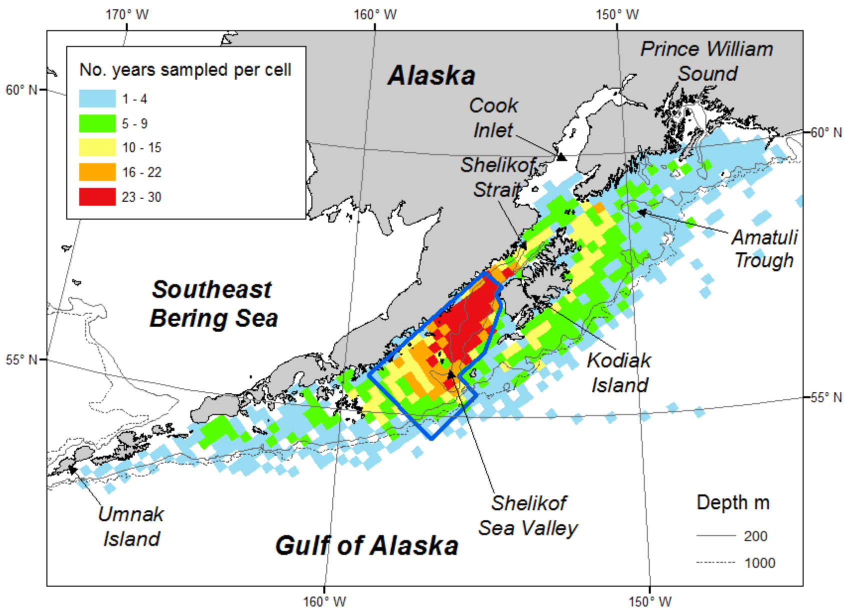


Figure 1. Distribution of historical ichthyoplankton sampling in the Gulf of Alaska. Sampling effort is illustrated by the number of years where sampling occurred in each 20 km^2 grid cell over these years. A late spring time-series ichthyoplankton abundance has been developed from collections in the area outlined in blue.

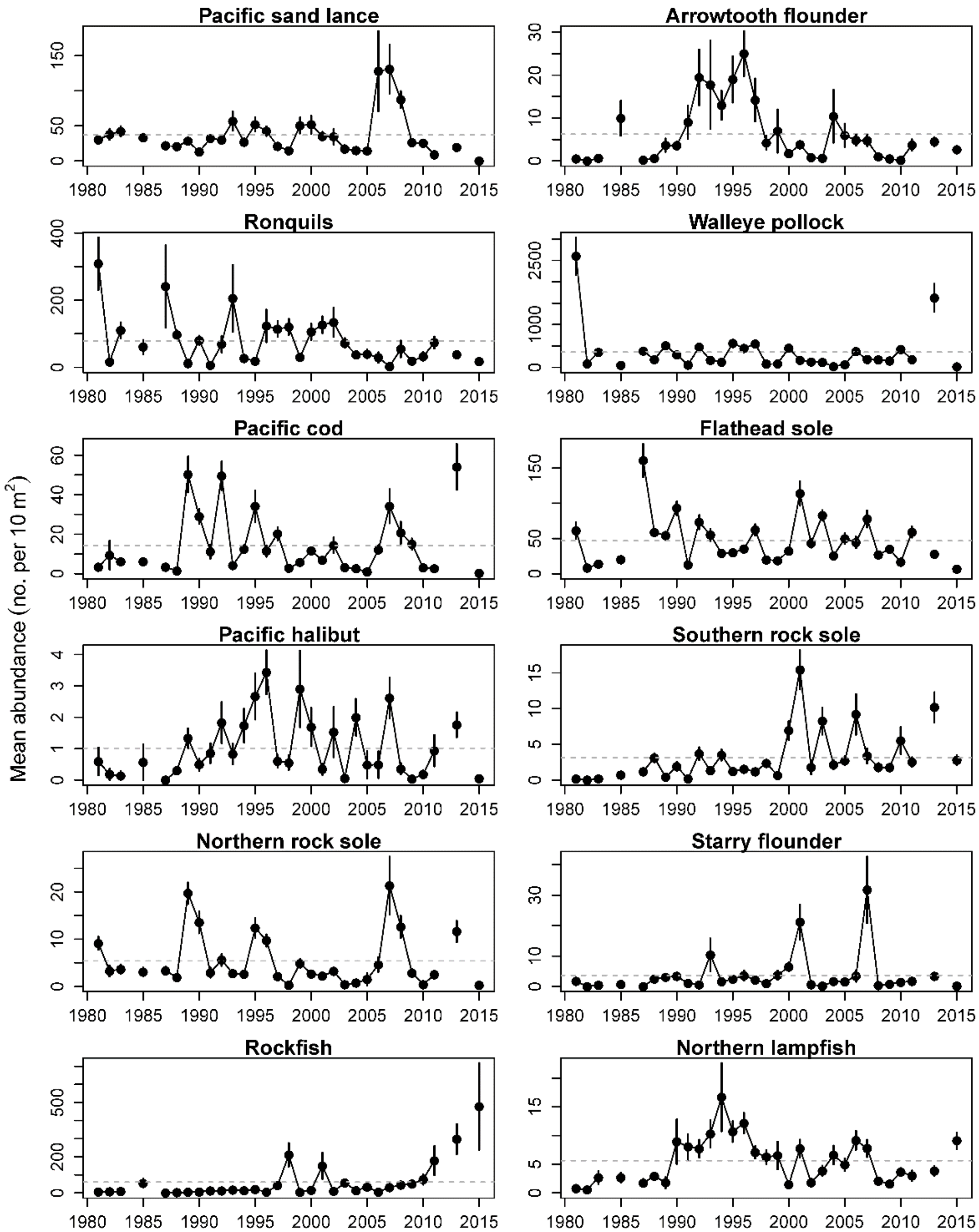


Figure 2. Interannual variation in late spring larval fish abundance in the Gulf of Alaska. The larval abundance index is expressed as the mean abundance (no. 10 m^{-2}), and the long-term mean is indicated by the dashed line. Error bars show +/- 1 SE. No data are available for 1984, 1986, 2012 or 2014.

Gulf of Alaska Project: Benthic Habitat Research - ABL

The primary goal of the Gulf of Alaska (GOA) benthic habitat research project is to characterize the preferred settlement habitat for the five focal groundfish species specified by the GOA Project Upper Trophic Level component. There are five main objectives for the habitat project: 1) conduct a literature review and synthesis of early life (EL) preferred habitat and observational data of five focal species, 2) collect, validate, digitize, and grid available benthic habitat data, 3) create benthic metrics from habitat data, 4) model species-specific habitat by early life stage, and 5) generate species-specific suitability maps of the literature and modeling results. All objectives for this project have been completed and the final report has been submitted to the North Pacific Research Board (NPRB). Additionally, a draft manuscript by Pirtle et al. (In Reivew) was submitted for review in a special issue of Deep-Sea Research II describing the work on the early juvenile stage habitat suitability models for the five species.

The Final Report to the NPRB (100+pgs) included the following information for the five focal species: 1) extensive literature review of habitat preferences with life stage tables, 2) methods and maps of the high resolution suite of benthic habitat variables, 3) methods and database of the field observations for the early juvenile stages, 4) methods and maps for the literature based habitat suitability, 5) methods, model selection, model results, and final maps for the model-based habitat suitability 6) regional based habitat suitability estimates, and 7) extensive discussion of project. The follow up Essential Fish Habitat (EFH) project (Pirtle, Shotwell, Rooper) was also completed this year. The baseline habitat suitability framework from the GOA Project was extended to include new biophysical habitat metrics (e.g. production, temperature, corals) and applied to a variety of groundfish species from the early juvenile life stage through adults (including the five focal species). The results from this project were included in the 2016 EFH update which was submitted to stock assessment scientists for review. These EFH results are also planned for inclusion in the new species-specific ecosystem considerations sections of the stock assessment fishery evaluation (SAFE) process and may assist fishery managers in future decisions regarding survey planning and habitat assessment. During the next phase of the GOA Project Synthesis, the baseline habitat suitability models will be combined with individual based models (IBMs) in a novel approach to delineating survival trajectories for understanding recruitment of groundfish. The case study for this approach will be Alaska sablefish. We will also be developing a habitat metrics geodatabase for future research.

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

The contribution of specific habitat types to the productivity of many rockfish species within the Gulf of Alaska remains poorly understood. It is generally accepted that rockfish species in this large marine ecosystem tend to have patchy distributions that frequently occur in rocky, hard, or high relief substrate. The presence of biotic cover (coral and/or sponge) may enhance the value of this habitat and may be particularly vulnerable to fishing gear. Previous rockfish habitat research in the Gulf of Alaska has occurred predominantly within the summer months. This project examined the productivity of the three most commercially important rockfish in the Gulf of Alaska (Pacific ocean perch, *Sebastes alutus*, northern rockfish, *S. polyspinis*, and dusky rockfish, *S. variabilis*) in three different habitat types during three seasons. Low relief, high relief rocky/boulder, and high relief sponge/coral habitats in the Albatross Bank region of the Gulf of Alaska will be sampled using both drop camera image analysis and modified bottom trawls. These habitats were sampled at two locations in the Gulf of Alaska during the months of August, May, and December. Differences in density, community structure, prey availability, diet diversity, condition, growth, and reproductive success were examined within the different habitat types. All field work for this project has been completed and sample processing and data analysis will be completed within the next year.

2016 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 2016, AFSC personnel analyzed the stomach contents of 33 species sampled from the eastern Bering Sea and Aleutian Islands regions. The contents of 20,975 stomach samples were analyzed including 2,183 stomach samples analyzed at sea during the Aleutian Islands groundfish survey and 2,388 stomach samples analyzed at sea during the eastern Bering Sea Continental Slope groundfish survey. This resulted in the addition of 53,037 records to AFSC's Groundfish Trophic Interactions Database. In addition, bill-load samples from 330 seabirds were analyzed for the Alaska Department of Fish and Game.

Collection of additional stomach samples was accomplished through resource surveys, research surveys, and special studies comparing stomach contents with prey-sampling. About 9,920 stomach samples were collected from large and abundant predators during bottom trawl and midwater trawl surveys of the eastern Bering Sea continental shelf. About 1,225 stomach samples were collected from groundfish during the bottom trawl survey of the eastern Bering Sea continental slope to supplement the 2,388 stomach samples analyzed at sea. About 1,795 stomach samples were collected from the Aleutian Islands to supplement the 2,183 stomach contents that were analyzed at sea in that region. Fishery Observers resumed collection of stomach samples from Alaskan fishing grounds in 2016, resulting in 330 additional samples.

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 2016: the Status of Alaska's Marine Ecosystems completed and posted online-- REFM/ESSR

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. New this year, the information was prepared in a separate report for each of three ecosystems: the eastern Bering Sea, Aleutian Islands, 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

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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.

References

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

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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.

References

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

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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.

<u>Amendment 91 EDR</u>

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
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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

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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

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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

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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).

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

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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.*

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

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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

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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

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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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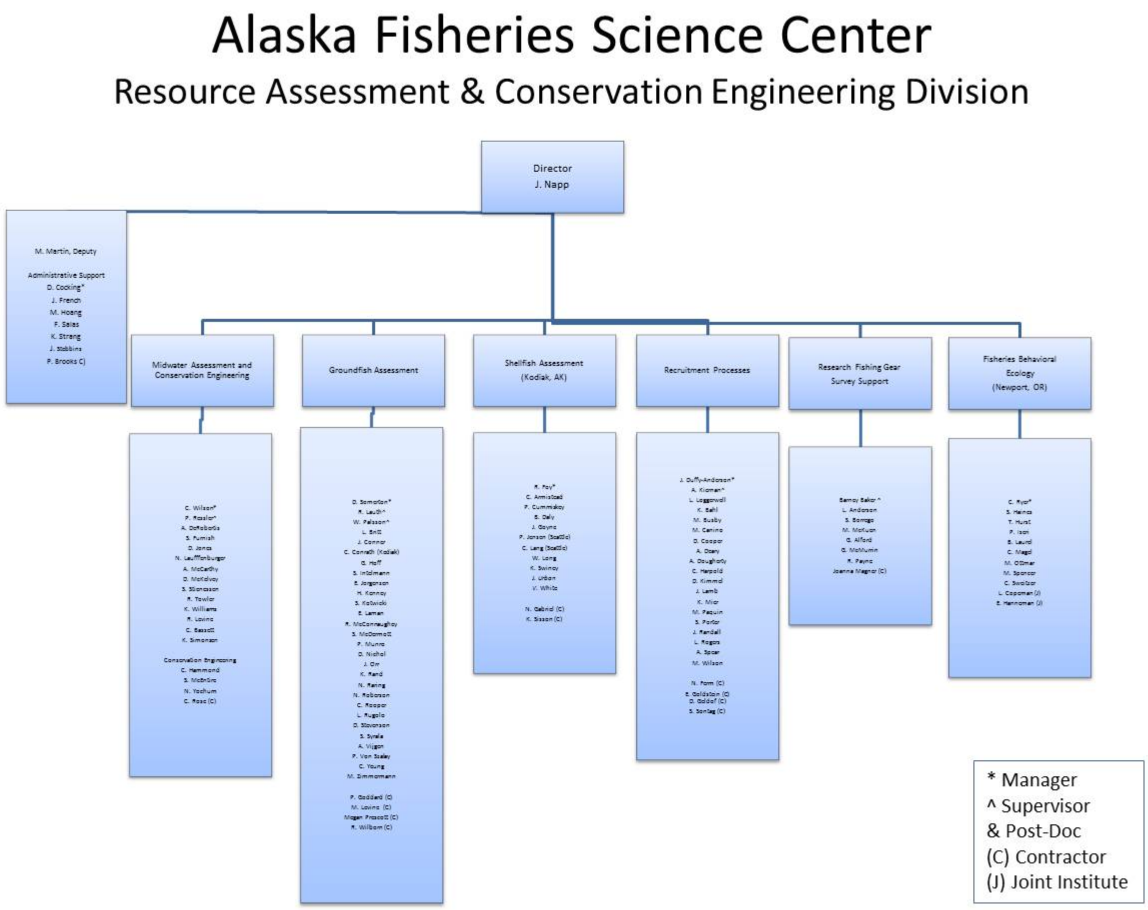
APPENDIX I. RACE ORGANIZATION CHART



APPENDIX II. REFM ORGANIZATION CHART

APPENDIX III – AUKE BAY LABORATORY ORGANIZATIONAL CHART

LABORATORY DIRECTOR

MUNDY (S/RO)

• Nelson

MESA — MARINE ECOLOGY & STOCK ASSESSMSENT PROGRAM

HEIFETZ (ACTING PM)

MARINE STOCK ASSESSMENTS

Lunsford (Temp S/RO)

- •Csepp
- •Hanselman
- •Hulson
- •Rutecki
- •Stone

Contractor

- •Peterson (N-A)

Heifetz (S/RO)

- •Echave
- •Lunsford
- •Malecha
- •Rodgveller
- •Shotwell
- •Tribuzio

Contractor

- •Coutre (N-A)
- •Pirtle (N-A)

RECA — RECRUITMENT, ENERGETICS & COASTAL ASSESSMENT PROGRAM

HEINTZ (PM)

RECRUITMENT, ENERGETICS & COASTAL ASSESSMENT

Heintz (S/RO)

- •Bradshaw
- •Carls (S/RO)
- •Fergusson
- •Lindeberg
- •Miller
- •Moran
- •Sewall
- •Siddon
- •Vollenweider

Contractor

- •Ballard (N)
- •Callahan (N)
- •Debenham (N)
- •Fournier (N)
- •Jarvis (N)
- •Mosher(N)
- •Neff (N)
- •Sreenivasan (N-A)

Carls (S/RO)

- •Fugate
- •Holland
- •Maselko
- •Masuda
- •Rogers

Contractor

- •Cormack (N)

EMA — ECOSYSTEM MONITORING & ASSESSMENT PROGRAM

FARLEY (PM)

FISHERIES OCEANOGRAP BASIS / SOEBA

Farley (S/RO)

- •Andrews
- •Cieciel
- ✚Eisner
- •Gray (S/RO)
- •Gann
- •Moss
- •Strasburger
- •Yasumiishi

Contractor

- •Dimond (N-A)
- •Grange (N-V)
- •Johnson (N-A)
- •Nicolls (N-A)

Gray (S/RO)

- •Eiler
- •Joyce
- •Murphy
- •Orsi
- •○ Vulstek

Contractor

- ★ Adams (N-A)
- •Bare (N)
- •Bell (N-A)

GENETICS — GENETICS PROGRAM

GUYON (PM)

GENETICS

Guyon (S/RO)

- •Guthrie
- •Kondzela
- •Nguyen
- •Wildes
- •Whittle

Contractor

- •Cuadra (N)
- •Thomson(N-A)

FACILITIES — FACILITIES PROGRAM

COOPER (PM)

FACILITIES

Cooper (S/RO)

- •Abbas
- •Anderson
- •Garcia
- •Hoover
- •Leopold
- •Weinlaeder
- ✗Stanley (Seas)

Contractor

- ★Adams (N)
- •Eller (N)
- •Heckler(N)
- •Mattson (N)
- •Pierce (N)
- ★Luedke (N)

OM — OPERATIONS MANAGEMENT PROGRAM

HAGEN DD (PM)

ADMIN / IT

Hagen (S/RO)

ADMIN

- •Johnson, F
- •Johnston, S
- •Mahle
- •Whiteley

Contractor

- •Steeves (N)

IT

- •Williams

Contractor

- •Heard, J (N-A)

FACILITIES

- •TSMRI
- ♦Auke Bay Marine Station
- ★Little Port Walter Marine Station
- ○ Auke Creek Research Station
- ✗ Pribilof/St Paul /St. George Islands
- ✚ Bldg 4, Sand Point, Seattle
- Juneau Subport

CODES

- F/AKC4 = ABL Routing Code
- * Organization Code
- ■Operating Unit Number

ABBREVIATIONS

- PM = Program Manager
- A = Associate
- N = Non-NOAA
- RO = Rating Official
- S = Supervisor
- Seas = Seasonal
- St = Student Appointment
- T = Term Appointment
- V = Volunteer

ABL Organization Totals

FTE	63
Associate	11
Contractors	17
Volunteer	1
TOTAL Active	92

F/AKC4*   AUKE BAY LABORATORIES   ■ FS7400

ORGANIZATIONAL CHART

June 21, 2016

APPENDIX IV – FMA ORGANIZATIONAL CHART