Alaska Fisheries Science Center of the National Marine Fisheries Service

2014 Agency Report to the Technical Subcommittee of the Canada-US Groundfish Committee

April 2015

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VIII. REVIEW OF AGENCY GROUNDFISH RESEARCH, ASSESSMENTS, AND MANAGEMENT IN 2014

A. 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.

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, pathobiologists, 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 2014 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). Two Alaskan bottom trawl surveys of groundfish and invertebrate resources were conducted during the summer of 2014 by RACE Groundfish Assessment Program (GAP) scientists: the annual Eastern Bering Sea Shelf Bottom Trawl 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 Shelf as well as winter acoustic trawl surveys in the Gulf of Alaska. Research cruises investigating bycatch issues also continued.

For more information on overall RACE Division programs, contact acting Division Director Jeffrey Napp at (206)526-4148.

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 acting Division Director Dan Ito at (206) 526-4232.

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, sharks, and grenadiers in Alaska and studies on benthic habitat. Presently, the program is staffed by 14 scientists and 1 post doc. ABL’s Ecosystem Monitoring and Assessment Program (EMA) has also been conducting groundfish-related research for the past few years.

In 2014 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) large-scale, epipelagic trawl survey of the northern Bering Sea shelf conducted by ABL's EMA Program; and 5) an upper trophic level fisheries oceanography survey of the Gulf of Alaska.

Ongoing analytic activities in 2014 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, northern rockfish, dusky rockfish, rougheye/blackspotted rockfish, shortraker rockfish, "Other Rockfish", and thornyheads, and Gulf of Alaska and Eastern Bering Sea sharks and grenadiers.

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.

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.

B. Multispecies Studies

1. Stock Assessment and Surveys

2014 Eastern Bering Sea Continental Shelf Bottom Trawl Survey – RACE GAP
The thirty-third in a series of standardized annual bottom trawl surveys of the eastern Bering Sea (EBS) continental shelf was completed on 6 August 2014 aboard the AFSC chartered fishing vessels *Vesteraalen* and *Alaska Knight*, which bottom trawled at 376 stations over a survey area of 492,898 km^2. Researchers processed and recorded the data from each trawl catch by identifying, sorting, and weighing all the different crab and groundfish species and then measuring samples of each species. Supplementary biological and oceanographic data collected on the bottom trawl survey was also collected to improve understanding of life history of the groundfish and crab

species and the ecological and physical factors affecting their distribution and abundance.

Survey estimates of total biomass on the eastern Bering Sea shelf for 2014 were 7.4 million metric tons (t) for walleye pollock, 1.1 million t for Pacific cod, 2.5 million t for yellowfin sole, 1.9 million t for northern rock sole, 28 thousand t for Greenland turbot, and 171 thousand t for Pacific halibut. There were increases in estimated survey biomass for most major fish taxa compared to 2013 levels. Walleye pollock biomass increased 62%, Pacific cod 35%, arrowtooth flounder 15%. yellowfin sole 10%, northern rock sole 6%, and Greenland turbot 12.5%. There were slight decreases for Alaska plaice (11%) and Pacific halibut (7%).

Average surface temperature was 8.2°C, the third warmest in the 33 year time series after 1983 and 2004, and in increase from last year's value of 6.4°C. Bottom temperatures averaged 3.0°C, greater than last year's average of 1.7°C and the warmest value since 2005.

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

2014 Biennial Bottom Trawl Survey of Groundfish and Invertebrate Resources of the Aleutian Islands – RACE GAP

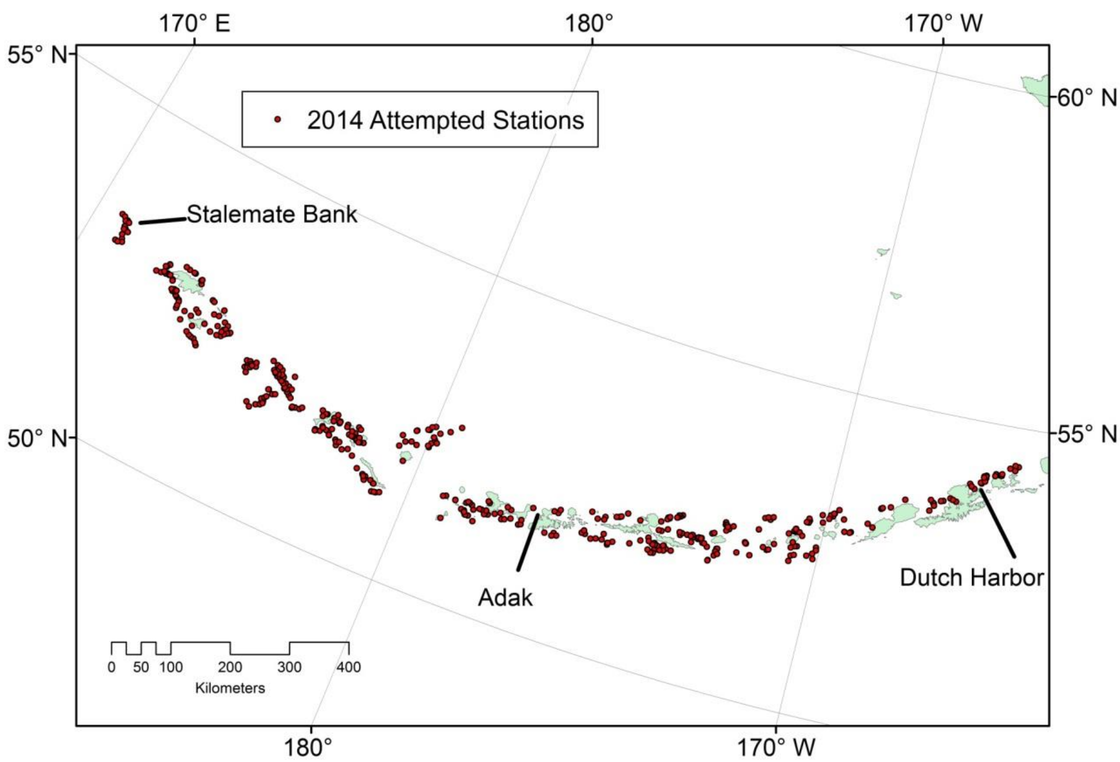
The National Marine Fisheries Service Alaska Fisheries Science Center (AFSC) Resource Assessment and Conservation Engineering (RACE) Division chartered the fishing vessels *Alaska Provider* and *Sea Storm* to conduct the 2014 Aleutian Islands Biennial Bottom Trawl Survey of groundfish resources. This was the thirteenth survey in the series which began in 1980, was conducted triennially for most years until 2000, and then biennially since. However, there was no survey in 2008. Both vessels were chartered for 70 days, and the cruise originated from and concluded at Dutch Harbor, Alaska . The charter began on 5 June 2014 and ended on 13 August. The Alaska Provider was chartered for an additional two days to conduct net efficiency studies for the survey trawl. After the vessels were loaded and other preparations (*e.g.,* wire measuring, wire marking, and test towing) were made before the first survey tows were conducted on 11 June. The vessels first proceeded eastwards conducting stations to Unimak Pass (165° W) and then proceeded westward to Stalemate Bank (longitude 170°E), west of Attu Island (Figure 1). The cruise was divided into three legs with breaks in 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 2014 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.

The survey design was a stratified random sampling scheme consisting of 420 stations selected randomly from a combination of successful tows completed during previous surveys and sites not previously trawled. The selected sampling sites were allocated to 45 sampling strata defined by geographical location, depth, and regulatory area, ranging from shallow, nearshore depths to approximately 500 m on the continental slope. 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.

Four-hundred fifty-eight stations were attempted during the regular survey (Figure 1). Of these, 410 hauls were successful and used for determining catch per unit effort and estimating biomass. Forty-eight hauls were unsuccessful because of net damage, poor net performance, or the station was duplicated. Four stations were not occupied because of poor weather at the end of the cruise. The survey activity resulted in a total fish catch of 534 mt and 878,000 individuals representing 163taxa. Nearly 16 mt of invertebrates were captured representing 497 taxa.

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



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

The MACE Program conducted winter acoustic-trawl (AT) surveys in 2014 aboard the NOAA Ship *Oscar Dyson*, targeting walleye pollock (*Gadus chalcogrammus*) in Sanak Trough, the Shumagin Islands, Marmot Bay, and Shelikof Strait. Midwater and near-bottom acoustic backscatter was sampled using an Aleutian Wing 30/26 Trawl (AWT), and on-bottom backscatter was sampled with a poly Nor'eastern (PNE) bottom trawl. A modified Marinovich trawl was also used once to determine compatibility for future operations.

The Shumagin Islands survey was delayed for 2 weeks from original plans due to vessel mechanical issues. The survey was subsequently conducted 23-26 February along parallel transects spaced 5 nautical miles (nmi) apart within Shumagin Trough, 1 nmi apart east of Renshaw Point, and 2.5 nmi apart elsewhere. The Sanak Trough survey was conducted 27 February 2014 along transects spaced 2 nmi apart.

Dense aggregations of walleye pollock were observed in the West Nagai Strait, Renshaw Point, and outer Shumagin Trough portions of the Shumagin Islands survey. The vast majority of walleye pollock found in the Shumagin Islands were age-2 walleye pollock (16-26 cm fork length (FL)). The measured maturity composition for males longer than 40 cm FL (n=117) was 0% immature, 11% developing, 25% pre-spawning, 43% spawning, and 21% spent. The maturity composition of females longer than 40 cm FL (n = 105) was 0% immature, 12% developing, 73% pre-spawning, 7% spawning, and 8% spent. The high percentage of pre-spawning females and the low percentage of spawning and spent females suggested that the survey timing was appropriate to coincide with the onset of spawning for the majority of the population based on findings from the Shelikof Strait pre-spawning pollock survey. The mean gonadosomatic index (GSI: ovary weight/body weight) for mature pre-spawning females was 0.13. The pollock AT survey abundance estimate in the Shumagin Islands area was 37,346 metric tons (t) (80% of which was age-2 pollock), based on catch data from 7 trawl hauls and acoustic data from 357.5 nmi of survey transects. The relative estimation error for this biomass estimate was 18.2%.

The densest pollock aggregations in Sanak Trough were located over the southeast portion of the trough and consisted entirely of adult pollock 42-78 cm FL (mode 59 cm). Unlike 2013, we found no age-1 or age 2 walleye pollock in Sanak trough. The unweighted maturity composition for males longer than 40 cm was 0% immature, 9% developing, 16% pre-spawning, 16% spawning, and 59% spent. The unweighted maturity composition for females longer than 40 cm FL was 0% immature, 0% developing, 50% pre-spawning, 6% spawning, and 44% spent. The average GSI for pre-spawning females was 0.14. The abundance estimate for Sanak Trough of 7,319 t (relative estimation error 9%) was the lowest in the survey's history and was based on catch data from 1 trawl haul and acoustic data from 36 nmi of survey transects.

The MACE Program also conducted winter AT surveys in Marmot Bay and Shelikof Strait. Marmot Bay was surveyed 22-24 March 2014 along parallel transects spaced 2 nmi apart in the outer bay and 1 nmi apart in the inner bay and in Spruce Gully. Shelikof Strait was surveyed from Ban Island off Afognak Island to southwest of Chirikof Island 15-22 March 2014 along parallel transects spaced 7.5-nmi apart.

The majority of pollock biomass in Marmot Bay consisted of dense schools of walleye pollock primarily in the 16 to 40 cm FL range and found north of Spruce Island and in Spruce Island Gully. Smaller fish, 10 to 16 cm FL (age-1 fish) were found in outer Marmot Bay. The unweighted maturity composition in Marmot Bay for males longer than 40 cm FL was 0% immature, 30% developing, 18% pre-spawning, 20% spawning, and 32% spent. The maturity composition of females longer than 40 cm FL was 0% immature, 37% developing, 63% pre-spawning, 0% spawning, and 0% spent. The biomass estimate for Marmot Bay was 14,992 t (relative estimation error 9.4%) from 5 trawl hauls and acoustic data from 152 nmi of survey transects.

As in previous years the highest walleye pollock densities found in Shelikof Strait were observed along the northwest side of the Strait near Kukak Bay. Within this deepest section of the strait along the steep banks of the Alaska Peninsula, dense aggregations of pre-spawning adult fish, primarily in the 40- 60 cm FL range, were detected. These pre-spawning adult fish were predominantly between the ages of 4 and 9 years old, with some as old as 13 years. Mid-sized fish (16 – 40 cm) were observed in the central portion of the Shelikof Strait north of Chirikof Island to Kukak, and a small amount of biomass represented by age-1 pollock was present in the north and central part of the Strait. The numerical dominance of age-2 fish in 2014 reflects continued success of the 2012 year class, which was abundant as 1-yr olds in the 2013 survey.

In Shelikof Strait, the unweighted maturity composition for males longer than 40 cm FL was 1% immature, 34% developing, 24% mature pre-spawning, 39% spawning, and 1% spent. The maturity composition of females longer than 40 cm FL was 0% immature, 61% developing, 30% pre-spawning, 7% spawning, and 1% spent. The small fraction of spawning and spent females relative to pre-spawning females suggests that the survey was timed appropriately to coincide with the onset of spawning for the majority of the population, based on findings from earlier Shelikof Strait pre-spawning surveys. The average GSI for mature pre-spawning females was 0.14. The pollock abundance estimate of 842,138 t for the Shelikof Strait is the second largest reported for the region since 1985, and similar to the 2013 estimate of 891,261 t (relative estimation error 4.7%). The 2013 estimate was based on catch data from 21 trawl hauls and acoustic data from 780 nmi of survey transects.

Winter acoustic-trawl survey in the southeast Aleutian Basin near Bogoslof Island

The MACE Program conducted an AT survey of walleye pollock in the southeastern Aleutian Basin near Bogoslof Island aboard the NOAA Ship *Oscar Dyson* during 7-11 March, 2014. Although the original survey plan was for 35 transects, the 4 western-most transects were dropped because of poor weather conditions. Thus, the surveyed area was contracted to 31 north-south parallel transects, spaced 3-nmi apart, covering 1,150 nmi^2 of the Central Bering Sea Convention Specific Area.

Walleye pollock were concentrated in two main regions, north of Samalga Pass and northeast of Umnak Island. Based on catch data from seven trawl hauls, the overall pollock size composition ranged from 13 cm to 70 cm FL, with prominent modes at 45 and 58 cm FL. The pollock size composition in the Samalga Pass region was bimodal (47 and 58 cm FL), whereas pollock in the Umnak region was unimodal (43-45 cm FL). Female and male pollock maturity composition varied between the two regions. In the Samalga Pass region, 89% of the female pollock were in pre-spawning condition, whereas in the Umnak region, only 21% of the females were in the same, pre-spawning condition. Similarly, 66% of the males in the Samalga Pass region were in pre-spawning condition, and 37% were in the pre-spawning condition. For both regions combined, the average gonado-somatic-index for mature pre-spawning females was 0.14.

The pollock abundance estimates for the southeastern Aleutian Basin near Bogoslof Island were 113 million fish, weighing 112 thousand t (relative estimation error 11.8%). The 2014 estimates represent a 133% increase in abundance and a 67% increase in biomass from the 2012 survey estimates, though both abundance and biomass remain extremely low compared to late 1980s and early 1990s. Fifty percent of the population was distributed in the Samalga Pass region, and 50% was distributed in the Umnak region.

The estimated age composition for 2014 was dominated by younger pollock. Fifty-eight percent of the pollock abundance was represented by the 5 and 6 year old fish (2009 and 2008 year classes) and 12% was represented by 8 year old fish (2006 year class). Overall, 80% of the pollock population was less than 9 years of age.

Summer Acoustic-Trawl Survey on the Bering Sea Shelf -- MACE Program

The MACE Program conducted an AT survey of midwater walleye pollock between 12 June and 13 August 2014 aboard the NOAA ship *Oscar Dyson*. This survey has been conducted since 1979; triennially through 1994, and biennially or annually since then. The survey design covered the EBS shelf between roughly the 50 m and 200 m isobaths, from 162° W across the U.S.–Russian Convention Line to about 178° 20 E, including the Cape Navarin area of Russia. It consisted of 28 north-south transects spaced 20 nautical miles (nmi) apart in the U.S. In mid-July, a motor board control failed resulting in 2 weeks of sailing at reduced ship speed and subsequent loss of about 4 days of ship time. After the repair, transect spacing was increased to 40 nmi in the Russian EEZ in order to complete the survey in the time available. The primary objective was to collect daytime 38 kHz acoustic backscatter and trawl data to estimate the abundance of walleye pollock. Additional survey sampling included conductivity-temperature-depth (CTD) measurements to characterize the Bering Sea shelf temperature conditions, and supplemental trawls to improve acoustic species classification and to obtain an index of euphausiid abundance using multiple frequency techniques. A number of specialized sampling devices were used during the survey, including a modified Marinovich midwater trawl to sample fish and macro-zooplankton which was rigged with pocket nets to estimate fish escapement, 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, and a set of 6 small, bottom-moored, trigger–camera systems to autonomously collect images of fish near the seafloor.

Biological data and specimens were collected from 142 trawl hauls. The majority of these hauls (122) targeted backscatter during daytime for species classification: 88 with an AWT, 18 with a bottom trawl, and 16 with a Methot trawl. The remaining 20 hauls, some of which also assisted with species classification, were nighttime Marinovich tows near surface to evaluate gear performance, the net's suitability for catching age-0 pollock, and the placement of pocket nets to monitor escapement. Among midwater hauls used to classify backscatter for the survey, walleye pollock was the most abundant species by weight (84.8%) and by number (96.1%), followed by northern sea nettle jellyfish (*Chrysaora melanaster*) (14.8% by weight and 2.7% by number). Among bottom trawls, pollock was the most abundant species (61.7% by weight and 48.5% by number) followed by northern sea nettle jellyfish (16.6% by weight and 9.5% by number). In Marinovich hauls, northern sea nettles (91.7%), Pacific herring (4.1%), and age-1+ pollock (3.5%) dominated the catch by weight, while euphausiids (91.1%), northern sea nettles (3.7%), and age-0 pollock (1.8%) dominated the catch numerically. Finally, Methot hauls were dominated by northern sea nettles (76.0%), euphausiids (12.6%), and unidentified jellyfish (10.2%) by weight, respectively, and numerically, by euphausiids (98.4%).

Water temperatures in 2014 (both surface and near bottom) were much warmer on average than they have been in the past several years; in particular, water temperatures during the previous AT survey in 2012 were the coldest of a sequence of several cold years (2006-2012). About 45% of the summed acoustic backscatter at 38 kHz observed between near the surface and 3 m off bottom during the 2014 survey was attributed to adult or juvenile walleye pollock. This was less than in the past several surveys (56% in 2012, 82% in 2010, and 62% in 2009). The remaining non-pollock water column backscatter was attributed to an undifferentiated plankton-fish mixture (53%), or in a few isolated areas, to rockfishes (*Sebastes* spp.) or other fishes (~2%). Most walleye pollock biomass was distributed relatively evenly across the shelf from a region north of Unimak Island to Navarin Canyon, between roughly the 50 m and 1000 m isobaths.

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 17.4 billion fish weighing 3.439 million t (relative estimation error 4.6%). This was nearly twice the 2012 biomass estimate (1.843 million t) and higher than has been observed since 2002. Pollock abundance east of 170° W was 6.623 billion fish, weighing 1.425 million t (40% of total midwater biomass); notably, two-year-old pollock (26 cm modal FL) comprised 49% of that biomass. This was an increase from 2012, and was the highest pollock biomass observed east of the Pribilof Islands since 2002. Pollock biomass increased by a similar amount inside the Steller sea lion conservation area (SCA), and annual variation there correlates well with the entire survey estimates ($r^2 = 0.76$, $p << 0.05$). In U.S. waters west of 170° W, pollock numbered 10.76 billion and weighed 2.013 million t (59% of total shelf-wide biomass). Dominant modal lengths were 15, 27, and 38 cm FL, corresponding to pollock aged 1, 2, and 4-5 years, respectively. In Russia, estimated midwater pollock abundance was 0.257 billion fish weighing 0.104 million t (3% of total biomass). There, the dominant modal length was 38 cm FL, corresponding to 4-5-year-old fish, with fewer 2-year-olds observed than west of 170° W in the U.S.

In terms of age composition, the 2014 survey estimated the largest group of two-year olds in the AT survey time series. Most of these fish were observed east of the Pribilof Islands, rather than north and west of the Pribilofs as in recent years. The preliminary age information for pollock in the U.S. EEZ confirmed that juvenile pollock (ages 1, 2 and 3) were dominant numerically (accounting for 26%, 48% and 8% of the population, respectively) overall. These three age groups represented 44% of the total biomass. Adult pollock (ages 4+) totaled 19% of the population numerically, and made up 56% of the total biomass. Six-year-old fish from the 2008 year class represented 23% of the shelf-wide midwater biomass. In Russia, age-5s were most numerous among the mix of predominantly age 3 to 6 year-old fish, consistent with 2012 survey observations of relatively large numbers of 3-year-olds there. Analyses of walleye pollock vertical distribution indicated that among adults (≥30 cm FL) shelf-wide, more than 93% were found within 50 m of the bottom, whereas for juveniles, the percentage in the near bottom region was lower, ranging from 75% east of 170° W to 81% west of 170° W.

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 2014. 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 2014, the thirty-sixth 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, 2014 by the chartered fishing vessel *Alaskan Leader*. Total groundline set each day was 16 km long and contained 160 skates and 7,200 hooks baited with squid.

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 62,809 sablefish, with an estimated total round weight of 197,068 kg (434,461 lb), were caught during the survey. This represents an increase of nearly 6,000 sablefish over the 2013 survey catch. Sablefish, shortspine thornyhead, and Greenland turbot (*Reinhardtius hippoglossoides*) were tagged with external Floy tags and released during the survey. Pop-up satellite tags (PSAT) were implanted in 43 sablefish. Length-weight data and otoliths were collected from 1,780 sablefish. Killer whales (*Orcinus orca*) depredating on the catch occurred at three stations in the eastern Aleutian Islands, and four stations in the western Gulf of Alaska. Sperm whales *(Physeter macrocephalus)* were observed during survey operations at 21 stations in 2014. Sperm whales were observed depredating on the gear at one station in the Aleutian Islands, four stations in the central Gulf of Alaska, six stations in the West Yakutat region, and four stations in the East Yakutat/Southeast region.

Several special projects were conducted during the 2014 longline survey. Sperm whale photo identification was done in the eastern and central Gulf of Alaska and depredation behavior was recorded. Killer whale observations were conducted in the western Gulf of Alaska.. In addition, Pacific halibut lengths were recorded in the eastern Aleutian Islands and western Gulf of Alaska. 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.

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 these shallower depths provides expanded population indices for the entire survey time series for species such as Pacific cod, Pacific halibut, and several rockfish species.

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

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

On January 1st 2013, new regulations that govern how observers are deployed into the fisheries of Alaska became effective. Amendments 86 to the Fisheries Management Plan (FMP) of the Bering Sea and Aleutian Islands and 76 to the FMP of the Gulf of Alaska establish the new North Pacific Groundfish (and Halibut) Observer Program. Since the way observers are deployed and paid for has changed, the Observer Program is considered to be "restructured". The new Observer Program replaces the "interim program" that was in place for the last for 23 years. Under the interim Program, vessels and plants paid for observers by the day at coverage rates specified in law based on *days in a calendar quarter* at-sea (not fishery as is often assumed) and on *tons processed* for shoreside processors. Catcher vessels between 60 and 125' in length were allowed to self-select which trips were to be observed under the interim Program. Since vessels less than 60' or those targeting Pacific halibut were not observed, the former static regulatory structure of observer coverage not only created an incentive for owners to change the length of their vessels (indeed a disproportionately high number of 124' and 58' vessels exist in the fleet), but also created a mechanism for owners to skew observer coverage towards trips with lower bycatch rates (e.g. pollock) and away from those with higher bycatch rates (e.g. most flatfish fisheries).

The 2013 Observer Program is the result of the third attempt by NMFS to restructure the interim Observer Program since 1990. The effort involved over 53 separate people from five agencies and took five years to accomplish. The new Program places *all* vessels and processors in the groundfish *and halibut* fisheries off Alaska into either full- or partial-coverage categories. No operations are exempt from the new Program. Vessels and processors in the full-coverage category will continue to obtain observers by contracting directly with observer providers. Vessels and processors in the partial coverage category will obtain observers through NMFS, paying a fee on landings to cover the costs.

The full-coverage category now includes:

- catcher/processors (CPs)
- motherships,
- catcher vessels while participating in American Fisheries Act (AFA) or Community Development Quota (CDQ) pollock fisheries,
- catcher vessels while participating in CDQ groundfish fisheries (except: sablefish; and pot or jig gear catcher vessels),
- catcher vessels while participating in the Central Gulf of Alaska Rockfish Program (RP), and
- inshore processors when receiving or processing Bering Sea pollock

Vessels and processors now in the partial coverage category include:

- catcher vessels designated on a Federal Fisheries Permit (FFP) when directed fishing for groundfish in federally managed or parallel fisheries, except those in the full coverage category,
- catcher vessels when fishing for halibut IFQ or CDQ,
- catcher vessels when fishing for sablefish IFQ or fixed gear sablefish CDQ , and
- shoreside or stationary floating processors, except those in the full coverage category.

The new Program establishes greater coverage requirements for those vessels with the potential to take long trips (i.e. CPs) compared to catcher vessels that cannot because of the potential for catch spoilage. Since the full-coverage requirement for CPs and motherships is based on the endorsement on a vessels' FFP and not their length, these changes bring new CPs less than 60' long into the Observer Program. The full-coverage requirements that remain for some catcher vessel operations represent those "inherited" from existing catch-share programs or required for detailed quota accounting (e.g. AFA, A80, RP, and CDQ). Catcher vessels greater than 125' that were previously fully observed could move to partial coverage in the new Program if they participate in certain target fisheries such as pollock in the Gulf of Alaska.

How vessels in partial-coverage attain their observers in the new Program represents a major change from the interim Program. Under the new Program, coverage requirements for the partial-coverage category are specified in an Annual Deployment Plan (ADP). The intent of the ADP is not to adjust policy, but rather to focus on science driven deployment to reduce potential bias and meet NMFS's data needs. The allocation strategy used to deploy observers in the partial-coverage category is the principal aspect of observer deployment that can be adjusted through the ADP. The ADP process is initiated as a science-based recommendation through committee that is vetted into an initial draft document by the Fisheries Monitoring and Analysis Division (FMA) of the AFSC and the Sustainable Fisheries Division (SF) of the Alaska Regional Office (AKR). The initial draft ADP is presented to the Council at their June meeting. NMFS will subsequently analyze Council recommendations and release a final draft ADP by September 1. This final draft ADP is presented to the Council's Plan Teams in September, the Council's Scientific and Statistical Committee (SSC) and Council in October. Based on accepted minor Council recommendations made in October, a NMFS final ADP is issued for the following year.

In May 2014, NMFS provided its first Annual Report to the North Pacific Fishery Management Council (Council) on observer deployment under the restructured observer program. The report, North Pacific Groundfish and Halibut Observer Program 2013 Annual Report (Annual Report) assesses the degree to which the objectives of the observer program restructuring have been met and includes recommendations to improve the program. Chapter 3 of the report, Deployment Performance Review, was formalized as a separate NOAA Technical Memorandum.
As part of the annual review process, a set of performance metrics were used to assess the efficiency and effectiveness of observer deployment into the trip-selection (vessels > 57.5 feet in length) and vessel-selection (vessels 40-57.5 feet in length) strata of the partial coverage category. There was a marked difference in the relative performance of the two deployment methods in 2013. In the vessel-selection stratum, coverage levels were less than expected during the five of the six 2-month selection periods. Coverage shortages in vessel-selection were due to a lack of a proper sampling frame and a substantial non-response (17-71% among selection periods). In total, 52% of the vessels, and 50% of the trips resulting from these vessels were not observed due to conditional releases from observer coverage. This high level of non-response, coupled with a low sample size resulted in systematic spatial coverage issues, most notably in NMFS Reporting Area 650.

In contrast, the trip-selection stratum met the anticipated coverage goals throughout the year. Based on the results presented in the Annual Report, at the June 2014 Council meeting NMFS recommended, and the Council agreed, that NMFS should consider placing participants in the vessel selection category into the trip selection category for 2015. This recommendation was further analyzed and formally proposed in the 2015 Draft Annual Deployment Plan (ADP) provided to the Council in October 2014. The Draft ADP proposed maintaining coverage rates of 12% for vessels 40-57.5 feet in length, but increasing observer coverage from 16 to 24% for vessels >57.5 feet. This was based on the Council's June recommendation to consider higher coverage rates for all trawl vessels and fixed gear vessels over 57.5 feet. The ADP also proposed limiting the conditional release policy for vessels 40-57.5 feet to include life raft capacity only in order to improve the sampling efficiency within this stratum.

At their October 2014 meeting, the Council unanimously approved the Draft ADP with the caveat that if vessels in the small vessel trip selection stratum are selected randomly three trips in a row, the third selected trip be released from coverage. The proposed changes to observer coverage will take effect in January 2015 and remain in effect for the calendar year.

During 2014, the Observer Program trained and deployed 778 observer cruises to vessels fishing in the full and partial coverage fleets off of Alaska. The Program was responsible for defining the sampling duties and data collection methods used by observers, training of the observers prior to deployment, debriefing of observers upon their return, and editing and managing the resulting data. The catch data were provided to the Alaska Regional Office to assist in management decisions regarding the catches of groundfish and prohibited species. Data were also collected regarding the operations of the groundfish fishery.

Status of Stocks and Multispecies Assessment Task - REFM

The Status of Stocks and Multispecies Assessment Program is responsible for providing stock assessments and management advice for groundfish and crab in the North Pacific Ocean and the Bering Sea. Scientists conducted status assessments and projected future stock status for managed fish stocks including both target species and species incidentally caught in target fisheries. In 2014, program members conducted statistical analyses of survey, fishery, observer, and life history data; assessed model performance; convened workshops and meetings to report stock assessment results to the Councils and the public, and provided technical support for the evaluation of potential impacts of proposed fishery management measures.

During the past year, 24 Bering Sea/Aleutian Islands (BSAI) and 13 Gulf of Alaska (GOA) groundfish assessments, 4 BSAI crab assessments, and 2 forage fish assessments were prepared by program members and submitted for review to the GOA and BSAI Groundfish and BSAI Crab Plan Teams of the North Pacific Fishery Management Council.

Assessment scientists provided analytic assistance on many current fisheries management issues. These included: 1) identification and prioritization of research activities intended to improve groundfish and crab stock assessments; 2) development and implementation of a generalized modeling framework for Alaskan crab stocks 3) development of a simulation model to evaluate the performance of different harvest strategies in a multi-fishery management system, 4) technical support for improvement of the multispecies technical interaction model, 5) research activities associated with the impacts of climate change 6) research activities associated with the incorporation of ecosystem variables in stock assessments 7) significant contributions and development of the analyses for the Bering Sea Chinook and Chum salmon bycatch environmental assessment and the Steller Sea Lion Environmental Impact Statement. In addition, program members participated in numerous national and international committees, advisory panels, stock assessment review panels, and symposia and workshops on a variety of issues.

The Fishery Interaction Team (FIT), a part of the Status of Stocks and Multispecies Assessment Task, in the REFM Division, conducts studies to determine whether commercial fishing operations are capable of impacting the foraging success of Steller sea lions either through disturbance of prey schools or through direct competition for a common prey. The present research focus is on the three major groundfish prey of sea lions: walleye pollock, Pacific cod and Atka mackerel.

FIT investigates the potential effects of commercial fishing on sea lion prey in two ways. First, by conducting field studies to directly examine the impact of fishing on sea lion prey fields and to evaluate the efficacy of trawl exclusion zones. FIT research examines the hypothesis that large-scale commercial fisheries compete with sea lion populations by reducing the availability of prey in relatively localized areas. Since 2000 FIT has been conducting field studies to examine the impact of fishing on sea lion prey fields in all three major Alaska regions: the Gulf of Alaska, Bering Sea and Aleutian Islands.

The second way that FIT investigates the potential effects of commercial fishing on sea lion prey is by studying fish distribution, behavior and life history at spatial scales relevant to sea lion foraging (tens of nautical miles). This scale is much smaller than the spatial scales at which groundfish population dynamics are usually studied and at which stocks are assessed. This information is needed to construct a localized, spatially-explicit model of sea lion prey field dynamics that can be used to predict spatial and temporal shifts in the distribution and abundance of sea lion prey and potential effects of fishing on these prey fields.

FIT researchers collaborate with other AFSC scientists who are studying Steller sea lions and their prey, such as scientists in the Resource Ecology and Ecosystem Modeling program and the National Marine Mammal Lab. For more information on the FIT program, contact Dr. Libby Logerwell or access the following web link.

http://www.afsc.noaa.gov/REFM/Stocks/fit/FIT.htm

Barbeaux, S. J. and S. Kang. Status of the Korean pollock stocks. US-ROK JPA (Funded)

Barbeaux, S. J. and J.B. Lee. Fisher Collected Ocean Data (FCOD). US-ROK JPA (Funded)

Beaudreau, A. Hunsicker, M., Dorn, M., and Ciannelli, L. (PCCRC) Developing an index of predation to improve the assessment of walleye pollock in the Gulf of Alaska. (Funded)

Conners, E. Cooperative Research - Developing pot survey gear for octopus. (Funded)

Hauser, L., Canino, M., Spies, I., Dorn, M. (FATE) Rapid genetic adaptation to changing climate and its effect on walleye pollock population dynamics and management in the Gulf of Alaska.

Helser, T. TenBrink, T., Spencer, P., Conrath, C. (NPRB) Improving stock assessments and management for Tier 5 rockfish through ageing methods and maturity at age analysis for shortspine thornyhead, shortraker, harlequin, and redstripe rockfish. (Funded)

Heppell, Selina, Paul Spencer, Nathan Schumaker, Andi Stephens (FATE) An individual-based model for evaluation of maternal effects and spatio-temporal environmental variability on dynamics and management of Pacific ocean perch, *Sebastes alutus.* (Funded)

Hollowed, A., Aydin, K., Holsman, K. (International Science) An international workshop for ecosystem projection model inter-comparison and assessment of climate change impacts on global fish and fisheries. (Funded)

Laurel, B., Thompson, G., and Canino, M. (ASAM) - Ben Laurel, Grant Thompson and Mike Canino. Comparing near shore and large scale surveys to estimate gadid recruitment. (Funded)

Logerwell, E., Dorn, M., Kruse, G., McDermott, S., Ladd, C., Cheng, Wei. (FATE). Spatial and temporal variability of walleye pollock fecundity estimates for the Gulf of Alaska and eastern Bering Sea. Sandi Neidetcher will be a project lead and Ben Williams, who is a UAK PhD student, will utilize part of this research for his dissertation. (Funded)

McDermott, S., Logerwell, L., and Todd Loomis. (NPRB). Small scale abundance and movement of Atka mackerel and other Steller sea lion groundfish prey in the Western Aleutian Islands. Field work starts in Summer of 2014. (Funded)

Quinn, T., P. Hulson, J. Ianelli (ASAM) Time-varying natural mortality: random versus covariate effects. (Funded)

TenBrink, T. and T. Wilderbuer (AFSC Coop.) Developing maturity schedules to improve stock assessments for data-poor commercially important flatfishes in the Gulf of Alaska.

For further information on the SSMA task group, contact Dr. Anne Hollowed (206) 526-4223.

2. Research

The Alaska Coral and Sponge Initiative (AKCSI): a NOAA Deep Sea Coral Research and Technology Program regional fieldwork initiative in Alaska - RACE GAP

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 (FY2012-2014) 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.

FY14 Research Activities

In FY14, the main task of fieldwork was to complete an underwater camera survey of the Aleutian Islands. This survey was conducted for 1 month in April-May and 116 stations were occupied from Dutch Harbor to Stalemate Bank. Image analysis is ongoing, but preliminary results indicate that coral and sponge are widely distributed in the area and can grow to heights of over 1 m. Densities of coral estimated to date ranged from 0 to 1.66 individuals*m^2, and averaged 0.13 individuals*m^2.The average density of sponges was 0.19 individuals*m^2 and ranged to 1.86 individuals*m^2. The average density of pennatulaceans was 0.03 individuals*m^2 and ranged as high as 1.33 individuals*m^2.

In addition to this survey of the Aleutian Islands, a research cruise in August collected comparative information on rockfish from coral and non-coral habitats in the central Gulf of Alaska. This data collection was designed to measure productivity (in terms of reproductive potential, growth and fish condition) of rockfish to determine if coral habitat conferred an energetic advantage to fish that occupied this habitat.

In addition to these cruises funded by AKCSI, there were also a number of field data collections carried out in partnership with other research activities in Alaska. In FY14 the final phase of a pilot project was conducted to construct a camera system that could be attached to longline and pot fishing gear in Alaska to collect information on the impacts of these gears on benthic habitats. A prototype camera system and inertial measurement system was constructed by research partners in the RACE division and tested throughout the winter of 2014. These instruments were successfully deployed in the Gulf of Alaska during the AFSC longline survey in July 2014 on 20 longline deployments. The inertial data and images collected on this cruise are currently being analyzed.

In FY14, with partners in the AFSC RACE division we collected O2, salinity, turbidity and pH measurements on the headrope of bottom trawls used to conduct annual stock assessment surveys. Oceanographic data were collected on 135 tows from the Seguam Pass in the eastern Aleutian Islands to Stalemate Bank in the western Aleutian Islands.

Oceanographic equipment to measure O2, pH, salinity and temperature installed at a long-term study site in Tracy Arm (southeastern Alaska) in 2013 was recovered and collected oceanographic data on 6-hour intervals until March 2014.

Field activities also included the collection of sponge and coral specimens for morphological taxonomic study and coral tissue samples for genetic analysis through collaboration with the Aleutian Islands bottom trawl survey.

Additional work was conducted at the AFSC and U.S. Geological Survey to compile bathymetry and sediment maps from NOAA smooth sheets for the Aleutian Islands and Gulf of Alaska in anticipation of completing a geologically interpreted substrate map for these regions in FY15. The compiled sediment and bathymetry map for the Aleutian Islands region was released as a NOAA Technical Memorandum. The data compilation in the Gulf of Alaska has been completed for the majority of this region as well, thanks to collaboration with the NPRB-funded Gulf of Alaska-Integrated Ecosystem Research Program, which has similar needs for bathymetric data.

Planned FY15 Activities

In FY15, the only field effort will focus on projects at the Dixon Entrance, Prince of Wales, Fairweather Grounds, and Cape Ommaney sites. We will again use a remotely operated vehicle (ROV) to conduct transect surveys at two of the study sites in southeastern Alaska that were not completed in FY13 (Fairweather Grounds and Dixon Entrance). A stereo drop camera will again be used to measure size structure of *Primnoa* at these sites, plus some additional transects at the Prince of Wales site. Samples for genetics analysis will also be collected at two sites (Dixon Entrance and Fairweather Grounds) to complete the collections for that project. In addition, two of the settlement plates deployed in FY13 will be recovered in FY15 and any newly settled recruits collected. Then the plates will be redeployed for collection at a later date.

With the completion of this final cruise, the AKCSI project will be finished and a final report written by December 2015.

Camera Survey of Coral Habitat on the Eastern Bering Sea Slope-RACE GAP and ABL

Last summer, NOAA Alaska Fisheries Science Center completed the first comprehensive camera survey targeting corals on the eastern Bering Sea outer shelf and slope. The survey was completed during 9 August - 5 September 2014. This research was requested by the North Pacific Fisheries Management Council in response to concerns about the distribution of potentially vulnerable coral habitat in Bering Sea canyons. Some of the largest submarine canyons in the world incise the eastern Bering Sea shelf break and are proximate to some of the worlds largest commercial fisheries.

The objectives of the survey were to:

- Validate coral and sponge distribution model predictions
- Acquire height and density data for coral using the stereo imaging capabilities of the camera system
- Identify the role of coral as fish habitat
- Document presence and degree of fishing gear effects on coral and sponge habitats
- Estimate the vulnerability of coral and sponge habitats to fishing gear effects, and
- If necessary improve or refine predictions of coral presence

A total of 250 successful camera drops were completed during the survey covering Bering, Pribilof, Zhemchug and Pervenets canyons and most of the slope in between. The depths sampled ranged from 91 to 810 m (median = 279 m). Navarin Canyon, the northernmost canyon (30 planned stations), and much of the area between Pervenets and Zhemchug canyons (10 planned stations), were left unsampled. The survey was conducted from the chartered fishing vessel Vesteraalen and the participating scientists were Chris Rooper (AFSC) and Steve MacLean (NPFMC) (leg 1) and Mike Sigler (AFSC) and Pat Malecha (AFSC) (leg 2).

Over 225,000 images were collected at the 250 camera drops. The results of preliminary reviews of the images collected during the camera drops indicates that coral densities were generally low throughout the area even at the 31 transects where they occurred (< 0.01 individuals*m^{-2}). In general, observations of coral were similar to predictions from an existing coral model, which was based on trawl survey data. The presence of coral was primarily observed in Pribilof canyon and the slope area to the northwest of the canyon. The heights of corals ranged from ~ 5 – 90 cm, with most individuals < 20 cm in height. A final report on the analyses will be presented to the North Pacific Fisheries Management Council meeting in Sitka in June 2015.

Contact Chris Rooper and Mike Sigler, NOAA Alaska Fisheries Science Center.

Recruitment and Response to Damage of an Alaskan Gorgonian Coral -- ABL

Benthic habitats in deep-water environments experience low levels of natural disturbance and recover slower than shallow-water habitats. Deep-water corals are particularly sensitive to disturbance from fishing gear, in part because they are long-lived, grow slowly, and are believed to have low rates of reproduction. Limited data describes recruitment and recovery of deep-water corals. However, this information is critical to understanding long-term effects of anthropogenic disturbances, such as commercial fishing, on the population dynamics of living benthic habitat.

In August 2009, a team of four divers located and tagged 48 *Calcigorgia spiculifera* colonies in Kelp Bay, Southeast Alaska. Of that total, 9 colonies were fitted with settlement rings equipped with natural rock tiles. The tiles were observed for recruitment of coral planulae and polyps. The remaining 39 tagged colonies were ascribed to three damage treatment groups and a control group to assess the response to damage of disturbed coral.

Response to Damage

The damage treatments were designed to mimic actual damage that can occur from passing fishing gear. These treatments were performed *in situ* and included deflection, gorgonin excision, and branch severance. The deflection treatment was completed by passing a simulated trawl footrope over each coral. The gorgonin excision treatment was completed by carefully cutting and scraping off the soft outer tissue (gorgonin) from three branches of each colony. Branch severance was completed by cutting three branches away from the main stem of each colony. Video of each colony was recorded before and immediately after the treatments were performed to establish baseline coral characteristics and to identify immediate treatment effects. Observations were also made at 9 months, 13 months, 2 years, and 5 years. Video review is ongoing for the most recent observations. Data generated from the video observations will include colony growth rates, tissue and branch regeneration rates, and colony survival.

Preliminary observations of damaged corals have revealed a mixed level of resiliency. For example, some colonies that had gorgonin removed showed signs of tissue regeneration (Fig. 1) while other damaged corals have exhibited fairly robust growth rates. One colony that was broken from its holdfast during the deflection treatment continued to have living tissue for over a year. However, this colony was eventually found completely denuded of living tissue and dead. Overall, the treatments have had negative effects on most colonies and many have necrotic tissues or have shed branches and a few colonies have disappeared completely. Analyses of the final observations from 2014 and the synthesis of previous observations will provide important information about the resiliency and recovery of these small coldwater gorgonian corals on both short-term and long-term scales.

Figure 1. *Calcigorgia spiculifera* colony #574 immediately after gorgonin excision (left) and 2 years later (right). The branches on the lower left were denuded of gorgonin in August of 2009 but the excised tissue was mostly regenerated 2 years later in August 2011.

Recruitment

Settlement rings were anchored to the seafloor with an adult coral colony located in the middle of the ring (Fig. 2) in August 2009. Each ring had 8 natural rock tiles and over the course of the study, a subsample of tiles were collected and inspected for adhesion of coral recruits. Tiles were collected 9 months, 13 months, 2 years, and 5 years after they were placed on the seafloor. During the first three collections, 16 tiles (in total) were removed from the settlement rings on each occasion and replacement tiles were installed where tiles had been removed so that each ring had its full complement of tiles throughout the study period. During the final site visit in 2014, all tiles were removed from the seafloor. Retrieved tiles were placed in seawater and immediately examined under a dissecting microscope for evidence of coral planulae and polyps.

Figure 2. *Calcigorgia spiculifera* colony #566 with a newly installed settlement ring and natural rock tiles.

After the first three settlement tile collections, no evidence of coral recruitment was observed among the 48 tiles examined. However, when all remaining tiles were retrieved during the final collection in July 2014, coral recruits were found on 18 of the 96 tiles collected and at least 60 individual recruits were identified. These observations may be the first documented coral recruitment events in Alaska and the discovery provides much needed insight into coldwater coral reproduction processes. The majority of recruits were small single- or two-polyp organisms (Fig. 3) that were likely recent recruits, presumably less than one year old. There were also some very small potential recruits that lacked definitive structural characteristics of coral polyps but were pigmented similarly to *Calcigorgia spiculifera*. These specimens are scheduled to be examined with genetic analyses to determine their identity. If these are indeed coral recruits, they may be only days or weeks old. Most recruits were small and probably relatively recent settlers. However, there were a few multi-polyp colonies observed that were probably more than a year old. Thus it is apparent that coral recruitment happened in multiple years and a rate of recruitment could be estimated based on the different sizes or “age classes” of the recruits. Tiles were placed on the seafloor on varied dates and thus were “seasoned” *in situ* for different amounts of time. The original tiles were in place for five years while the most recently installed tiles were on the seafloor for 35 months. Recruits were found on tiles of all ages, however. Genetic analyses will also be utilized to explore the relatedness between recruits and adults and to examine genetic diversity and dispersion potential.

Figure 3. ***Calcigorgia spiculifera*** **recruits on a marble settlement tile. Each recruit is approximately 2 mm long and consists of one large polyp and one small polyp developing on the lower right of each recruit. The edge of a 25 mm stainless steel washer can be seen at the bottom of the image.**

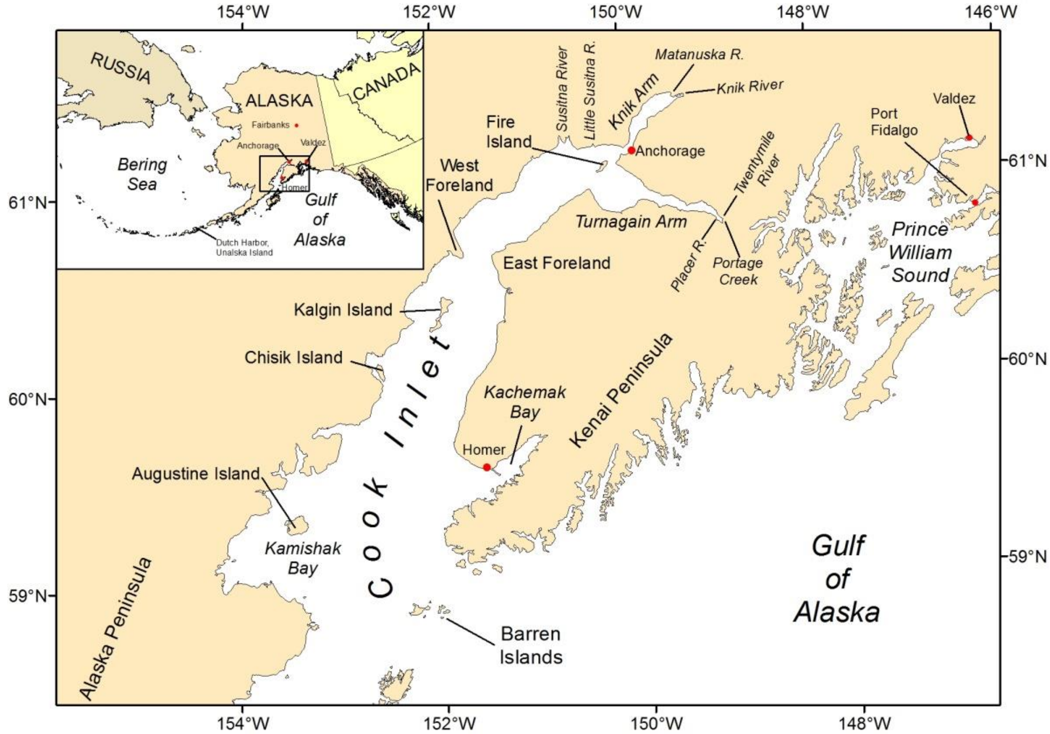
For more information, contact Patrick Malecha at (907) 789-6415 or pat.malecha@noaa.gov.

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 will examine 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. We will sample these habitats examining differences in density, community structure, prey availability, diet diversity, condition, growth, and reproductive success within the different habitat types. This research will enable us to examine the importance of different habitat types for these rockfish species providing data critical for both protecting essential habitat as well as effective management of these species. In the spring and summer of 2012 two research cruises were conducted in May and August. An additional two cruises were conducted in May and December 2014. All field work for this project has been completed and sample processing and data analysis will be completed within the next year.

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

Smooth Sheet Bathymetry of Cook Inlet, Alaska



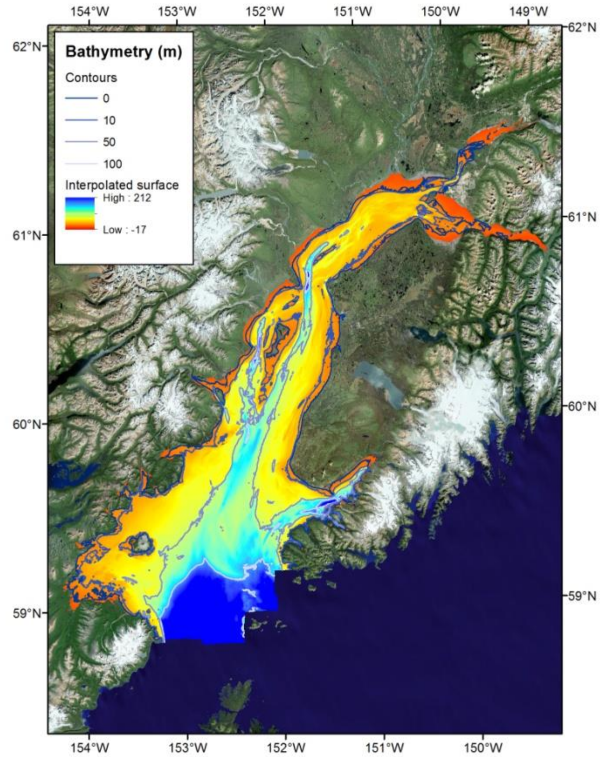
Scientists with the AFSC's Groundfish Assessment Program (GAP) have expanded earlier mapping efforts for the Aleutian Islands to include Cook Inlet, Alaska. This work is part of an effort to provide better seafloor information for fisheries research. The Cook Inlet project included the same smooth sheet bathymetry editing and sediment digitizing as the Aleutian Islands effort, but also included:

1) digitizing the inshore features, such as rocks, islets, rocky reefs, and kelp beds;
2) digitizing the shoreline; and
3) replacing some areas of older, lower resolution smooth sheet bathymetry data with more modern, higher resolution multibeam bathmetry data.

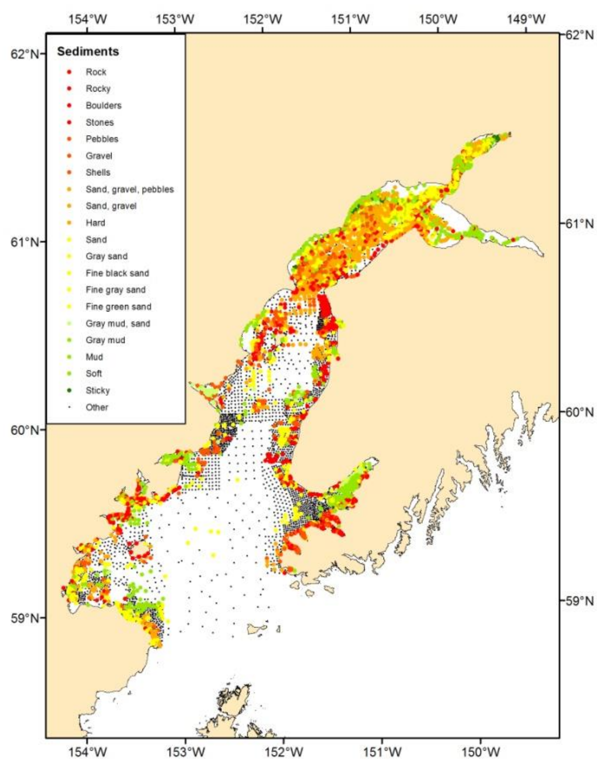
   The smaller area of Cook Inlet, greater amount of project time, and higher quality of smooth sheets than in the Aleutian Islands made these additions possible. The NMFS Alaska Regional Office's Essential Fish Habitat funding made much of this work possible.

Bathymetry of Cook Inlet

A total of 1.4 million National Ocean Service (NOS) bathymetric soundings from 98 hydrographic surveys represented by smooth sheets in Cook Inlet were corrected, digitized, and assembled. Overall, the inlet is shallow, with an area-weighted mean depth of 44.7 m, but is as deep as 212 m at the south end near the Barren Islands. The original, uncorrected smooth sheet bathymetry data sets are available from the [National Geophysical Data Center (NGDC)](), which archives and distributes data that were originally collected by the NOS and others.



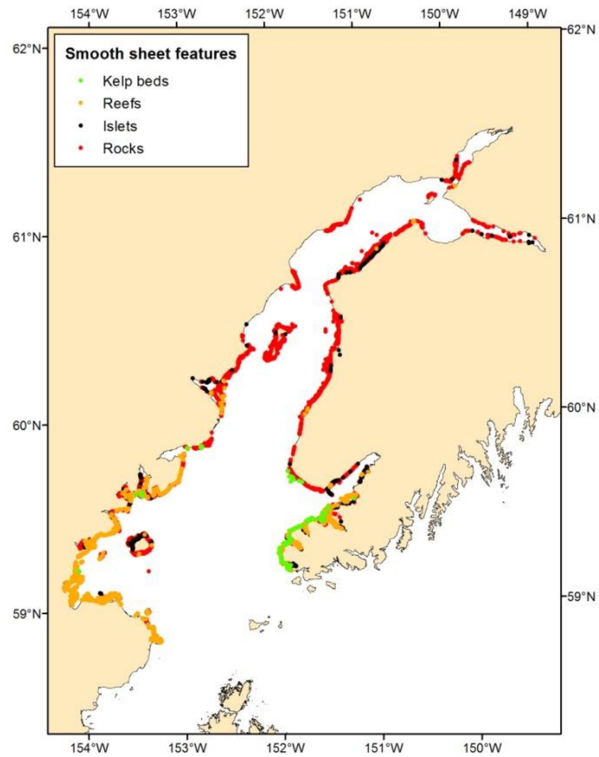
Sediments of Cook Inlet



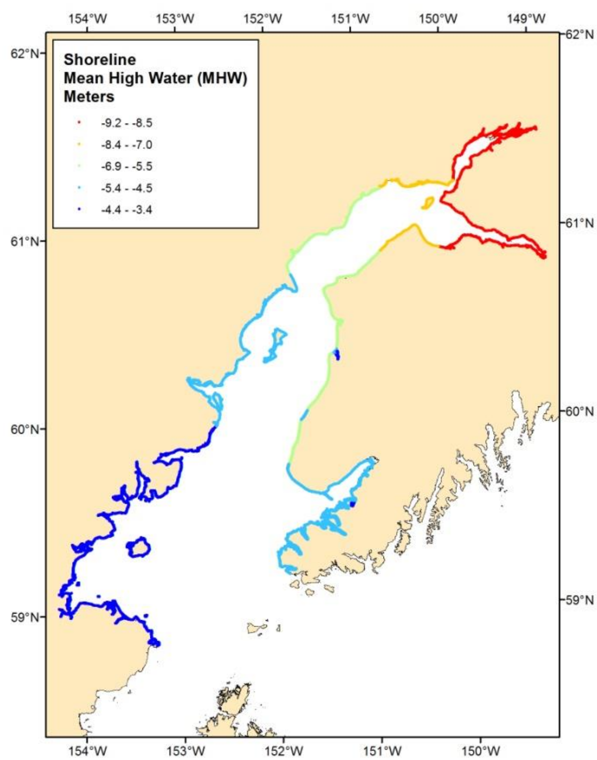
A total of 9,000 verbal surficial sediment descriptions from 96 smooth sheets were digitized, providing the largest single source of sediment information for Cook Inlet. There were 1,172 unique verbal descriptions, with most of the sediment description categories (58%) only having a single occurrence. That means that most descriptions were fairly lengthy and specific. Of the sediment descriptions which occurred more than once, Hard (n = 1335), Sand (n = 721), Rocky (n = 608), and Mud (n = 365) were the most common, which ranged from Rock to Clay, Sand ridges to Mud flats, Weeds to Stumps, and Mud to Coral. The 20 most common sediment categories are depicted along a color gradient in the Figure, where red shows larger/harder sediments such as Rock, Rocky, and Boulders, and green shows smaller/softer sediments such as Mud, Soft, and Sticky.

Smooth Sheet Features of Cook Inlet

A total of 12,000 features such as rocky reefs, kelp beds, rocks, and islets were digitized from the smooth sheets and added to the original files from NGDC, resulting in a total of 18,000 features. Almost 10,000 of these points indicated the edge of rocky reefs, covering much of the shore in Kamishak Bay, the southern shore of Kachemak Bay, and near Chisik Island, but reefs were rare north of there. More than 7,000 rocks and more than 800 islets were found along most of the Cook Inlet shore. There were less than 300 kelp beds, almost all of which occurred in outer Kachemak Bay. Altogether there were almost 18,000 rocks or rock ally features such as rocky reefs, kelp beds, and islets, which were added to the sediment data set.



Shoreline of Cook Inlet



A total of 95,000 individual shoreline points were also digitized, describing 2,418.3 km of mainland shoreline and 528.9 km of island shoreline from 507 individual islands, providing the most detailed shoreline of Cook Inlet. The shoreline is defined on the smooth sheets as MHW (Mean High Water), the same vertical tidal datum as the bathymetry, which typically ranges only as shallow as MLLW (Mean Lower Low Water), defined as zero meters depth. The MHW shoreline was highest in the northern end of Cook Inlet, ranging up to -9.2 m in Turnagain Arm, and -9.1 m in Knik Arm, and lowest at Augustine Island and Kamishak Bay (-4.4 to -3.4 m, respectively).

By adding the digitized shoreline to the digitized bathymetry, a complete bathymetry map for Cook Inlet was assembled without the typical gaps between the shallowest soundings and the shoreline. Thus, researchers were able to determine that at high tide (MHW) the total volume of the inlet is 1,024.1 km^3 and the total surface area is 20,540 km^2. When the tide drops from MHW to MLLW, the Inlet loses 99.7 km^3 of water, or 9.7% of its volume, and exposes 1,616 km^2 of seabed, or 7.9% of its surface area.

While the Alaska Fisheries Science Center has been conducting marine research for decades in Alaskan waters, a lot of basic information about the seafloor, such as depth, is generally not known beyond what is depicted on small scale (1:100,000) NOS Navigational Charts. Therefore GAP scientists have been creating more detailed bathymetry and sediment maps in order to provide a better understanding of how studied animals interact with their environment. This information is being used by NOAA's Deep Sea Coral Research and Technology Program to predict the presence/absence and abundance of corals and sponges (Rooper et al., 2013). GAP scientists who conduct stock assessment bottom trawl surveys are also using the information to delimit areas that cannot be sampled effectively with bottom trawls. The results from this project may result in a separate survey conducted by another method, such as underwater cameras or acoustics, to assess the abundance of fish in the untrawlable areas. An inter-agency collaboration called the Gulf of Alaska Integrated Ecosystem Research Program (GOA-IERP) sponsored by the North Pacific Research Board (NPRB) is using the detailed bathymetry and sediment information to predict the preferred settlement habitat juveniles of five important groundfish species. Results from GOA-IERP will be used towards developing a better understanding of the ecosystem processes that regulate stock recruitment. The Alaska Regional Office will investigate use of the bathymetry and sediment information to oversee sustainable fisheries, conduct Essential Fish Habitat (EFH) reviews, and manage protected species. The Bureau of Ocean Energy Management may use the information for preparing National Environmental Policy Act (NEPA), Essential Fish Habitat (EFH), and Endangered Species Act (ESA) documents for the possibility of a federal lease sale in lower Cook Inlet.

Details of the processing methods for the smooth sheet data for Cook Inlet will be published in the NOAA Technical Memorandum series.

Rooper, Chris, Mike Sigler, Gerald Hoff, Bob Stone, and Mark Zimmermann. 2013. Determining the Distributions of Deep-sea Corals and Sponges Throughout Alaska. AFSC Quarterly Report Feature (October-November-December 2013) 4 p.

Evaluating Smooth Sheet Bathymetry for Determining Trawlable and Untrawlable Habitats - RACE GAP

This project supported by NMFS' Habitat Assessment Improvement Plan (HAIP) evaluates whether enhanced bathymetric and other sea floor data obtained from hydrographic smooth sheets can predict whether the sea floor can be trawled during research surveys.

Biennial bottom trawl surveys in the Gulf of Alaska (GOA) and Aleutian Islands (AI) provide fishery independent estimates of catch per unit effort, abundance, and biological parameters used in stock assessments for managed fisheries and species in the North Pacific. Not all bottom types or oceanographic conditions accommodate the bottom trawl survey method. The bottom trawls can only be towed on smooth and unconsolidated seafloors, so whether trawl stations are "trawlable" or "untrawlable" becomes a major factor limiting the sampling frame of the survey. In the AI, much of the seafloor consists of rock, pinnacles, and steep drop-offs and stations are resampled from a limited pool of previously sampled stations. In GOA, about half of all stations have been visited and about 20% were found to be untrawlable. Having prior and complete knowledge of trawlable areas would clearly define the survey frame for bottom trawl surveys and could become the basis for defining a survey of untrawlable habitats with acoustic or visual survey tools.

We wanted to evaluate whether hydrographic smooth sheets which are charts contains original soundings and seafloor observations could be used to predict whether areas the survey have not visited are trawlable or untrawlable. These charts are electronically available from the National Ocean Service through the National Geophysical Data Center. They contain many more observations than are found on nautical charts, but they require extensive validation for analytical use (visit http://www.afsc.noaa.gov/RACE/groundfish/bathymetry/). The reprocessed sheets may offer a data source to identify untrawlable habitats from criteria and approaches from focused seafloor studies. We wanted to identify criteria to predict untrawlable habitat from smooth sheet data, test these criteria with a predictive model with known areas of rocky habitat and unsuccessful bottom trawls, and assemble and interpret existing smooth sheet data into a map of untrawlable habitat that can be evaluated in future surveys and studies.

We applied digitized coverages of National Ocean Service (NOS) hydrographic smooth sheet soundings and seafloor observations to evaluate and physical attributes associated with habitat suitable to bottom trawl surveys in GOA. We used random forest methods to evaluate the relative importance of a suite of benthic terrain (depth, slope, rugosity, and substrate composition) and oceanographic predictors (bottom currents) on whether an area was accessible to bottom trawl gear. To do this, we used records of unsuccessful bottom trawls where the net was torn or the vessel was stopped by underwater obstructions. We calculated the approximate position of the trawl and matched the trawl path with the underlying seafloor features. We examined the marginal importance of each physical predictor and quantified the response gradient, then applied a piecewise regression to determine threshold values. Confidence bounds for threshold values and indices of threshold strength (e.g., monotonicity, bimodality) and diagonality (e.g., influence of multiple predictors) were developed. We then developed preliminary, predictive maps of trawlable habitat on the basis of these thresholds. Using available data, preliminary results indicate that untrawlable habitat was associated with increased depth, slope, rugosity, bottom current and coarser sediments at the scale of both discrete tow paths and aggregate survey stations. Distinct thresholds were noted in rugosity, slope, and depth range within the survey area. Preliminary maps of critical thresholds suggest different suites of variables will constrain the probability a successful trawl in different areas of the system. A draft manuscript is in progress detailing the finding of the random forest methods and results.

We are still comparing and modeling the thresholds to independent assessments of trawlability obtained during survey operations. These comparisons between survey stations and actual towpaths suggest smooth sheet data are useful in predicting trawlable habitat at coarse scales, but reflects low resolution beyond nearshore or highly transited areas.

For further information, contact Matthew Baker (matthew.baker@noaa.gov), Mark Zimmermann or Wayne Palsson.

Estimating the survey catchability of Rock Sole in the Gulf of Alaska-RACE and REFM
Rock soles are captured in trawl and other groundfish fisheries in the Gulf of Alaska (GOA) and yield 7 to 9 million dollars in ex-vessel value per year. They are a component of shallow-water and other flatfish species principally targeted by catcher and catcher-processor trawl vessels. An age-structured stock assessment model has been developed for rock soles and this model is related to fishery-independent estimates of abundance from the Gulf of Alaska (GOA) Biennial Bottom Trawl

Survey. Direct comparisons, however, are difficult because the catchability of the survey is not completely known, and survey selectivity and availability of groundfishes is identified as a frequent and important data gap in the stock assessment process. Through a grant from NOAA Fisheries' Improve a Stock Assessment (ISA) Program, we are attempting to estimate the total catchability for rock soles captured during the bottom trawl surveys in order to provide a direct comparison to age-structure stock assessments in the GOA. To estimate total catchability, we will combine estimates of trawl efficiency, or how many rock soles are captured that were in the path of the net, with a new estimate of how many rock soles were available to the survey gear.

We used acoustic data obtained from 38kHz Simrad ES-60 echosounders deployed on all AFSC bottom trawl survey vessels since 2005 to determine whether acoustic data can be used to characterize trawlable and untrawlable sea floors. To date, we have collected about 200,000 nautical miles of acoustic trackline data in the GOA alone, but we have never explored these data for their suitability to determine roughness or hardness of the seafloor. We evaluated and analyzed acoustic trackline data with a newly available acoustic Bottom Classification module by Echoview. Output variables from this module were used to estimate the proportion of trawlable to untrawlable habitat within suitable rock sole habitat. Combined with other availability information and estimates of trawl efficiency, we aim to estimate the total catchability of rock soles to the survey trawl and to estimate the total rock sole biomass.

Several AFSC researchers and contractor Neal McIntosh have been focusing effort on this project. To date, they found that the Echoview bottom typing software could be applied to ES-60 acoustic data, and metrics produced by the software could differentiate a series of areas that were clearly trawlable from those that were clearly untrawlable. Based upon this result, we are refining and testing the prediction power of the software and underlying GAM model on a wider range of grid cells with acoustic observations. We have evaluated the data frame of 10,667 ES-60 acoustic files collected since 2005. This evaluation consisted of several labor-intense activities including indexing these data to the station numbers of the GOA sampling grid and the times of previous vessel visits, calibrating the data, removing the systematic dithering "triangle wave" from suitable acoustic files, determining whether a second return echo was present in the file, and developing a database for the GOA acoustic files. We have found that the ES-60 acoustic data will not be as informative as we desired. Acoustic data from 2005 and 2007 were not usable because of the single beam transducers and poor calibrations. Acoustic data were better calibrated beginning with one boat in 2009 and each of two vessels during the 2011 and 2013 surveys. Additionally, we discovered that the critical second echo return of seafloor was only recorded in 31% of the ES-60 data stream. At present the nature of this limitation is not understood, but between the lack of a second echo and uncalibrated echo returns, only 16% of the ES-60 may provide usable information on the nature of the seafloor.

Regardless of these limitations, 1,663 files contained calibrated, undithered acoustic data with second echo returns. We selected 26, fifteen minute segments of acoustic data in previously visited grid cells that were either classified as trawlable (at least two successful trawl samples) or as untrawlable (determined by the skipper's classification of echo returns). Nine variables of seafloor characteristics were obtained by applying the Bottom Classification module of Echoview, and these were entered into a stepwise General Linear Model (GLM) to determine the best set of bottom type variables for predicting trawlability. When used without any other environmental information, these bottom type variables correctly predicted trawlable or untrawlable seafloors 83% of the time. This indicates that the trawlability model may be quite informative for predicting the likelihood of trawlability in areas of the sampling grid that have never been examined, and thus predict the proportion of the GOA that is trawlable and therefor included in the survey sampling frame. The bottom type data are also being used, along with other environmental variables, in a companion study using GLM models to predict the presence/absence and abundance of rock sole based on GOA survey catches. If both modeling approaches are successful, the rock sole habitat model will then be used to estimate the proportion of the area within untrawlable grid elements that comprises suitable rock sole habitat. Further work is being conducted to expand the sample size of the reference test and to see if other variable combinations improves the predictability of the GLM. Work during the next few months will define proportions of trawlable and untrawlable habitat in the depth range of rock soles where acoustic data exist and to see if other information from hydrographic smooth sheets, other acoustic data, and a habitat occupancy model can be used to define the amount of habitat available to rock sole.

With support of other AFSC funds, we have been collecting new information on the herding and escapement terms of trawl efficiency. Together, the estimates of availability obtained from this project and trawl efficiency obtained from other projects will be used to estimate total rock sole biomass in the Gulf of Alaska, and these survey biomass estimates will be compared and evaluated against the stock assessment biomass obtained from catch-at-age analysis.

Contact Wayne Palsson, David Somerton, or Teresa A'mar for more information (wayne.palsson@noaa.gov).

Bering Sea Infauna Communities and Flatfish Habitats - RACE GAP
Research continues on characterizing flatfish habitat and productivity in the eastern Bering Sea (EBS). Climate change has spurred impetus for research into the marine resources of the subarctic and arctic oceans north of the EBS. A report on flatfish habitat in the subarctic: "Habitat and infauna prey availability for flatfishes in the northern Bering Sea" (Yeung and Yang 2014) resulted from the northward expansion of EBS bottom trawl survey in 2010 (Lauth 2011). The survey marked the return of large-scale, systematic groundfish research in the northern Bering Sea after a 30-year hiatus. The study found plentiful infauna prey and relatively low competition among flatfishes in the northern Bering Sea. The northern Bering Sea appeared especially favorable for yellowfin sole (*Limanda aspera*), and may possibly become more so should there be further increase in bottom temperature and decrease in ice cover. Recent studies also focused on juvenile habitats in the EBS, particularly on how prey availability affect the distribution and condition of yellowfin sole and rock sole (*Lepidopsetta* spp.). Studies were conducted in 2011 and 2012 on juvenile (<20 cm total length) flatfish habitats near Bristol Bay and along the Alaska Peninsula. Juvenile fish distribution, diet and condition are being analyzed in relation to prey fields to define prime habitats. In 2013, a juvenile rock sole "hotspot" – area of high concentration - around Nunivak Island was investigated. Northern (Nunivak) and the southern (Bristol Bay) hotspots are hypothesized to be utilized alternately – the former during periods of "warm" oceanographic environment in the EBS, and the latter during "cold" periods (Cooper et al. 2015). This hypothesis is proposed for both rock sole and yellowfin sole. Incidentally, ocean and air temperatures in the EBS in 2013 were one of the highest in 30 years. A test of the hypothesis will require monitoring at these hotspots over multiple "warm" and "cold" periods.

Cooper D, Duffy-Anderson JT, Norcross BL, Holladay BA, Stabeno P (2015) Northern rock sole (*Lepidopsetta polyxystra*) juvenile nursery areas in the eastern Bering Sea in relation to hydrography and thermal regimes. ICES J Mar Sci 72 (2):515-527.

doi:doi:10.1093/icesjms/fst210
Lauth RR (2011) Results of the 2010 eastern and northern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. US Dep Commer NOAA Tech Memo NMFS-AFSC-227
Yeung C, Yang M-S (2014) Habitat and infauna prey availability for flatfishes in the northern Bering Sea. Polar Biol 37 (12):1769-1784. doi:10.1007/s00300-014-1560-4

Northern Rock Sole and Yellowfin Sole Nursery Habitats in the Bering Sea - RACE FBEP
The Fisheries Behavioral Ecology program is collaborating with the RACE-Recruitment Processes Program to examine the use of coastal nursery habitats by important flatfish species. Work in 2014 continued on processing of specimens collected in the vicinity of Port Moller along the Alaska Peninsula in Autumn 2012 and initial work on distributional patterns across species. Northern rock sole and yellowfin sole were the most common flatfishes encountered in coastal habitats.

Age-0 flatfish (northern rock sole and yellowfin sole <50 mm) were captured at high abundances (>50 per tow) at a small number of stations (n=4) along the Alaska Peninsula. Depths of these stations were 38, 33, 32, and 23 m. The age-0 cohort of these species was generally absent from deeper and shallower sites.

Age-1 and age-2 northern rock sole and yellowfin sole (50-150mm TL) were more widespread, using both coastal waters along the Peninsula and coastal embayments. They were more abundant in coastal samples near Port Moller (mean 43 NRS and 8 YFS per tow) than in the coastal embayments of Port Moller and Herendeen Bay (mean 7 NRS and 4 YFS per tow) and in offshore Bering Sea shelf samples (<5 fish per tow). Both species tended to be absent from shallow (<3 m) wave-swept areas along the coast. There was a trend for NRS to be found in higher abundances on sandier sediments with YFS on muddier sediments, both along the coast and in coastal embayments. The high abundances of these species in coastal waters is consistent with previous observations along other portions of the Alaska Peninsula.

Long-term Monitoring of Demersal Macrofauna in Alaskan Arctic Seas Using Bottom Trawls: A Comparison Study - RACE GAP
Long-term monitoring of the Arctic marine biota is needed to understand how community structure is changing in response to diminishing ice (i.e., climate change) and increasing anthropogenic stimuli. Dating back to 1959, bottom trawls (BT) have been a primary research tool for investigating bottom fishes, crabs and other demersal macrofauna in the Arctic (however, the BTs used in past surveys have varied widely in terms of their construction, dimensions, mesh-sizes, etc.) Moreover, the spatial and temporal coverage of past BT surveys has been patchy, and sampling procedures employed using various BTs have generally lacked standardization. Such inconsistencies prohibit synthesizing results into a coherent time series for investigating changes in the community structure. By adhering to rigorous standards, BTs can be effective research tools for monitoring general population trends and detecting geographic shifts of bottom fishes, crabs and other demersal macrofauna. Although relatively limited in their application, two BT gears have been used in Arctic surveys employing moderately consistent sampling techniques: the University of Alaska Fairbanks 3 m plumb-staff beam trawl (PSBT) and the Alaska Fisheries Science Center 83-112 Eastern bottom trawl (EBT). The PSBT has been used periodically for small-scale surveys on the eastern Bering Sea shelf since 2000. North of the Bering Strait, the PSBT was first used in

2004 for a transboundary study of demersal fishes, crabs and other macrofauna in the eastern and western Chukchi Sea. Since 2007, there have been annual demersal surveys using the PSBT in either the Chukchi or Beaufort Seas. In comparison, the EBT's primary use has been for investigating the population dynamics of commercial bottom fishes and crabs on the eastern and northern Bering Sea shelf. North of the Bering Strait, the EBT has also been used for surveying demersal macrofauna in the eastern Chukchi Sea in 1976, 1990,1991, and 2012 and in the Beaufort Sea in 2008.

The objective of this study was to do a paired comparison experiment in the eastern Chukchi Sea to investigate differences between the PSBT and EBT in terms of catch composition and size selectivity of bottom fishes, crabs and other demersal macrofauna. Experimental results will help managers and scientists to interpret results from existing and future BT surveys, as well as underscore the importance of using standard gear and survey methods for long-term monitoring. Managers and scientists need to compare the catching characteristics of the PSBT and EBT compare to understand how data from the two bottom trawls can best be utilized for understanding ecosystem processes and for long-term monitoring of demersal macrofauna in the Alaskan Arctic region.

For more information, contact Bob Lauth, e-mail: bob.lauth@noaa.gov

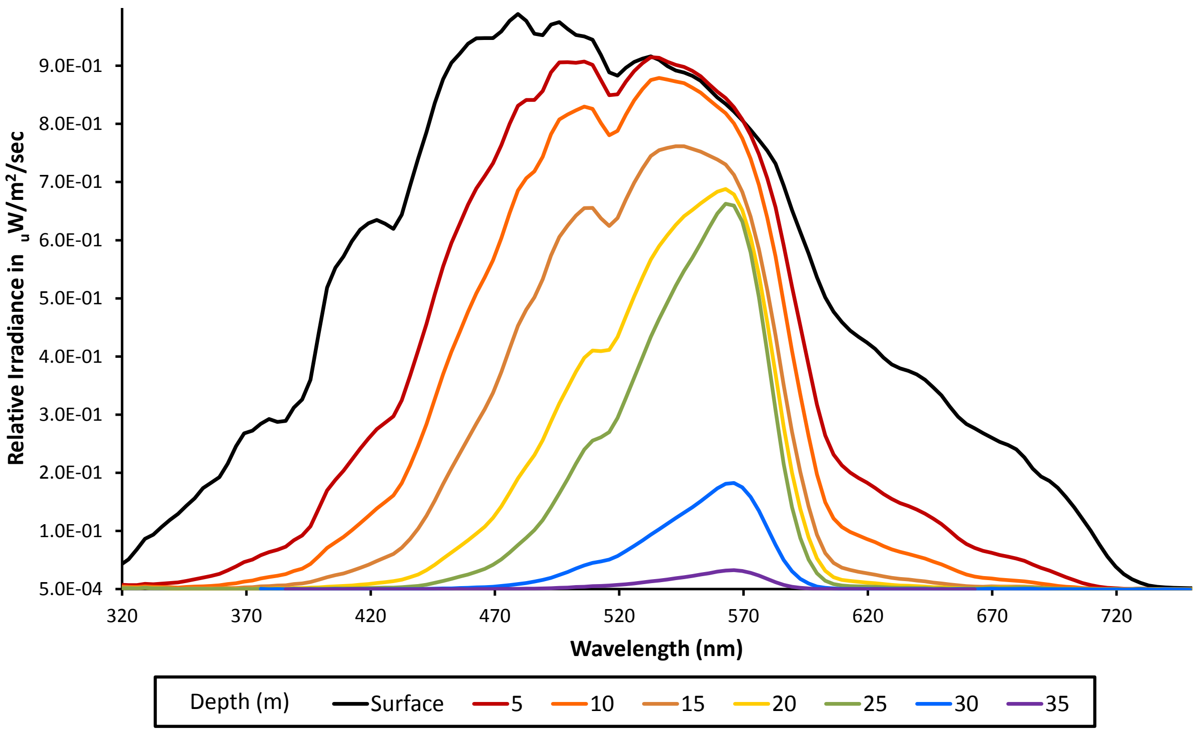
The Development and Use of a New Spectral Irradiance Logger (SIL) on Groundfish Surveys: Seeing the Bering Sea in a New Light.

Collection of underwater ambient light level data on the RACE Groundfish Assessment Programs' bottom trawl surveys began in 2004. Early measurements were of the relative brightness of light as it penetrated downward through the water column (known as downwelling irradiance) and were collected using a modified Wildlife Computers MK-9 fish tag. This simple measure of brightness proved useful for understanding vertical and horizontal distribution patterns of walleye pollock (Kotwicki et al. 2009, 2013) and in current modelling efforts of essential fish habitat. For instance, fish size, bottom depth, and light intensity at the bottom have been found to be the three most important factors in determining the vertical distribution of walleye pollock. These results have increased the interest by several researchers to incorporate measurements of environmental light into investigations on the distribution, abundance, and ecology of commercially important fishes. However, the MK-9 light data are relatively crude, lack resolution at low light levels, require tedious calibrations, and provide absolutely no information on the spectral qualities of light in the water column.

To address the need for accurate light intensity and spectral distribution data, we recently developed the first-ever trawl-mounted spectral irradiance logger (SIL) that was successfully tested and deployed during the eastern Bering Sea bottom trawl survey in 2014. The SIL uses a spectral irradiance sensor coupled with a programmable data logger developed by Rick Towler of the MACE program. This spectroradiometric characterization of the underwater light field will enable scientists to address questions involving the impact of spectral distribution, as well as light intensity, on aquatic organisms. Studies have shown that even subtle changes in the intensity and spectral characteristics of the water column can greatly influence the distribution of a fish, the ability of fish to detect and successfully acquire prey, and the ability of fish to evade capture. Routine spectral measurements using the SIL during AFSC bottom trawl surveys are planned in future years, and scientists plan to use this new time series of environmental data to provide more insight into processes such as larval survival and recruitment success, spatial patterns of distribution and abundance, availability of individual fish species to bottom trawls, and gear avoidance. Additionally, this high-resolution spectral irradiance data serves as an efficient way to monitor environmental changes in the water column, such as the presence or absence of plankton blooms or other scattering layers present at depth, and optical changes due to the extent of the cold pool each year within the Bering Sea.

Testing and confirmation of the quality of this exciting new set of environmental data are still underway, but should soon be available to AFSC researchers.

The SIL consists of an underwater spectroradiometer and data logger (A) that contains a power supply for autonomous deployments. For trawl survey use, the spectroradiometer is placed in a protective housing and mounted vertically through a bracket that secures the data logger (B) and mounts directly to the headrope of the net (C). A hole is cut into the top of the trawl net to give the sensor unobstructed access to the downwelling light field for measurement.



Representative spectral irradiance curves from Bristol Bay, Alaska, collected at survey station J-16 during the 2014 eastern Bering Sea bottom trawl survey using the SIL. Figure shows the normalized attenuation of light above between 320 nm (UV) and 720 nm (near-infrared) with depth.

Contact Lyle Britt@noaa.gov for more information.

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 and research on individual species are found in Section C By Species.

Shelf-associated Flatfish Juveniles in the Bering Sea
Eco-FOCI studies on early life history stages of flatfishes help to understand mechanisms controlling recruitment variation. We continue to conduct field studies of juvenile distributions, habitat, and diet in the EBS of northern rock sole (*Lepidopsetta polyxystra*), flathead sole (*Hippoglossoides elassodon*), arrowtooth flounder (*Atheresthes stomias*), Pacific halibut (*Hippoglossus stenolepis*), and yellowfin sole (*Limanda aspera*).

Northern rock sole juvenile spatial distribution and abundance are correlated in RACE groundfish survey data. Large abundances small fish (ages 2 and 3) have more northwards distributions, suggesting density dependent spatial patterns or spatially dependent production. To date, age-0 distribution is reflected 2 years later in the groundfish survey of age-2 fish. A large area of the EBS between Cape Newenham and Nunivak Island served as age-0 northern rock sole habitat in 2003 (a warm year survey conducted by B. Norcross University Alaska, Fairbanks), but not in 2008 or 2010 (cold years), and in 2012 (another cold year) densities were low and age-0 northern rock sole were small. Age-2 and age-3 fish distributions were significantly correlated with EBS temperatures two and three years prior to the survey (i.e. in years when the small juveniles were age-0 fish), however distributions were not significantly correlated with current survey year temperatures, suggesting that temperature in the age-0 year controls distribution small juveniles more that temperature in the current year.

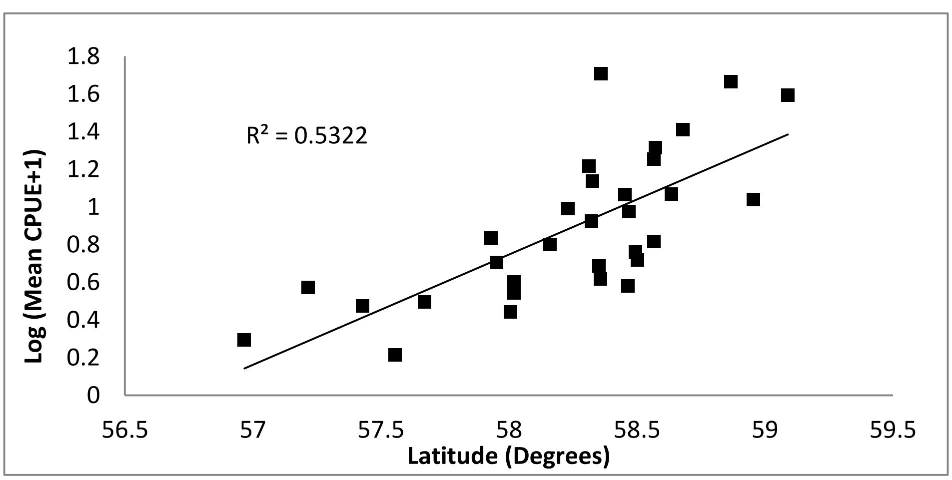


Figure 1. Relationship between annual mean catch per unit effort and the latitude of the catch-weighted center of age-2 and age-3 sized northern rock sole in the EBS groundfish survey from 1982 through 2012.

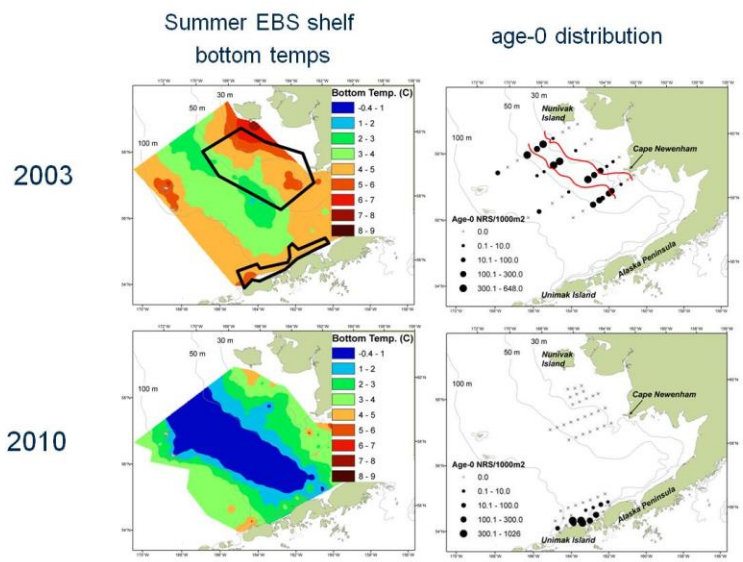


Figure 2. EBS Summer bottom temperatures in 2003 (upper left) and 2010 (lower left) and autumn age-0 northern rock sole distributions in 2003 (upper right) and 2010 (lower right).
Age-0 northern rock sole mean length is higher in warm, nearshore areas than in cold, offshore areas, suggesting temperature dependent growth and/or shoreward movement after settlement.

Contributed by D. Cooper, e-mail: Dan.Cooper@noaa.gov

Deep-sea Spawning Flatfishes in the Bering Sea

Eco-FOCI has been examining canyon and slope habitat utilization, and spawning to nursery area connectivity for Greenland halibut (*Reinhardtius hippoglossoides*) and Pacific halibut (*Hippoglossus stenolepis*), two deep-sea spawning flatfish in the eastern Bering Sea. Distribution and abundance of adults, larvae and juveniles are seasonally assessed using field surveys and results are compared to predominant circulation patterns. Transport along and across the Bering Slope was derived from 23 years (1982-2004) of simulations from an ocean circulation model (ROMS). It was hypothesized that changes in the strength and position of the Bering Slope Current would affect recruitment of Greenland halibut, Pacific halibut and arrowtooth flounder. Seasonal variations in flow were observed, with transport typically highest during fall and winter months. Significant correlations were found between transport, position, and recruitment. In particular, it was noted that Pacific halibut recruitment increased in relation to increased on-shelf transport through southern canyons.

Contributed by J. Duffy-Anderson, e-mail: Janet.Duffy-Anderson@noaa.gov

Shelf-associated Flatfishes in the Gulf of Alaska

Stations across the western GOA shelf were sampled in late summer 2011 for settled juvenile flatfish species, including age-0 arrowtooth flounder. These data were used to test the predictive ability of habitat models developed in GOA bays for application over the continental shelf. The models predict presence or absence of specific species-age groups of juvenile flatfishes depending on variables such as bottom temperature, bottom depth, and sediment composition (e.g., mud, sand, or gravel percent of total weight). The models performed well for two of the species-age groups. We are currently exploring whether model performance improves with the introduction of new independent variables and parameters. This study is increasing our knowledge of juvenile flatfish habitat in the GOA, including improving estimates of juvenile flatfish habitat for GOAIERP models.

Contributed by M. Wilson, e-mail: Matt.Wilson@noaa.gov

Synthesis of Gulf of Alaska Ichthyoplankton Data Illuminates the Recruitment Process Among Species with Variable Life History and Ecological Patterns

Data are from historical and ongoing collections of ichthyoplankton samples and associated oceanographic and climate measurements in the GOA. Ichthyoplankton surveys that sample the early ontogeny pelagic phase (eggs/larvae) of fish integrate information on a diverse range of species with variable adult habitats and ecologies. Synthesis of these ichthyoplankton and associated environmental data are being carried out in order to evaluate species pelagic exposure patterns and response outcome during early ontogeny. The research is contributing to a mechanistic understanding of environmental forcing on early life history aspects of recruitment processes among GOA fish species. Multivariate analysis of the historical GOA ichthyoplankton has revealed synchronicities and similarities among species early life history patterns and their links to the environment. This research has yielded an effective conceptual framework for evaluating the exposure and response of fish species to the pelagic environment during early life The working hypothesis for this ongoing research is that we can utilize similarities in reproductive and early life history characteristics among species to identify: 1) ecologically-determined species groups that are pre-disposed to respond to environmental forcing during early life in similar ways, and 2) plausible environmental predictors of early life history aspects of recruitment variation. Evaluation of the effectiveness of this conceptual framework will continue as the ichthyoplankton time-series (1981-2011) continues to be investigated in relation to interannual variation in the oceanographic environment. Application of this research to stock assessments is being explored. The objective is to determine which species-specific larval abundance data and environmental drivers should be incorporated into groundfish stock assessment models to best account for environmental forcing of recruitment

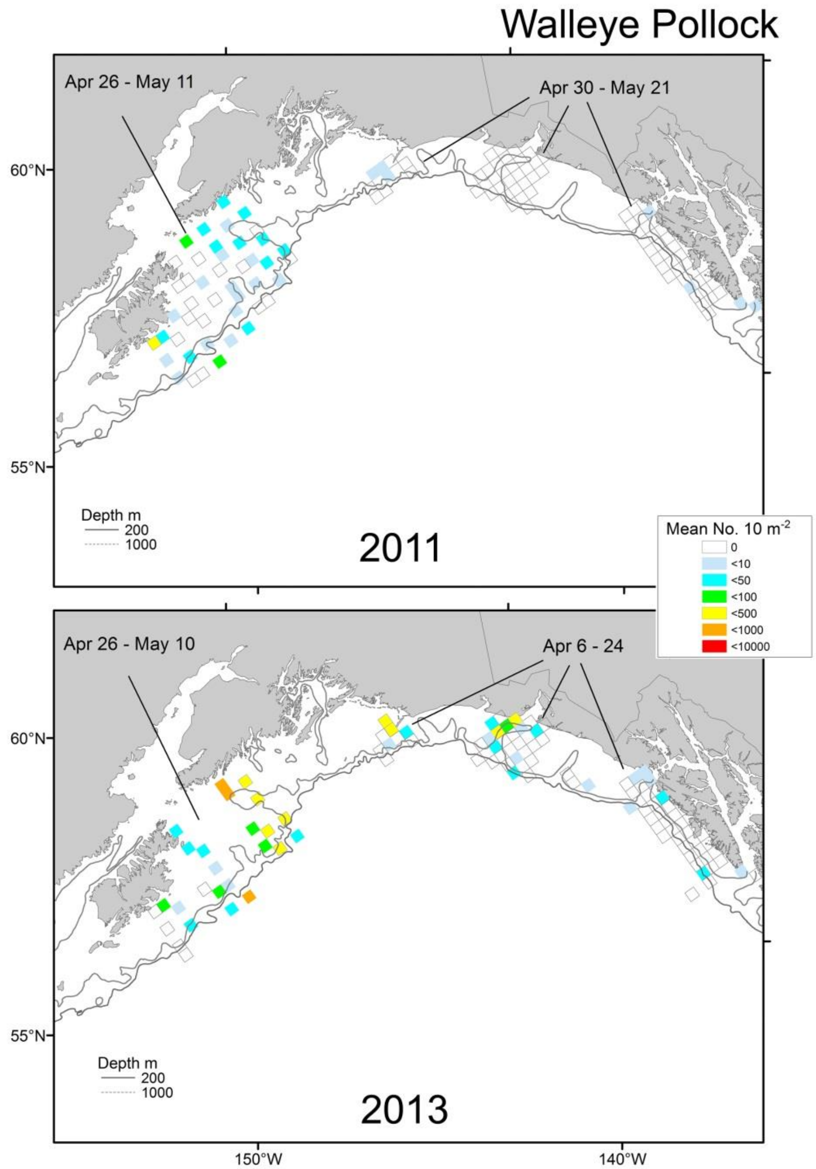
Multi-species Approaches – Development of DNA-based Methods for Identification of Fish Eggs, Larvae and Prey Remains

We developed a mitochondrial DNA (mtDNA) sequence database and restriction fragment length polymorphism protocols to accurately identify any life history stage of commercially important marine fish species, with special emphasis on select species that have been difficult or impossible to identify by conventional taxonomic means. Seven PCR-based restriction fragment length polymorphism (PCR-RFLP) protocols screening portions of the mitochondrial cytochrome *c* oxidase (COI) and cytochrome *b* (cyt *b*) genes were diagnostic for 19 species in five families Results from this study demonstrated the potential to fill important knowledge gaps for commercially and ecologically important species routinely studied at AFSC, with particular regard to species composition in fish diets and ichthyoplankton. The database provided the foundation for development of rapid, cost-effective, and accurate molecular protocols to identify species under circumstances where traditional taxonomic approaches founder or fail.

Lower Trophic Level Contributions to the GOAIERP Project

The Gulf of Alaska Integrated Ecosystem Program (GOA-IERP) is a four year (2011–2014) multi-disciplinary study examining the interactions between physical and biological oceanography to understand how the environment influences the survival of early life history stages (egg to age-0 juvenile) and recruitment of five commercially and ecologically important groundfishes: *Gadus chalcogrammus* (Walleye Pollock), *Gadus macrocephalus* (Pacific Cod), *Atheresthes stomias* (Arrowtooth Flounder), *Anoplopoma fimbria* (Sablefish), and *Sebastes alutus* (Pacific Ocean Perch). Biological and oceanographic surveys were conducted in the eastern and western Gulf of Alaska over two primary field years (2011 and 2013). More than 40 scientists (fishery biologists, oceanographers, and modelers) from 11 institutions are taking part in this study funded by the North Pacific Research Board.

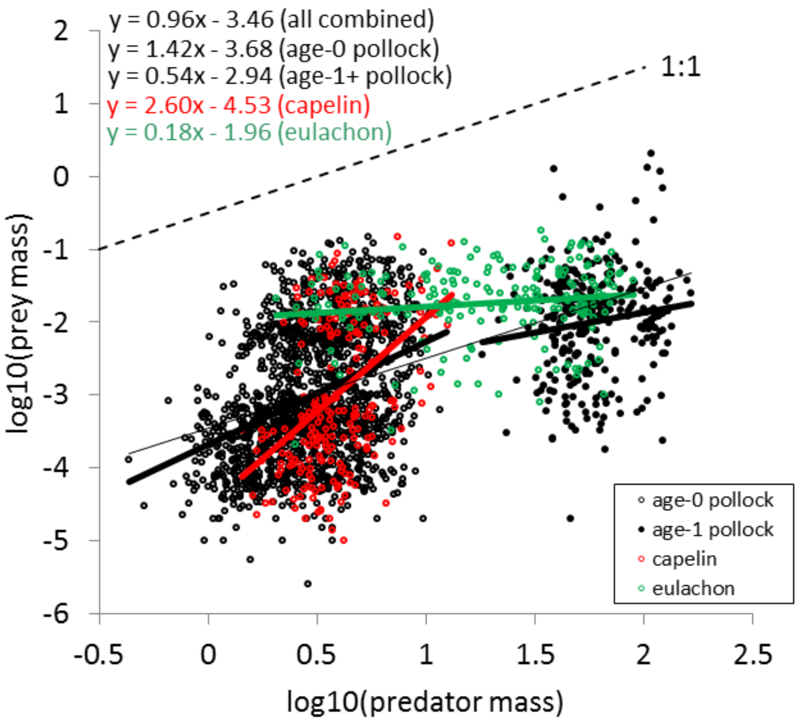
As part of the Lower Trophic Level Component of the GOA-IERP, the Recruitment Processes Program has been involved in the planning and execution of ichthyoplankton and oceanographic sampling in the eastern and western Gulf of Alaska for the 2011 and 2013 field years. Currently, we are analyzing results from the surveys in preparation for a manuscript on the distribution and abundance of GOA ichthyoplankton. In the spring (April–May), larvae of all five target taxa and eggs of only one target taxa (Walleye Pollock) were collected. In general, the two gadid species (Walleye Pollock and Pacific Cod) were collected in higher abundance in the western Gulf of Alaska while both Arrowtooth Flounder and Sablefish were collected in higher abundance in the eastern Gulf of Alaska. Rockfish were ubiquitous throughout the study area in the spring. Between the two field years, abundance in 2013 was higher for gadid species (both regions) and Arrowtooth Flounder (eastern Gulf of Alaska). Conversely, Sablefish were lower in abundance in 2013 (both regions). In the summer months (July–August), only two target taxa were collected; rockfish larvae were collected in both the eastern and western Gulf of Alaska and Sablefish were collected in low abundance in the eastern Gulf of Alaska only. It should be noted that at this time we are unable to identify larval rockfish collected in our samples to the species level due to ambiguous morphological characters. Genetic analysis on specimens collected in the spring and summer has shown that in the spring Pacific Ocean Perch make up the majority of rockfish larvae collected, while in the summer it appears that another rockfish species is dominant.



Ecology of small neritic fishes in the western Gulf of Alaska. III. Linking predator selectivity to prey size and trophic transfer efficiency

Prey selection by juvenile pollock (*Gadus chalcogrammus*), capelin (*Mallotus villosus*), and eulachon (*Thaleichthys pacificus*) helps support the predator-dominated trophic structure of the Gulf of Alaska ecosystem. These fishes select zooplankton partly on body size. Preliminary results indicate that prey selection by age-0 pollock and capelin resulted in steep (slope >1) logarithmic predator-prey size relationships (Fig. 1). Selection by older pollock and eulachon resulted in low-slope (<1) logarithmic predator-prey size relationships. Observed predator-prey mass ratio theoretically implies that at 10 g these predators would produce about 75 mg for every 1 g produced by their prey, and that capelin and eulachon tend to be more efficient than pollock due to relatively low predator-prey mass ratio.

Contributed by Matt Wilson, FOCI

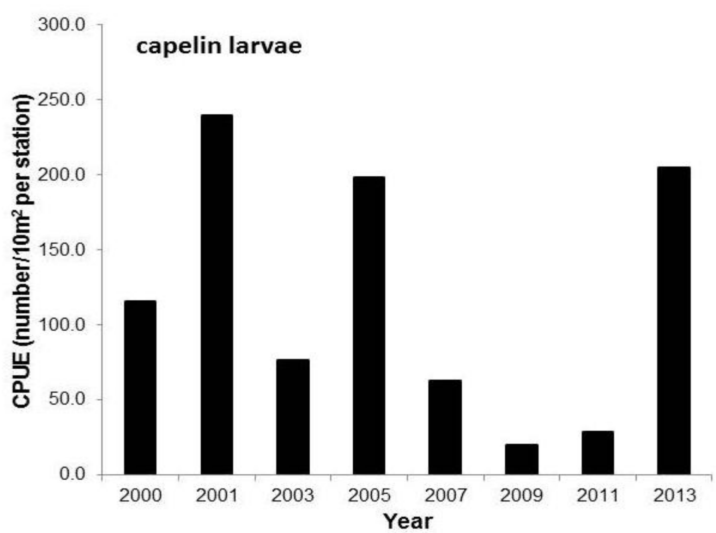


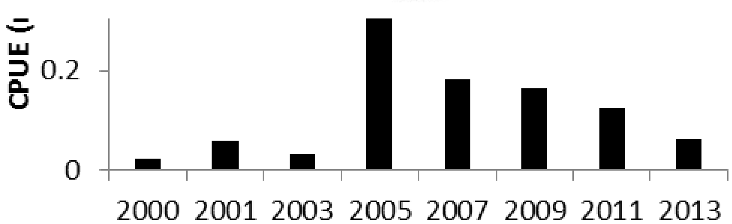
Contributed by Matt Wilson, FOCI

Time Series of Capelin Abundance in the Western Gulf of Alaska, 2000-2013

The Ecosystem and Fisheries-Oceanography Coordinated Investigations Program (Eco-FOCI) is developing time series of larval and post-larval forage fish abundance and body size from on-going sampling of zooplankton and small neritic fishes in the western Gulf of Alaska (GoA). We present here some results on capelin (*Mallotus villosus*) from surveys conducted in late summer during odd years since 2000, inclusive. The results are preliminary because the geographic area has not been standardized, and a potential day-night effect on catch efficiency has not been accounted for. Ichthyoplankton species are collected with 60-cm bongo nets (or 1-m Tucker trawls during 2000-2003). Small neritic fishes are collected with a small-mesh trawl. Samples were collected at predetermined sites from the upper 200 m of water depth. Abundance of capelin larvae was variable over the years examined (Fig. 1). Peak abundance occurred in 2001 and abundance was lowest in 2009 and 2011. Survey-wide abundance of post-larval capelin (*Mallotus villosus*) collected in small-mesh trawls appears to have been decreasing in the GoA since peaking in 2005 (Fig. 2). A proposal to examine the factors affecting changes in the abundance and distribution of forage fish species in the GoA is currently in review at NPRB.

Contributed by Steve Porter and Matt Wilson, FOCI





New Approaches to Sampling for Small Neritic Fishes in the Eastern Bering Sea
Eco-FOCI and EMA researchers have been working on updating the sampling design for age-0 pollock and other forage fishes during the EBS BASIS survey. The efforts include development of a new midwater trawl to replace the Cantrawl, changing from surface tows to oblique midwater tows, and using acoustics to study fish vertical distribution. A new trawl is being designed to replace the Cantrawl and attempt to improve retention of smaller age-0 pollock. MACE pocket net studies of the Cantrawl indicate small gadoid fishes have low retention. The new midwater trawl will have smaller mesh and will be towed more slowly than the Cantrawl in an attempt to increase retention of smaller age-0 pollock. A previous gear comparison conducted by Eco-FOCI and EMA between the Stauffer trawl (aka anchovy) and the Cantrawl indicated that the two gears caught a similar species composition, so the new trawl will have a mouth opening size similar to the Stauffer trawl. The new survey design will also use oblique tows instead of surface tows to reduce the effect of variability in vertical fish distribution on the catch. Acoustics will be used primarily to understand the vertical distribution of age-0 pollock; particularly, the difference between warm and cold years in the Bering Sea. Oblique trawls, instead of targeted trawls, will be used to identify the dominant acoustic scatterers.

Contributed by Dan Cooper, Adam Spear (FOCI) and Alex Andrews (EMA)

Early Life History Ecology and Recruitment Processes of Fish Species in the Gulf of Alaska
Ichthyoplankton surveys that sample the early ontogeny phase of fish integrate information on a diverse range of species with variable adult habitats and ecologies. Synthesis of these ichthyoplankton and associated environmental data from historical (spanning four decades) and ongoing surveys in the Gulf of Alaska (GOA) ecosystem continue both at a single species and multiple species level. The broad objective is to evaluate species' pelagic environmental exposure patterns and response outcome during early ontogeny. This research provides a mechanistic understanding of environmental forcing on early life history aspects of recruitment processes. Results are applied to the development of models both at the level that represent the ontogenetic pathway of an individual from egg stage to recruitment (Individual Based Models), as well as at the level of integrating physical and biological processes across different trophic levels in the pelagic ecosystem (Integrated Ecosystem Assessments).

Historical sampling is concentrated in the western GOA and has been most intense during mid-May through early June in the vicinity of Shelikof Strait and Sea Valley from where data has been developed into a time series of larval abundance and length indices for the numerically dominant species (Fig. 1). This time series spans from 1981 through 2011 annually, and from 2013 onwards sampling occurs every other year. It has been updated through 2011 and is presented and reviewed in the 2013 Ecosystem Considerations chapter of the Stock Assessment and Fisheries Evaluation report. The time series continues to provide valuable information on interannual trends in early ontogeny stages of important commercial and ecologically important species, and associated ecological patterns and environmental forcing. It has been incorporated into the retrospective analysis component of the North Pacific Research Board sponsored Gulf of Alaska Integrated Ecosystem Research Program (GOAIERP), as well as the development of three new research proposals in 2013.

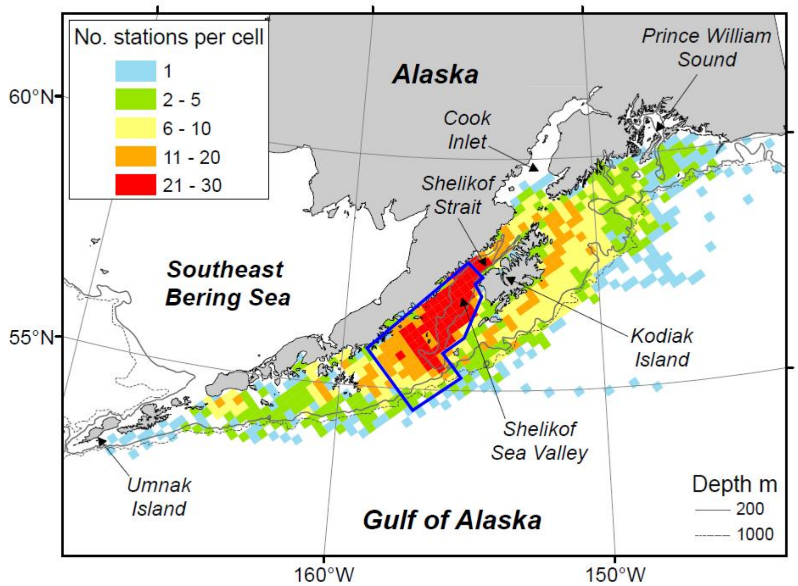


Figure 1. Distribution of historical ichthyoplankton sampling in the GOA by the Alaska Fisheries Science Center (1972, 1977-2009), based on 60-cm bongo net sampling of the upper 100 m of the water column. The polygon outlined in blue is the area from which the late spring ichthyoplankton time series has been developed.

Retrospective analysis of GOA historical ichthyoplankton data for the GOAIERP program has been completed this year. Syntheses of data for the five focal species (Walleye Pollock, Pacific Cod, Sablefish, Pacific Ocean Perch, and Arrowtooth flounder) have been incorporated into a) the development of Individual Based Models for each species by the Modeling component of the GOAIERP program, and b) a manuscript that presents a comprehensive review of the early life history patterns and processes for these species in the GOA. The manuscript is in review for submission to the GOAIERP special issue of Deep Sea Research II.

Synthesis of historical data continues with the investigation of phenology of the early ontogeny phase across GOA (and Bering Sea in the future) species and pelagic habitats. The timing and temporal extent of occurrence of eggs and larvae in the pelagic environment is a primary gradient of early life history variation among GOA fish species, and progression along this gradient is associated with variable patterns of exposure that modulate species response to environmental forcing[1]. For instance fish larvae of various species are present in the plankton during all seasons, and the period and extent of peak abundance varies (Table 1). For many species, larvae are temporally or spatially separated from the major spring production of copepod nauplii that are considered the primary source of nutrition for fish species during early ontogeny. This prompts many questions regarding the temporal and spatial availability of components of the zooplankton as food for fish larvae, and the feeding habits and prey selectivity among different species at different times of year and sub-intervals of early ontogeny. New research is proposed to address these questions by examining larval gut contents from archived samples.

[1] Doyle, M.J. and Mier, K.L. 2012. A new conceptual framework for evaluating the early ontogeny phase of recruitment processes among marine fish species. Can. J. Fish. Aquat. Sci. 69: 2112-2129.

Contributed by M. Doyle, e-mail: Miriam.Doyle@noaa.gov

Table 1. Schematic of monthly succession in occurrence and relative abundance of numerically dominant species of fish larvae in historical Gulf of Alaska ichthyoplankton samples (Doyle, unpublished data).

Species	**Common Name**	**H**	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Hippoglossus stenolepis	Pacific Halibut												
Atheresthes stomias	Arrowtooth Flounder												
Leuroglossus schmidtii	Nrthrn. Smoothtongue												
Hemilepidotus hemilepidotus	Red Irish Lord #												
Hexagrammos decagrammus	Kelp Greenling #												
Pleurogrammus monopterygius	Atka Mackerel #												
*Ammodytes personatus**	Pacific Sand Lance												
Gadus macrocephalus	Pacific Cod												
Gadus chalcogrammus	Walleye Pollock												
Lepidopsetta polyxystra	Northern Rock Sole												
Stenobrachius leucopsarus	Northern Lampfish												
Pleuronectes quadrituberculatus	Alaska Plaice												
Anoplopoma fimbria	Sablefish #												
Ophiodon elongatus	Lingcod #												
Clupea pallasi	Pacific Herring												
Hippoglossoides elassodon	Flathead Sole												
Platichthys stellatus	Starry Flounder												
Glyptocephalus zachirus	Rex Sole												
Microstomus pacificus	Dover Sole												
Bathymaster spp.	Ronquils												
Lepidopsetta bilineata	Southern Rock Sole												
Isopsetta isolepis	Butter Sole												
Sebastes spp.	Rockfish												
Mallotus villosus	Capelin												
Limanda aspera	Yellowfin Sole												

*Used to be considered *A. hexapterus* prior to Mecklenberg et al. (2011)[2]

#Larvae associated with neuston

Level of abundance: Lowest Moderate Highest Absent

Primary larval habitat (**H**): Coastal Shelf Slope/Deeper

Modeling Contributions to the GOAIERP Project

Eco-FOCI personnel have been involved in the Modeling Component of NPRB's Gulf of Alaska Integrated Ecosystems Research Program (GOAIERP, aka the GOA Project). This project is focused on examination of recruitment dynamics of five focal groundfish species in the GOA.

[2] Mecklenburg, C.W., MØller, P.R., and Steinke, D. 2011. Biodiversity of arctic marine fishes: taxonomy and zoogeography. Mar. Biodiv. 41: 109-140.

Several types of models have been done for this project to complement the GOAIERP field work. A time series run of the 3km GOA implementation of the ROMS model (with integrated Nutrient-Phytoplankton-Zooplankton, NPZ, dynamics) has been run, from 1996 to 2011. This biophysical model has been used to show current patterns and patterns of scalars such as temperature and salinity, plus mesoscale dynamics such as eddies, all of which can influence transport of early life stages of fish. One product of the Modeling Component has been the development of a method to identify eddies in the ROMS output with the goal of examining the role of eddies in recruitment dynamics. At this initial stage, some correlations between indices based on these eddies, and recruitment has been found.

The output of this biophysical model is being used to drive individual-based models (IBMs) for the five GOAIERP focal species. These models are intended to allow us to examine connectivity between spawning and nursery areas, and also the environments encountered by the early life stages of the fish, for the purposes of examining how these factors affect recruitment variability. IBMs for Pacific cod and walleye pollock have been developed by Eco-FOCI personnel. A time series run (1996-2011) of the Pacific cod IBM has been completed, and initial connectivity analyses are done. Figure 1 shows the connectivity zones used for analyzing the output of the Pacific cod IBM.

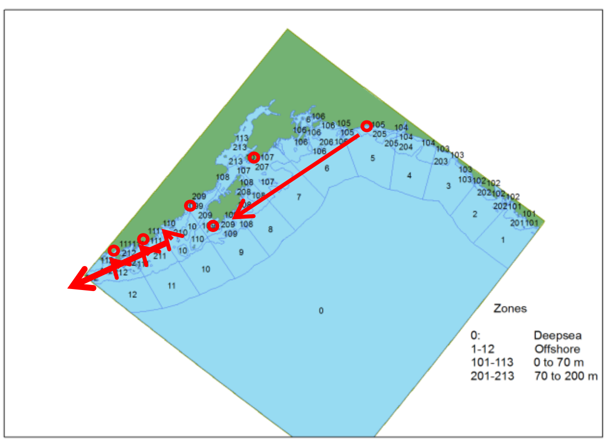


Figure 1. Connectivity zones for Pacific cod. Spawning zones are 101-113 and 201-213. Nursery zones are 101-113. Red circles and arrows indicate areas where variability in connectivity due la Nina may be high (see below).

Figure 2 shows the mean connectivity matrix for the years 1996-2011. From this figure it can be seen that retention (i.e. settlement in the same locations as spawning occurred, indicated by the white line) is important for Pacific cod. It is clear in this matrix that Pacific cod are not generally transported great distances between spawning zones and nursery areas. This is in accord with several other studies indicating that Pacific cod have very local distributions. It is also clear from this matrix that few Pacific cod seem to be transported to offshore areas.

Another analysis of connectivity showed that there may be an association between variability in connectivity in the western GOA (but not the eastern GOA) and La Nina (see Figure 1).
Results of analyses of IBM output will be incorporated into a Multispecies Model for the GOA, in an attempt to discover how recruitment variability affects other elements of the ecosystem.

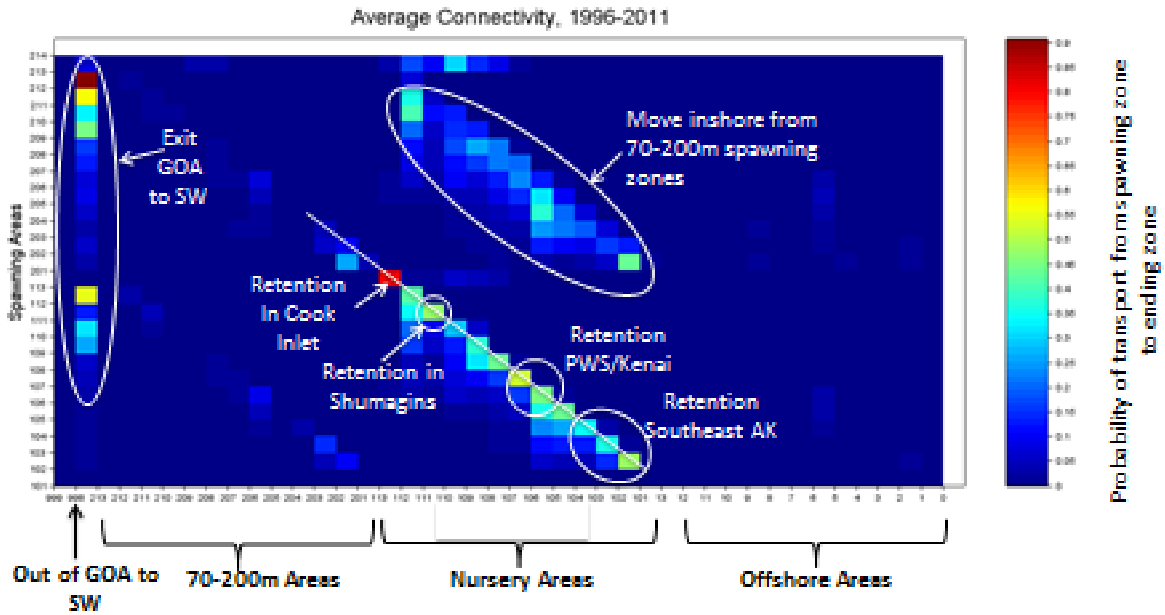


Figure 2. Mean connectivity matrix for the years 1996-2011 (right) from the Pacific cod IBM. The X-axis represents ending zones of individuals, the Y-axis indicates spawning (start) zones. Zones 101-113 represent nursery areas.

Scientific Exchange

The National Oceanic and Atmospheric Administration's Alaska Fisheries Science Center and the International Pacific Halibut Commission co-hosted the 9th International Flatfish Ecology Symposium at Suncadia Lodge in Cle Elum, WA, from November 9-14, 2014. The Symposium is organized every 3 years and provides the international platform for flatfish scientists and managers to meet, share their research, and discuss management applications. There were six themes for the 9th IFS: *Flatfish and the Pelagic Realm: New Perspectives*, *The Influences of Flatfish on Trophic Interactions and Community Structure*, *Flatfishes and Climate Variability*, *Disentangling Multivariate Effects*, *Stock Assessment and Fisheries Management*, and *Physiology*, *Development*, *and Aquaculture*. The 9th IFS was generously supported by academic, state, federal, and industry representatives. For more information please visit: www.flatfishsymposium.com or contact Janet Duffy-Anderson (NOAA) at Janet.Duffy-Anderson@noaa.gov or Tim Loher (IPHC) at Tim@iphc.int.

Gulf of Alaska Assessment: Fisheries Oceanographic Surveys - ABL

The Gulf of Alaska (GOA) Assessment completed its first year of fisheries oceanographic surveys during July and August 2014. This new long-term monitoring project was developed from the GOA Project, a North Pacific Research Board Integrated Ecosystem Project, which was designed to understand ecological processes across years, seasons, and regions in the GOA. The GOA Assessment is focused on furthering understanding of biophysical processes as well as monitoring the health and abundance of select groundfish and salmon species in the southeast region of the GOA. These objectives will be accomplished by focusing on the early life history of Chinook salmon, chum salmon, pollock, and Pacific cod and identifying and quantifying the major ecosystem processes that regulate survival by monitoring interannual variability in distribution, energetic condition, and food habits.

The GOA Assessment was conducted during July and August 2014 off southeast by the F/V

Northwest Explorer, a chartered commercial trawler. Fish samples were collected using a midwater rope trawl (Cantrawl model 400) that was fished at surface by stringing buoys along the headrope, with the footrope typically descending to a depth of 30m. Surface tows were made at predetermined grid stations and were 30 minutes in duration. Immediately after the trawl was retrieved, catches were sorted by species and standard biological measurements (length, weight, and maturity) were recorded. Whole age-0 marine fish, juvenile salmon, and forage fish were collected and frozen for transportation to the laboratory for food habits, energetic, and genetic analyses.

Physical oceanographic data were collected at gridded survey stations by deploying a conductivity, temperature, and depth meter (CTD) with ancillary sensors. These provided vertical profiles of salinity, temperature, fluorescence, and photosynthetic available radiation (PAR). Zooplankton and ichthyoplankton samples were collected at gridded stations using double oblique bongo tows from the surface to within 5 meters of bottom, with a maximum depth of 200 m.

The five species of marine fish that were most often captured in surface trawls during the 2014 field season were arrowtooth flounder, rockfish, pollock, Pacific cod, and sablefish (Figures 1-3). We intend to sample a reduced sample grid that will span from Sitka Sound north to Yakutat Bay during summer 2015. For more information, contact Jamal Moss at (907)-789-6609 or jamal.moss@noaa.gov

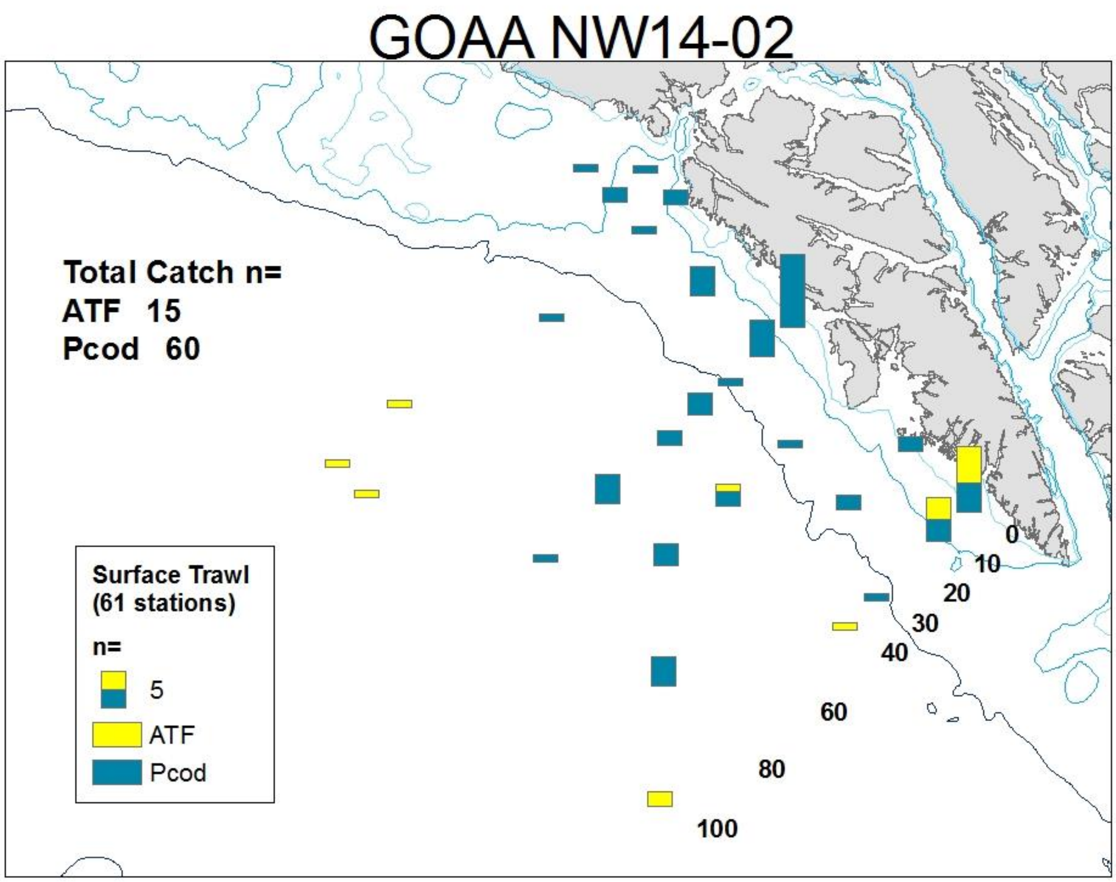


Figure 5. Catch per 30 minute net tow for age-0 arrowtooth flounder (ATF) and Pacific cod (Pcod) in the eastern Gulf of Alaska during July 2014.

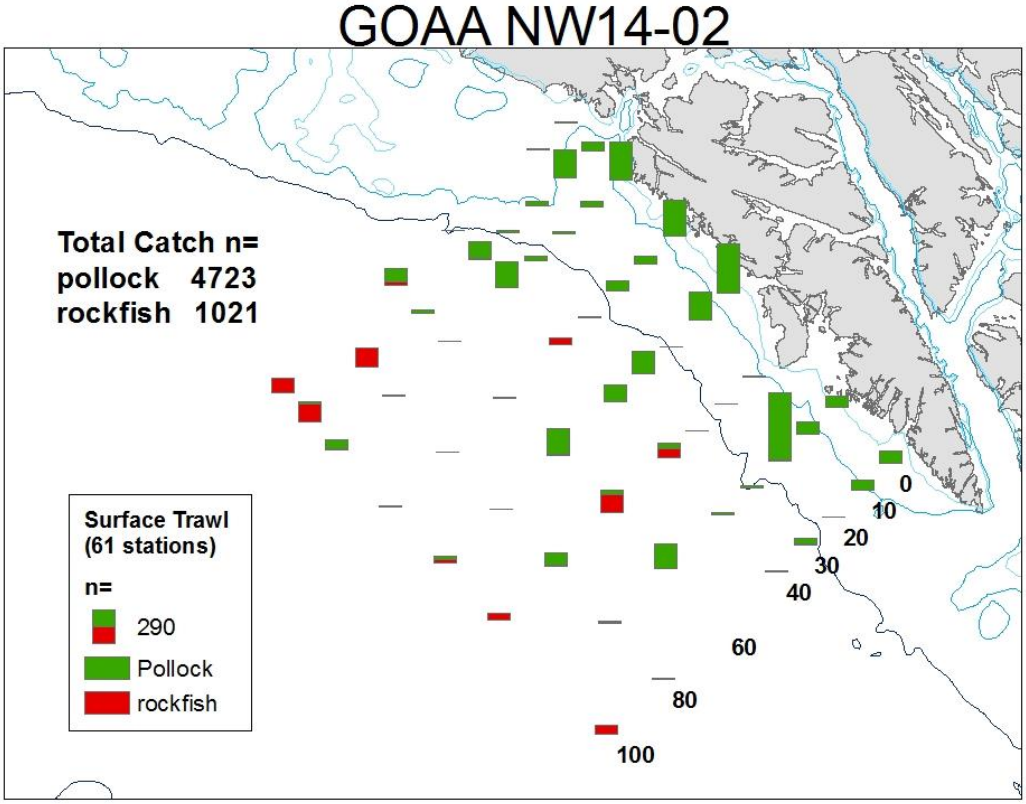


Figure 2. Catch per 30 minute net tow for age-0 pollock and rockfish in the eastern Gulf of Alaska during July 2014.

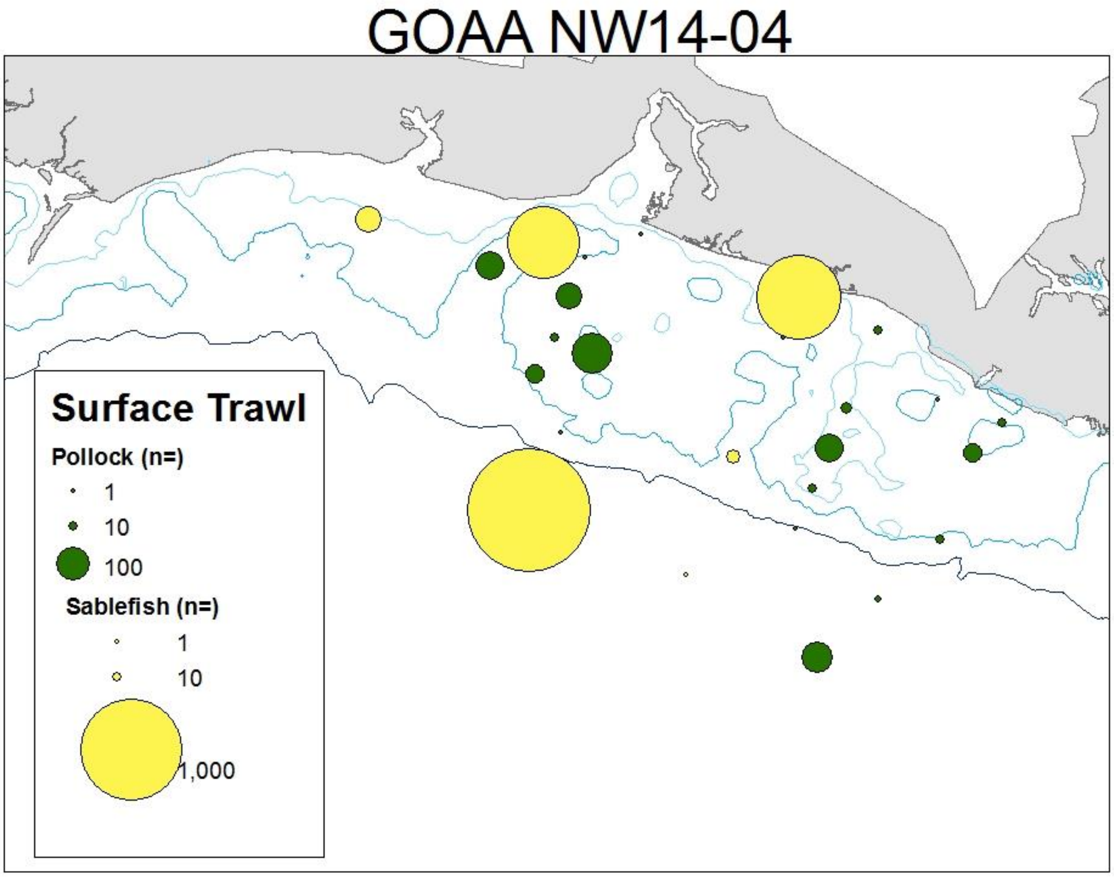


Figure 3. Catch per 30 minute net tow for age-0 sablefish in the eastern Gulf of Alaska during August 2014.

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. Objectives 1-3 have been completed by the habitat team which includes full life history tables of habitat preference for the five focal species, extensive EndNote library of the literature synthesis, collection and validation of high resolution bathymetry (over 20 million soundings) and sediments (100 thousand plus points), GIS framework with gridded benthic habitat metrics and digitized species observations, final literature-based habitat suitability surfaces, and preliminary modeled habitat suitability surfaces.

Final literature surfaces were provided to the various components of the GOA Project (e.g. lower, middle, upper trophic level and modeling). These surfaces are currently being used in a variety of ways to inform conclusions on survey distributions, energetic analyses, and individual based model

(IBM) connectivity and trajectories. Draft modeled habitat suitability surfaces were also produced for the recent final primary investigators meeting (April 7-10, 2015). These surfaces were shown as examples of the final product for this benthic habitat research project and inspired several discussions on useful avenues for incorporating this information to improve model trajectories and interpretation. These modeled benthic habitat suitability surfaces are also slated for providing the base structure of a newly funded essential fish habitat (EFH) project (Pirtle, Shotwell, Rooper). This project will coordinate with another EFH effort to characterize the EFH of the groundfish fishery management plans (FMP) species. The final output of these projects would assist with improving the current and upcoming EFH five-year updates for the early juvenile to adults stages. For more information, please contact Kalei Shotwell at (907) 789-6056 or kalei.shotwell@noaa.gov.

RACE Habitat Research Group (HRG)
Scientists in the RACE Habitat Research Group (HRG) continue research on essential habitats of groundfish, including identifying informative predictor variables for building quantitative habitat models, developing efficient tools to map these variables over large areas, investigating activities with potentially adverse effects on Essential Fish Habitat (EFH), such as bottom trawling, and conducting benthic community ecology studies to characterize groundfish habitat requirements and assess fishing gear disturbances. Research in 2014 was primarily focused on evaluating acoustic backscatter as a quantitative predictor of groundfish distributions in the eastern Bering Sea (EBS) and the development of next generation habitat-utilization models for managed species. An analysis of short-term trawling effects on soft-bottom benthos was published, and a global study of mobile bottom-contact fishing gears continued as part of an international effort.

For additional information, see *http://www.afsc.noaa.gov/RACE/groundfish/hrt/default.php* or contact Bob McConnaughey, bob.mcconnaughey@noaa.gov, 206-526-4150. Other members of the HRG are Steve Intelmann, Keith Smith, Theresa Smith, and Steve Syrjala.

Habitat Modeling
The HRG is building numerical models to explain the distribution and abundance of groundfish and benthic invertebrates in the eastern Bering Sea (EBS). Abundance estimates from annual bottom trawl surveys are being combined with synoptic environmental data to produce basin-scale continuous-value habitat models that are objective and have quantifiable uncertainty. The resulting quantitative relationships not only satisfy the Congressional mandate to identify and describe essential fish habitat (EFH), but may also be used to gauge the effects of anthropogenic disturbances on EFH, to elevate stock assessments to SAIP tier 3, and to predict the redistribution of species as a result of environmental change. In practice, we use systematic trawl-survey data to identify EFH as those areas supporting the highest relative abundance. This approach assumes that density data reflect habitat utilization, and the degree to which a habitat is utilized is considered to be indicative of habitat quality. The models are developed with an iterative process that assembles existing data to build 1st generation expressions. Promising new predictors are then evaluated in limited-scale pilot studies, followed by a direct comparison of alternative sampling tools. Finally, the most cost-effective tool is used to map the new variable over the continental shelf and the existing model for each species is updated to complete the iteration.

Current research (the “FISHPAC” project) is investigating whether quantitative information about seafloor characteristics can be used to improve existing habitat models for EBS species. Preliminary work[3] demonstrated that surficial sediments affect the distribution and abundance of groundfish, however direct sampling with grabs or cores is impractical over large areas. Subsequent pilot studies[4,5] showed that acoustic systems were suitable for broad-scale seafloor surveys and that processed acoustic data can be used to improve the numerical habitat models.

A major field experiment in 2012 collected more than 3,800 gigabytes of acoustic data and groundtruthing information on multiple tracklines spanning strong gradients in groundfish and crab abundances (Fig. 1). Five different sonars were deployed on multiple passes over each line and these data were post-processed in 2014, for multiple purposes. Bathymetric data were cleaned and submitted for nautical charting. Backscatter data were post-processed to produce standardized statistics, using quantitative sediment properties from grab samples to normalize the values. Still image mosaics of the seafloor were generated from towed video to serve as additional groundtruthing for the acoustic data.[6] Thirty-three years of trawl survey data (catch per unit effort, kg ha^{-1}) have been assembled and statistical analyses with the backscatter statistics are being prepared to compare the contributions of the different sonar systems in the habitat models. The most cost–effective sonar system will be used to systematically map and characterize the seabed of the EBS shelf (Fig. 2), and will be the basis for improved EFH models for multiple species.

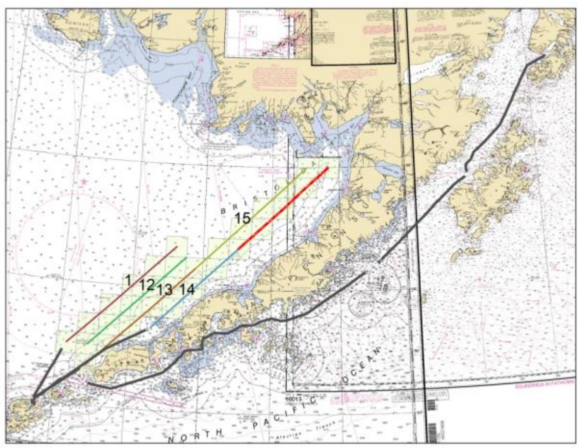


Figure 6. Completed FISHPAC 2012 survey tracklines. Shaded boxes represent 20 by 20 nautical mile squares centered on RACE bottom trawl survey stations for the Bering Sea shelf. Each line was surveyed with five different sonar systems, with the exception that only multibeam echosounder data were collected over the northeast section of line 14 and during the transits to and from the numbered tracklines. For additional information, see http://www.afsc.noaa.gov/RACE/surveys/cruise_archives/cruises2012/results_Fairweather_FISHPAC-2012.pdf.

[3] McConnaughey, R.A. and K. R. Smith. 2000. Associations between flatfish abundance and surficial sediments in the eastern Bering Sea. Can. J. Fish. Aquat. Sci. 57: 2410-2419.
[4] McConnaughey, R.A. and S.E. Syrjala. 2009. Statistical relationships between the distributions of groundfish and crabs in the eastern Bering Sea and processed returns from a single-beam echosounder. ICES J. Mar. Sci. 66: 1425-1432.
[5] Yeung, C. and R.A. McConnaughey. 2008. Using acoustic backscatter from a side scan sonar to explain fish and invertebrate distributions: a case study in Bristol Bay, Alaska. ICES J. Mar. Sci. 65: 242–254.
[6] Representative video and the resulting geo-referenced mosaic are available at http://www.afsc.noaa.gov/Quarterly/jas2012/divrptsRACE4.htm.

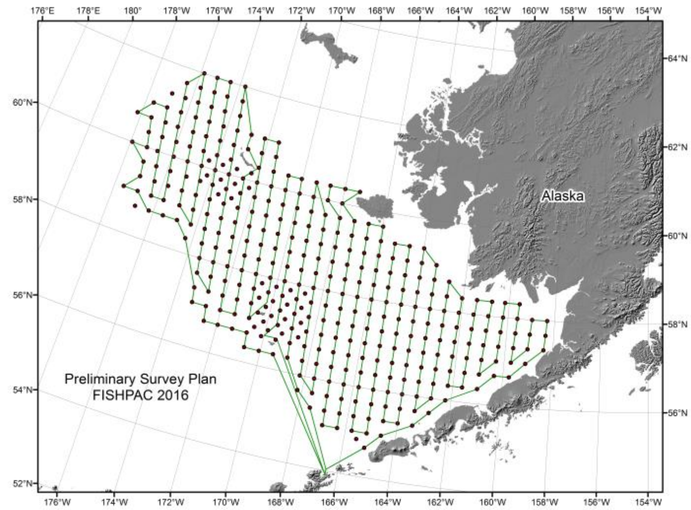


Figure 7. The Bering Sea shelf will be systematically mapped to improve groundfish habitat models and fishery stock assessments. Quantitative sonars will be used characterize the seafloor at 349 trawl-survey stations during a planned multi-mission cruise. In addition to quantitative backscatter data, the survey will also produce IHO-quality bathymetric data for updating nautical charts of areas with outdated or non-existent information, as well as continuous measurements of chemical and physical properties in the pelagic and benthic environments.

Tool Development for Broad-scale Habitat Mapping

The Klein 7180 long-range side scan sonar (LRSSS) is new technology that was purpose-built for HRG fish-habitat research. It is distinguished from all other sonar systems by its ability to collect fully adjusted quantitative information about seafloor characteristics and is thus ideally suited for modeling applications. The very large swath coverage (to 1.0 km) and high maximum tow speed (12 kts) of the LRSSS greatly increase the efficiency of survey operations thereby reducing costs and the time required to complete missions. Multiple acoustic, environmental and navigational sensors generate co-registered high-resolution backscatter and bathymetry from a dynamically focused multibeam side scan sonar and integrated nadir-filling sonars. Secondary acoustic systems, including a 38 kHz single-beam echosounder, a Mills-cross-configured downward-looking sonar, and a pair of scatterometers also provide bathymetric and/or backscatter data for interpretation. Calibrated backscatter is available across the entire survey area with an innovative "cascade calibration" that uses overlapping swaths of data to transfer the calibrated backscatter from a simple downward-looking sonar (altimeter) to the other acoustic subsystems covering the nadir (under the towfish) and the outlying side-scan regions. This Mills-cross type altimeter is easily removed for tank calibration and can then be readily reinstalled in a fixed position as needed for periodic recalibration of the LRSSS system.

There was considerable interaction with commercial software developers in 2014, related to the continuing development of LRSSS capabilities and the need for high-quality backscatter data in next-generation habitat models. In particular, the HRG worked closely with the new owners of *Fledermaus* (QPS, Inc, a division of Saab Maritime) and *IMPACT* (Maritime Way Scientific, Ltd.) software in order to improve the accuracy of statistical outputs and to enable processing of very large data sets with their commercially available products.

The Rolls Royce free-fall cone penetrometer (FFCPT) [7] is a 52 kg instrumented probe that is designed to free fall through the water column and can penetrate up to 3 meters into the seabed. Measurements of deceleration and pore pressure allow for the determination of undrained sheer strength and a profile of sediment types. Sensor data are captured 2000 times per second on flash memory and transmitted to topside computers where they can be quickly processed with specialized software. In addition to sediment data, an instrument in the tail fin of the FFCPT acquires sound velocity profiles for use by the ship's acoustic systems. When combined with an appropriate winch, it is possible to yo-yo the instrument through the water column and into the seafloor while the ship is underway at speeds up to 6 kts, thereby improving surveying efficiency over more traditional sediment- and sound-velocity-sampling methods that require the ship to slow or even stop headway for data acquisition. The geotechnical data are being evaluated as new predictor variables for use in the HRG habitat models.

A triplet of optical sensors (Wet Labs Puck; 660 nanometer wavelength) incorporated into the LRSSS towfish continuously measures colored dissolved organic matter (370/460 nm excitation/emission), turbidity by particle scattering (660 nm), and chlorophyll-a fluorescence (470/680 nm) in the pelagic environment. These properties show considerable spatial variability, may be related to fish-habitat quality, and are ~~also~~ being considered for use in next generation models.

HAIP-QTC Opilio

The HRG is also investigating whether acoustic backscatter from the seafloor can be used to improve stock assessments. In stock assessment models, catchability is the link between an index of relative abundance from a fishery-independent survey and the modeled population size. For bottom trawl surveys that estimate the population size using swept-area methods, catchability can be estimated because it is largely determined by sampling efficiency (*i.e.*, the proportion of animals within the sampled area that is caught) which can be experimentally measured. However, estimating survey catchability is complicated because trawl efficiency has been shown to vary over a survey area in response to variation in bottom sediment type.

Catchability experiments have been conducted on the bottom trawl used for the annual EBS survey, [8] resulting in a survey-wide estimate of catchability for snow crab (*Chionoecetes opilio*) which, when included in the stock assessment model, produced significant changes in the Allowable Catch Limit. This catchability model accounted for spatial variation in trawl efficiency as a function of crab size, sex, water depth, and sediment type. Unfortunately, sediment data over the geographic distribution of snow crab are quite fragmentary due to the remoteness of the area, and direct estimates of sediment properties such as grain size are generally unavailable at the trawl-sampling locations.[9] In some cases, estimates were based on sediments collected over 60 miles away. The option to collect sediment data at all 270 trawl-sampling stations included in the snow crab distribution is prohibitively expensive considering the additional ship time required and the sample

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[7] For additional information, see http://www.brooke-ocean.com/document/product_sheet-RRCLNM-FFCPT-660_(4-page)-2011-01-web_Rev1_(2012-05-02).pdf

[8] For additional information, see http://www.afsc.noaa.gov/RACE/groundfish/ebs.htm

[9] Smith, K. R. and R. A. McConnaughey. 1999. Surficial sediments of the eastern Bering Sea continental shelf: EBSSED database documentation. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-104. 41 p. For additional information, see http://www.afsc.noaa.gov/Publications/AFSC-TM/NOAA-TM-AFSC-104.pdf

processing costs.

This project is examining whether indices of bottom type, derived from standardized and calibrated ES-60 acoustic data collected at each snow crab sampling station, are more informative in the snow crab bottom trawl catchability model than measured values of sediment type that were broadly extrapolated. This determination will be based solely on the amount of spatial variation in the snow crab efficiency model that is explained by the two kinds of sediment information. While the currently used data are based on a directly measurable attribute of the sediment (mean grain diameter), the acoustically derived index is related to this attribute but also to a variety of previously unmeasured variables affecting the time-dependent shape of the bottom echo. Although there is not a simple mathematical relationship between the two types of information, we believe an acoustic index is sufficiently related, will be more reliable, can be collected more efficiently, and will result in a better fitting catchability model for EBS snow crab. In the future, it may be possible to expand this study to other species after completion of the systematic acoustic survey for all EBS trawl-survey stations (Fig. 2).

Effects of Bottom Trawling

In 2014, the HRG published an analysis of short-term effects of bottom trawling on soft-bottom benthos of the EBS.[10] In particular, a Before-After Control-Impact (BACI) experiment was conducted to investigate the effects of a commercial bottom trawl on benthic invertebrates in a sandy and previously untrawled area of the EBS. Six pairs of experimental and control corridors were sampled with a research trawl before and after four consecutive tows with the commercial otter trawl. A major storm event occurred during the experiment and it was possible to differentiate its effect from that of the trawling using the BACI model. Species composition changed very little; *Asterias amurensis* and *Paralithodes camtschaticus* comprised over 80% of the total invertebrate biomass (kg ha^{-1}) during each year of the study. In general, the commercial trawl did not significantly affect the biomass of the benthic invertebrate populations. The trawling effect after 4-14 d was statistically significant at $\alpha = 0.10$ for only three of the 24 taxa that were analyzed, a number expected due to nothing more than random variation. Biomass immediately after the trawling disturbance was lower for 15 of the taxa and higher for the other nine, with a median change of -14.2%. Similarly, the effect of trawling on invertebrate biomass after one year was not statistically significant for any of the taxonomic groups ($p \geq 0.23$ for each group), indicating no evidence of a delayed response to the commercial-trawl disturbance. Further analysis suggests that storms have an overall greater effect on the benthos than do bottom trawls at this location. Both the numbers of taxa significantly affected by trawling and the storm (3 *vs.* 12), and the median sizes of these effects (-14.2% *vs.* -22.0%), were greater for the storm event. Results from this study are combined with those from a related investigation of chronic trawling effects (Fig. 3) to propose an adaptive management strategy for the study region, including rotating area closures to mitigate for temporary trawling effects.

[10] McConnaughey, R. A. and S. E. Syrjala. 2014. Short-term effects of bottom trawling and a storm event on soft-bottom benthos in the eastern Bering Sea. ICES J. Mar. Sci. 71: 2469-2483.

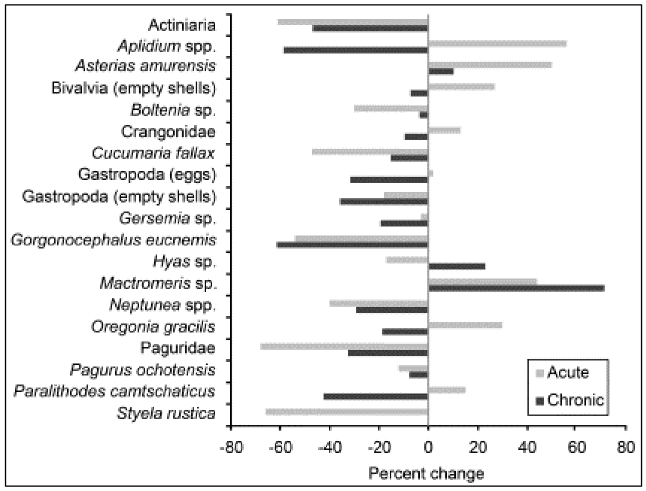

Figure 8. Changes in the biomass (kg ha^{-1}) of benthic invertebrate taxa 4-14 d after four consecutive passes of a commercial trawl (acute effects; present study) and after decades of intensive trawling by the fishery (prior HRG study of chronic effects). The chronic effect for *Styela rustica* was 0%.

International Committee Forms to Study Bottom-trawl Effects

There is considerable evidence that mobile bottom-contact gears (MBCG) such as trawls and dredges affect the integrity of benthic environments that support prey and provide habitat for managed populations of fish and crab. Widespread use of these gears could thus have substantial effects on the growth, survival, and productivity of these stocks. There is, however, considerable variability in the magnitude and characteristics of the effects. Hard-bottom areas with surface-dwelling invertebrate fauna are particularly sensitive, whereas soft-bottom areas with frequent natural disturbances are relatively insensitive. Given that approximately 25% of world fish catch comes from the use of these gears, a clear understanding of the overlap between trawling effort and different benthic habitats is of considerable global importance.

An international group has formed to summarize the global use of mobile fishing gears, their impacts on marine habitats and the productivity of fish stocks, and related management practices. The committee is comprised of individuals from both academia and government and is being lead by Professors Ray Hilborn (University of Washington, Seattle), Simon Jennings (Centre for Environment, Fisheries and Aquaculture Science, Lowestoft, U.K.), and Michel Kaiser (Bangor University, Bangor, U.K.). Other members of the committee are Drs. Jeremy Collie (University of Rhode Island, Narranganset), Jan Hiddink (Bangor University, Bangor, U.K.), Bob McConnaughey (NOAA Alaska Fisheries Science Center, Seattle), Ana Parma (Argentine Council for Science and Technology, Chubut, Argentina), Roland Pitcher (Commonwealth Scientific and Industrial Research Organization, Brisbane, Australia), and Adriaan Rijnsdorp (Wageningen University and Research Center, IJmuiden, Netherlands). Three post-doctoral research associates (Drs. Ricardo Amaroso, Kathryn Hughes, and Tessa Mazor) are working full-time on the project.

The full project consists of five phases. Phase 1 of this project is systematically mapping MBCG effort and its distribution with respect to benthic habitats (Fig. 4). Phase 2 has compiled data and conducted a meta-analysis to evaluate the impacts of MBCG on the abundance and diversity of biota.[11] Phase 3 will use information from the first two phases to conduct a risk assessment of the effects of trawling and to illustrate trends in the risk of change to seabed habitats and communities. Phase 4 is studying the medium- and long-term impact of trawling on the productivity and sustainable yield of different target species and ecosystems. Phase 5 will identify and test a range of management options and industry practices that may improve the environmental performance of trawl fisheries, with a view to defining 'best practice.' The scope of the Phase 5 effort was broadened in 2014 to include a closer look at trawl-fishery management in South and Southeast Asia. There are approximately 80,000 trawlers operating in the region under a variety of management practices and contrasting policy drivers. Additional details about the project, products, and the study group are available at http://trawlingpractices.wordpress.com/.

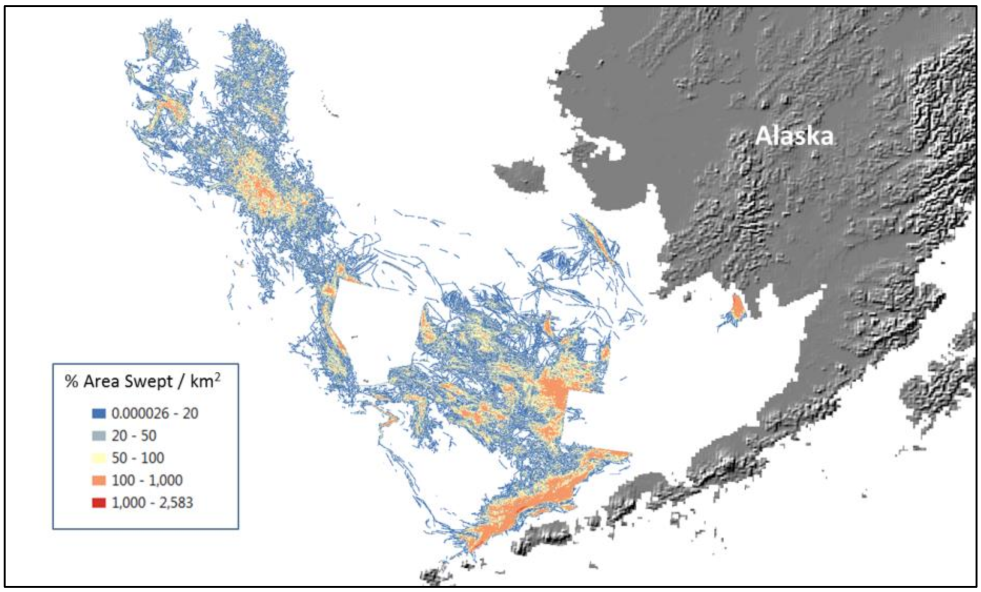

Figure 9. Distribution of trawling effort in the eastern Bering Sea, based on VMS data. Percentages indicate the total area swept in each 1 km^2 grid cell during 2008. Values greater than 100% indicate the total area swept in a cell exceeded 1 km^2. (Summary produced by S. Intelmann.)

Invertebrate Species Synopsis - *Asterias amurensis*

Invertebrates are an important element of the benthic ecology on the EBS continental shelf, with a significant role in the food web supporting not only the benthos, but also commercially important demersal fish species. The HRG is synthesizing sparse literature and reports to produce synopses of the life history and ecology of significant species. The second in a series of NOAA Technical Memoranda has been completed to aid the interpretation of mobile fishing gear effects on these invertebrates, their linkages to fishery production, and their overall role in the ecosystem.[12] The

[11] Hughes, K. M., M. J. Kaiser, S. Jennings, R. A. McConnaughey, R. C. Pitcher, R. Hilborn, R. Amoroso, J. S. Collie, J. G. Hiddink, A. M. Parma, and A. D. Rijnsdorp. 2014. Investigating the effects of mobile bottom fishing on benthic biota: a systematic review protocol. Environmental Evidence 3: 23.

[12] Smith, K. R. and C. E. Armistead. 2014. Benthic invertebrates of the eastern Bering Sea: a synopsis of the life history and ecology of the sea star *Asterias amurensis*. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-273, 58 p.

document presents a synopsis of the current knowledge of the life history and ecology of the *Asterias amurensis*; it includes detailed maps of its distribution in the EBS based on abundance data from the 1982-2013 RACE bottom trawl-surveys. The biological characterizations are from the available published literature and are based on observations of populations in the native and invaded ranges of the species.

The asteroid species *Asterias amurensis* represents a major portion of the benthic invertebrate biomass over most of the shelf, but it is especially prevalent in the inshore domain out to about the 50 m isobath. The species is also native to coastal areas of the northwestern Pacific, including the Tatar Strait, eastern and western Sea of Japan, and the east coast of Japan. It is a predator upon numerous shelled mollusk species, as well as other invertebrates of limited motility, and is also an opportunistic scavenger. Asteroids appear to have few predators, and in food webs *A. amurensis* is a terminal consumer. It therefore competes with some commercially important demersal fish species, as well as commercially important invertebrates such as the king crab *Paralithodes camtschaticus*. A possible mitigating circumstance in its ecological role is the large contribution to secondary production constituted by the release of potentially millions of eggs by each spawning female during the annual reproductive cycle. With its low susceptibility to predation, the species has proven a threat to the ecological balance in areas where it is not native, but has been inadvertently introduced by such means as release of planktonic larvae in ballast water jettisoned by foreign ships in port; for example, in some coastal waters of southeastern Australia and Tasmania. Here native species of bivalves have proven especially vulnerable to the predator.

Consistent Taxonomic Classification of Invertebrates Caught in AFSC Bottom Trawl Surveys
The RACE Division's annual bottom trawl survey of fish and invertebrates spans the EBS shelf from the Alaska Peninsula on the southeast to approximately 62º N near St. Matthew Island in the northwest, and extends cross-shelf from the 20 m isobath to the 200 m isobath. Thanks to consistent gear and sampling methods used from 1982 to the present, the survey data constitute an invaluable time series of distribution and abundance. However, there have been inconsistencies in the taxonomic resolution to which a particular species has been identified and these inconsistencies can easily contribute to errors when compiling data for analysis.

A specialized software query and lookup tables have been developed to address cases where classification has varied among years, vessels, cruises, or hauls. For a user-selected set of years, the tool accesses data in the Division's Oracle database and groups the aggregate weights and numbers of invertebrate caught by the lowest accountable inclusive taxon (LAIT). As an example, inconsistent classification of the neptunid snails as *Neptunea heros, Neptunea pribilofensis*, and *Neptunea* spp. over three survey years would be consolidated as *Neptunea* spp. for reporting purposes.

Miscellaneous projects
<u>Bibliography on the applicability of sonars for habitat mapping:</u>

A great variety of biotic and abiotic factors define the habitats of marine species such that knowledge of their spatial and temporal variability can be used to understand biological patterns of distribution and abundance. The importance of habitats for the sustainable management of fishery stocks was formally acknowledged in the US with passage of the Sustainable Fisheries Act in 1996. At that time, the Magnuson-Stevens Fishery Conservation and Management Act was amended to include new requirements to identify and protect essential fish habitat (EFH). By legal definition, EFH means those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity. Using the best scientific information, federal fishery management plans must describe and identify EFH in text that clearly states the habitats or habitat types determined to be EFH for each life stage of the managed species. In so doing, the plans should explain the physical, biological, and chemical characteristics of EFH and must also identify the specific geographic location or extent of habitats described as EFH.

The broad scope of the EFH mandate requires an efficient process for describing and mapping the habitats of federally managed species. Factors such as temperature, salinity, and depth are generally accepted as habitat-defining characteristics for marine fish and invertebrates, and synoptic data sets are frequently available. Research also indicates that surficial sediments are an important habitat factor for many species, with both direct and indirect effects on survival and growth. Traditional sampling with grabs and cores is, however, impractical over large areas and the availability of geo-referenced data is usually limited as a result. Acoustic methods, on the other hand, are suitable for large-scale surveying and show great promise as a substitute for direct-sampling methods, but they are still at a "nascent"stage of development [13] and have not been proven for EFH purposes.

The complex relationship between acoustic returns and seafloor sediments has been actively studied for decades. According to Holliday [14], as many as 80 different parameters have been used to describe the physical and material properties of the seafloor, of which six to 12 of these may have major influence on acoustic returns from the seabed. However, many of these parameters are confounded such that an area of seabed has a characteristic return but that acoustic return is not unique to that particular seabed type. Known as the "inverse problem", various combinations of grain size, surface roughness, and slope, for example, may be indistinguishable. In actual practice, the situation is even more complex, given the seabed frequently is not static due to time-varying forces such as waves, currents, certain fishing activities, and natural biological processes.

The primary focus of this bibliography is benthic habitat characterization using backscatter and bathymetric data from single-beam echo sounders, multibeam echo sounders, and side-scan sonars. The coverage ranges from methods for acquiring and processing data, data extraction and synthesis from imagery, production and use of habitat maps for fishery management and other purposes, modeling species distributions using processed data, and some relevant theoretical treatments. The bibliography was compiled from extensive searches of online literature databases, as well as secondary reviews of literature cited in the selected references. The collection includes peer-reviewed articles, as well as state and federal reports, conference papers, conference presentations, bulletins, and books. The abstracts and keywords for each reference were obtained from the original source whenever possible. If one or the other was not available for use, a brief summary and/or keywords were added.

This bibliography will be published as a NOAA Technical Memorandum and posted on the AFSC web site as a searchable, dynamic database.

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[13] Anderson, J. T., D. V. Holliday, R. Kloser, and D. Reid [ed.] 2007. Acoustic seabed classification of marine physical and biological landscapes. ICES Cooperative Research Report no. 286. Copenhagen. 185 p.

[14] Holliday, D. V. 2007. Theory of sound-scattering from the seabed. Pages 7-28 *in* J. T. Anderson, D. V. Holliday, R. Kloser, and D. Reid [ed.] Acoustic seabed classification of marine physical and biological landscapes. ICES Cooperative Research Report no. 286. Copenhagen.

Benthic Mapping Specialist billet

In June 2014, NOAA Corps hydrographer LTJG Theresa Smith reported to the HRG for a three-year assignment as a Benthic Mapping Specialist. This is the first such cross-over billet between NOAA hydrography and fisheries. She replaced LTJG Adam Pfundt, who returned to sea duty on NOAA Ship *Rainier*.

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 2014, AFSC personnel analyzed the stomach contents of more than 40 species sampled from the eastern Bering Sea, the Aleutian Islands, the Gulf of Alaska, the northern Bering Sea, and the Chukchi Sea regions. The contents of 16,326 stomach samples were analyzed including 3,636 stomach samples analyzed at sea during the Aleutian Islands groundfish survey. This resulted in the addition of more than 53,000 records to AFSC's Groundfish Food Habits Database in 2014. In addition to stomach samples from groundfish, we analyzed bill-load samples from 129 Tufted Puffins and 28 Horned Puffins collected from breeding colonies on Buldir and Aitak Islands for the Alaska Department of Fish and Game.

Collection of additional stomach samples was accomplished through resource survey, special studies comparing stomach contents with prey-sampling, and Fishery Observer sampling. Over 5,800 stomach samples were collected from large and abundant predators during the eastern Bering Sea bottom trawl survey of the continental shelf. At-sea analysis of stomach contents was conducted on almost 1,500 groundfish during the Aleutian Islands bottom trawl survey. These samples were supplemented by the collection of 1,674 stomach samples from Alaskan fishing grounds by Fishery Observers. Rockfish stomachs and zooplankton tows were sampled during a special study examining habitats around Kodiak Island by the RACE Division.

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.cfm.

Comparisons of At-Sea vs In Lab Stomach Content Analysis

Quantifying food web linkages is essential to understanding energy flow in the ecosystem and how external forces such as fishing and climate change may cause unanticipated shifts in ecosystem composition. For several years, REEM conducted Stomach Content ANalysis at Sea (SCANS) in addition to regular collection and preservation of groundfish stomach samples (to be analyzed in the laboratory) during surveys of the Gulf of Alaska and Aleutian Islands regions. During some surveys, stomach samples from the same predator species were analyzed both in the laboratory and at sea, thus providing the opportunity to examine how our ability to identify key prey types may differ between the two methods.

Identification of coelenterates (Cnidaria and Ctenophora) and pelagic urochordates (pelagic Tunicata and Larvacea) differs between the two methods for some zooplanktivores. SCANS more frequently detected coelenterates in the diets of Dark rockfish, Dusky rockfish, Prowfish and Sablefish, but not in the diets of Walleye pollock or Atka mackerel. Dissolution of coelenterate tissues during the preservation process is likely the main factor in the differences observed. Neither method of analysis commonly detected coelenterates in the diets of Walleye pollock or Atka mackerel. Pelagic urochordates were more frequently identified in the preserved and laboratory examined stomachs of Walleye pollock. Unlike coelenterates, pelagic urochordates have some tissues that do not dissolve during the preservation process, and their small size makes them more easily detected with the aid of a microscope in the laboratory.

The identification level of prey-fish was also found to differ between the two analysis methods for some piscivores. Identification of fish to species was higher using SCANS of Pacific cod, Arrowtooth flounder, Pacific halibut, and Walleye pollock (Fig. 1). One factor that contributes to this result is the greater ability to detect hard to identify larval-stage fishes and residual hard parts from fully digested fishes by using a microscope in the laboratory, and visual identification of digested prey to narrow taxonomic categories often proves difficult. Another contributing factor is the ability to freeze the visually unidentifiable prey-fish for genetic identification when SCANS is being performed. Numerically, large percentages are not identified to species, but these are mostly well digested fish with few parts remaining in the stomach, so when weight is considered, the percentages that are identified to species is larger for both methods (Fig. 1). The exception to this appears to be Walleye pollock that are analyzed in the laboratory, and may be due to greater uniformity in size of the (mostly larval and juvenile) prey-fish regardless of the level of digestion.

Conducting SCANS during groundfish surveys results in lower sample sizes due to the greater time required on the vessel to process each sample compared to collection and preservation, and possibly also results in lower precision regarding the composition of each stomach's contents. However, conducting SCANS results in faster delivery of the data for use in management models, reduced chemical usage and transportation, and the ability to coordinate genetic analyses of some prey-fish. The later benefit has allowed evaluation of some of our standard visual identification practices. Genetic analysis of prey-fish that could not be visually identified at least to family (to order, non-gadoid or unidentified teleost categories) indicated that these fish were in fact different species than the prey-fish that were visually identified. Several common forage fish can be identified to species at all levels of digestion because of distinctive bones and otoliths that remain intact throughout the digestion process, while other fishes become indistinguishable through visual means after very little digestion occurs. When diet composition data is being aggregated for ecosystem energy-flow models, the assumption that the unidentified fish portion of the diet can be represented by the composition of the identified prey-fishes is unlikely to be true.

Using both stomach content analysis methods will result in better descriptions of the marine foodweb linkages in Alaskan waters than using either method alone. SCANS can better identify consumption of soft-bodied prey, and, coupled with genetic identification techniques, poorly described portions of the diet may be more precisely described. Standard preservation and analysis practices can better detect small prey (or small parts of prey), allow for greater samples sizes across regions with heterogeneous habitat, and provide greater precision for the weight composition of each sample.

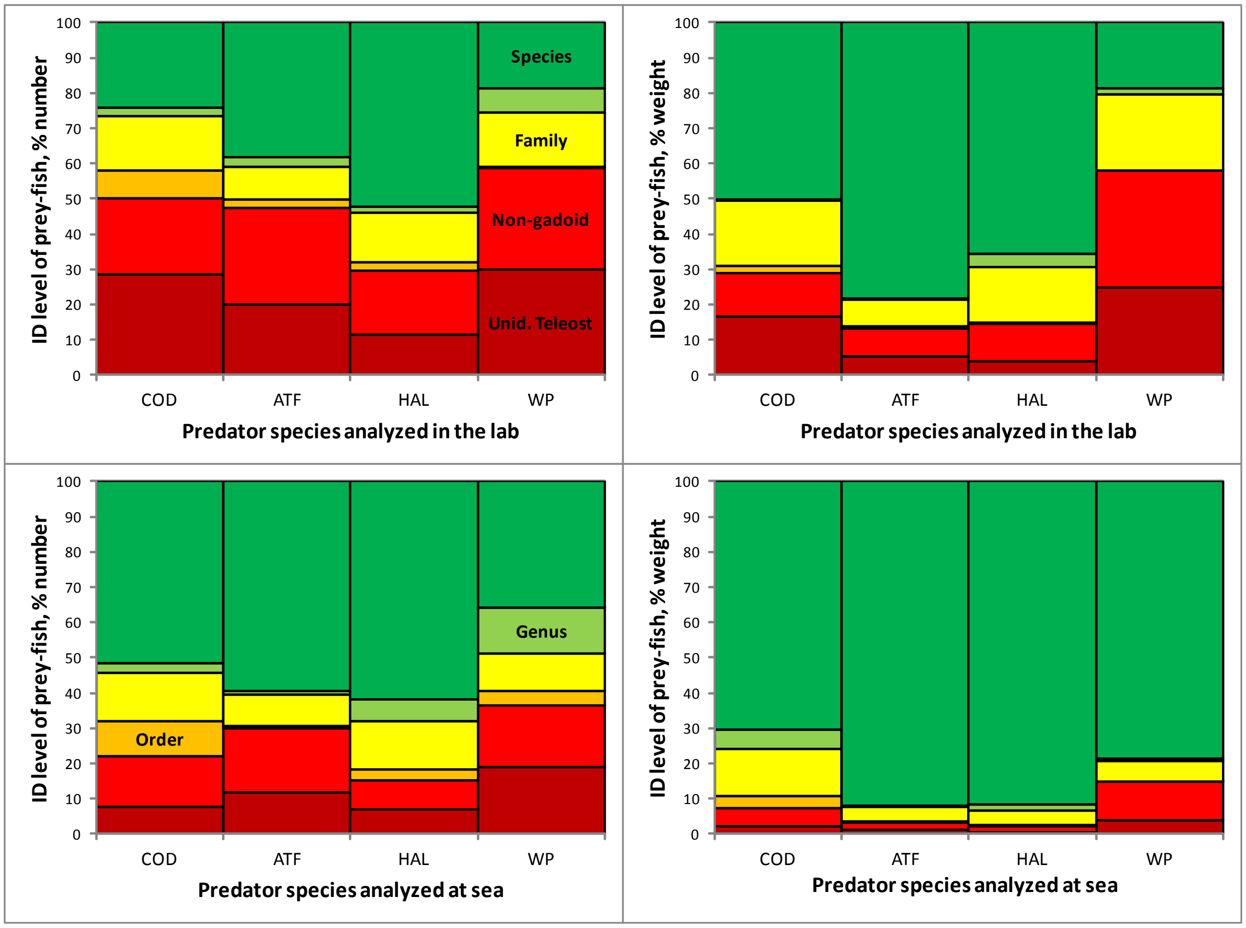


Figure 1. Identification levels of prey-fish in the diets of four predators, Pacific cod (COD), Arrowtooth flounder (ATF), Pacific halibut (HAL) and Walleye pollock (WP) averaged from three surveys where stomach content analyses were performed both in the laboratory (upper panels) and at sea (lower panels). The numeric distribution of the prey-fish among the identification levels is shown in the two panels on the left side, and the weight distribution of the prey-fish among the identification levels is shown in the two panels on the right side.

Seabird Bycatch Estimates for Alaskan Groundfish Fisheries, 1993-2013

In 2013 the restructured observer program expanded coverage, including vessels less than 60 feet overall and vessels in the halibut fleet. Despite this expansion, the total seabird mortality associated with the fleet was the lowest we have recorded, at 4,730 birds overall (Table 1, Fig. 2). As was expected, however, the bycatch of albatross did increase, to 438, the second highest recorded number since 2007 and well above the average of 347.6 throughout this time period. Overall bycatch remains low when compared to the years prior to 2002, when the cod freezer longline fleet and other longline vessels began extensive use of paired streamer lines (Fig. 2). These numbers include all gear types, but do not include mortality from the trawl fleet where mortality occurs due

to warp, net wing, or third wire interactions. Current estimates, beginning in 2007, are produced from the Alaska Regional Office Catch Accounting System. A report of seabird bycatch, 2007-2013 with more detailed information, including information by fishery, can be found on the AFSC website's seabird page, at
http://www.afsc.noaa.gov/refm/reem/Seabirds/Default.php

Table 1. Total estimated seabird bycatch in Alaskan federal groundfish fisheries, all gear types and Fishery Management Plan areas combined, 2007 through 2013.

Species/ Species Group	Year						
	2007	2008	2009	2010	2011	2012	2013
Unidentified Albatross	23	0	0	0	0	0	0
Short-tailed Albatross	0	0	0	15	5	0	0
Laysan Albatross	17	226	148	233	205	135	189
Black-footed Albatross	208	314	56	48	221	141	249
Northern Fulmar	4,806	3,334	8,200	2,452	6,214	3,022	3,268
Shearwater	3,587	1,224	622	653	195	514	191
Storm Petrel	1	44	0	0	0	0	0
Gull	1,360	1,551	1,335	1,145	2,158	890	556
Kittiwake	10	0	16	0	6	5	3
Murre	6	6	13	102	14	6	3
Puffin	0	0	0	5	0	0	0
Auklet	0	3	0	0	0	7	4
Other Alcid	0	0	105	0	0	0	0
Other Bird	0	0	136	0	0	0	0
Unidentified	522	541	696	240	306	285	267
Total	10,540	7,243	11,325	4,894	9,324	5,005	4,730

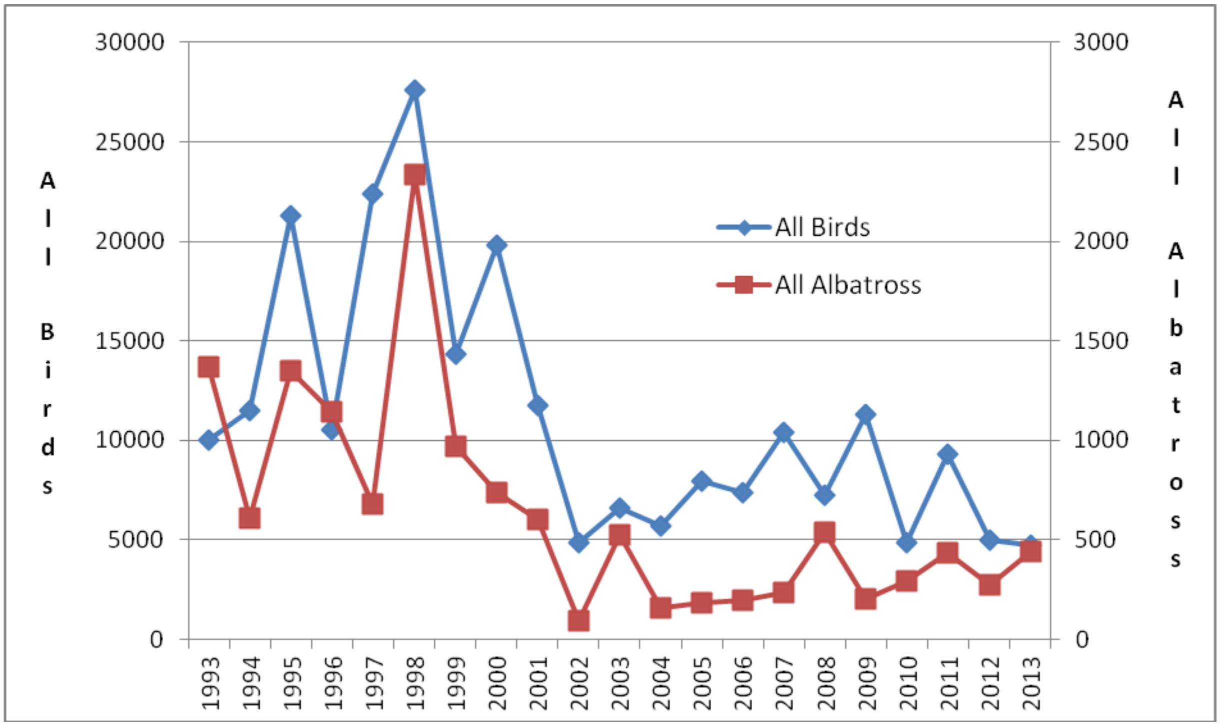


Figure 2. Total estimated bycatch of all seabirds and all albatross in Alaskan Groundfish fisheries, all gears combined -- 1993 to 2013.

In September 2014, there was an incidental take of an endangered Short-tailed albatross in the hook-and-line groundfish fishery of the Bering Sea/Aleutian Islands, and the take of a second unidentified albatross in the same haul. The last three documented Short-tailed Albatross takes in Alaska were in August 2010, September 2010, and October 2011. A response to the latest incident was coordinated with the NMFS Alaska Regional Office, the North Pacific Groundfish Observer Program, and the U.S. Fish and Wildlife Service. The confirmed Short-tailed albatross had a leg band identifying its natal breeding colony in Japan, and was five years old.

BSIERP FEAST 6 Year Project Wrap-up and Future Work

Delivery of the final report for the Forage Euphausiid Abundance in Space and Time (FEAST) model – part of The Bering Sea Project – concluded a 6 years multi-disciplinary project that produced 12 peer reviewed publications (several currently in review) and 31 presentations at international meetings. FEAST has been used to focus fieldwork and started a collaborative framework between field researchers and modelers, a process that has now been implemented at the AFSC across several Divisions, research teams as well as PMEL. FEAST will also be a centerpiece of this strategy developing an Integrated Ecosystem Assessment (IEA) for the Alaska region. NOAA's national IEA program (http://www.noaa.gov/iea) will include regular updates to FEAST, but will also use the model as a focus for collaborative fieldwork from disciplines from physics through biology, economics, and social sciences. As IEAs focus on delivering management results, this will serve as a direct conduit for bringing process-oriented fieldwork into the management arena via management strategy analyses, ecosystem indicator development and improved prediction capabilities both in the short and long term.

Alaska Marine Ecosystem Considerations
The Ecosystem Considerations report is produced annually for the North Pacific Fishery Management Council as part of the Stock Assessment and Fishery Evaluation (SAFE) report. The goal of the Ecosystem Considerations report 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. The ecosystems under consideration include the Arctic, the eastern Bering Sea, the Aleutian Islands, and the Gulf of Alaska.

The report includes additional new and updated sections, including the 2014 Eastern Bering Sea and Aleutian Islands Report Cards and ecosystem assessments. This year, the Hot Topics section includes topics from most ecosystems. In the Arctic, a large phytoplankton bloom observed beneath the sea ice suggests that primary production pathways may be changing in the Chukchi Sea. The hot topic for the eastern Bering Sea was the observed mortalities of two endangered short-tailed albatross in association with a longline fishing vessel. The hot topics for the Gulf of Alaska include the "warm blob" of record high sea surface temperatures that developed in early 2014 and persisted through the end of summer and the exceptionally high reproductive success across several seabird species in the western Gulf. The section in the report that describes ecosystem and management indicators includes updates to 44 individual contributions and presents 6 new contributions. These include contributions on temporal trends in Pacific sand lance as revealed by puffins; using ecosystem indicators to develop a Chinook salmon abundance index for southeast Alaska; an eastern Bering Sea pollock recruitment index that incorporates sea temperature and salmon; occurrence of mushy halibut syndrome; and two on groundfish condition in the Aleutian Islands and Gulf of Alaska.

Additional regional 2014 ecosystem highlights include the warm summer conditions in the eastern Bering Sea, including the early break up of sea ice, a reduced cold pool of bottom water, and warm surface air conditions. This was the first warm year following a sequence of seven cold years in the eastern Bering Sea. The Aleutian Islands also experienced warm temperatures; survey biomasses of most fish species increased compared with the last survey in 2012. In addition, a review of Gulf of Alaska indicators suggests that there was a shift in ecosystem state in 2006. The report is available online at the Ecosystem Considerations website at:
http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

For more information on the REEM program, contact Kerim Aydin (206) 526-4225

Fishery Interaction Team (FIT), SSMA, REFM
The Fishery Interaction Team (FIT), a part of the Status of Stocks and Multispecies Assessment Program, in the REFM Division, conducts studies to determine whether commercial fishing operations are capable of impacting the foraging success of Steller sea lions either through disturbance of prey schools or through direct competition for a common prey. The present research focus is on the three major groundfish prey of sea lions: walleye pollock, Pacific cod and Atka mackerel.

FIT investigates the potential effects of commercial fishing on sea lion prey in two ways. First, by conducting field studies to directly examine the impact of fishing on sea lion prey fields and to evaluate the efficacy of trawl exclusion zones. FIT research examines the hypothesis that large-scale commercial fisheries compete with sea lion populations by reducing the availability of prey in relatively localized areas. Since 2000 FIT has been conducting field studies to examine the impact of fishing on sea lion prey fields in all three major Alaska regions: the Gulf of Alaska, Bering Sea and Aleutian Islands. The second way that FIT investigates the potential effects of commercial fishing on sea lion prey is by studying fish distribution, behavior and life history at spatial scales relevant to sea lion foraging (tens of nautical miles). This scale is much smaller than the spatial scales at which groundfish population dynamics are usually studied and at which stocks are assessed. This information is needed to construct a localized, spatially-explicit model of sea lion prey field dynamics that can be used to predict spatial and temporal shifts in the distribution and abundance of sea lion prey and potential effects of fishing on these prey fields.

In late winter-early spring 2012, FIT staff conducted an Atka mackerel tag recovery cruise in the Aleutian Islands. Tagging experiments are being used to estimate abundance and movement of Atka mackerel between areas open and closed to the Atka mackerel fishery. In 2013, staff estimated local abundance and movement probability inside and outside trawl exclusion zones with an integrated model that uses maximum likelihood to estimate all parameters simultaneously. These studies are needed to improve our understanding of whether trawl exclusion zones are effective at maintaining sufficient quantities of Atka mackerel prey for Steller sea lions foraging in the Aleutian Islands. In addition, data from multiple years of tagging will provide independent estimates of mortality rates that can be used to improve Atka mackerel stock assessment.

FIT staff also contribute to SSMA research objectives. In 2013, FIT staff began a two-year study of spatial and temporal variability of walleye pollock fecundity. Stock assessments for the Gulf of Alaska and Eastern Bering Sea would be markedly improved by the incorporation of contemporary fecundity estimates under current stock levels and climate regimes. During the first year of this project, archived ovary samples from NMFS research cruises were examined to determine which fecundity assessment methodology is appropriate, given the condition and preservation medium of the samples. Second year work will be an analysis of the demographic and environmental drivers of spatial and temporal variability observed in the fecundity estimates.

FIT also supports giant Pacific octopus stock assessments. In 2013 FIT staff initiated a field project to continue development and testing of habitat pot gear for directed octopus research. The AFSC wishes to develop this gear to facilitate life history, tagging, and other studies in support of the federal stock assessment for the octopus species group. The main objective is to determine the scope, effort, and costs that would be associated with a species-specific biomass index survey for octopus, using habitat pot gear. The project provided a loan of habitat pot gear from AFSC to two selected vessels in Kodiak, Alaska. These vessels fish the habitat pot gear on their own schedule and experiment with different configurations, soak times, and fishing methods. The participating vessels will provide AFSC and ADF&G researchers with detailed catch data and periodic access to the catch for life history specimens. This project represents a partnership between AFSC, ADF&G, and industry. Industry partners are interested in assessing the potential of octopus as a possible commercial species. AFSC and ADF&G need to develop field methodologies that will support future management decisions for octopus.

FIT research supports SSMA and AFSC priorities to advance ecosystem based fishery management, in particular in the Arctic. FIT participated in a multi-disciplinary survey of the Chukchi Sea in 2013. The Chukchi Sea is important for marine mammals, marine birds, numerous fish species, invertebrates and subsistence hunters of northern Alaska. Ecosystem studies in the Chukchi Sea have been limited in spatial and temporal coverage. For this reason, there is not enough information to characterize the status of the main tropic levels (fish and invertebrates) that support the majority of the top predators in the Chukchi Sea. The goals for this project (lead by the North Slope Borough, NSB) will be to collect data on: (1) water mass properties; 2) species composition, distribution and abundance of marine invertebrates 3) species composition, distribution and abundance of fish; and 4) fish diet. This information will be collected by providing research vessels as a platform of opportunity to various researchers, including staff from SSMA FIT. SSMA FIT staff, in collaboration with NSB and RACE surveyed the distribution and abundance and collected samples of demersal fish and benthic invertebrates.

Another key task of FIT staff is to provide analyses, advice and support to the Regional Office and the NPFMC in the preparation of Biological Opinions and Environmental Impact Statements. Libby Logerwell (FIT lead) is the Point of Contact, coordinating responses not only from FIT, but from other programs in REFM and RACE.

For more information on the FIT program, contact Libby Logerwell or access the following web link: http://www.afsc.noaa.gov/REFM/Stocks/fit/FIT.htm

MARVLS (Maturity Assessment Reproductive Variability and Life Strategy) – REFM, RACE, ABL

The MARVLS group was created by reproductive fish biologists at the AFSC in 2013 to 1) share work accomplishments and challenges, 2) discuss literature, 3) increase collaboration, and 4) bring reproductive biology needs to the attention of the AFSC. Throughout 2014 this quickly bloomed into a national group including stock assessment and reproductive biologists from all five NMFS science centers and other agencies. In 2014, the MARVLS group at AFSC created a white paper that describes the AFSC's reproductive biology needs to support stock assessments and presents ideas for future sampling on surveys and fisheries. For the first time an AFSC activity plan was developed for fiscal year 2015 for reproductive work (at NMFS activity plans direct the work for the coming year). From November 6-8th MARVLS held their first workshop at the AFSC in Seattle. Biologists from around the country met to present research, ask each other questions, and share cutting edge technologies. The enthusiasm from this meeting inspired a session at the AFS meeting in Portland in 2015, chaired by Susanne Mcdermott and a second MARVLS workshop is tentatively planned for spring 2016.

For more information contact Susanne Mcdermott at 206-526-4417, Susanne.mcdermott@noaa.gov

C. By Species

1. Pacific Cod

a. Research

Coastal Age-0 Pacific Cod Survey– Gulf of Alaska - RACE FBEP
The Fisheries Behavioral Ecology Program conducts research on the early life-history habitat requirements of commercially important Alaskan fish and crab species. Age-0 stages of Pacific cod are often restricted to surface waters or coastal nursery habitats where they are not available to the stock assessment trawl survey. As such, there are few direct measures of age-0 abundance data to fit stock-recruitment models and examine recruitment processes at this important early life stage. The Newport laboratory has been conducting an annual summer beach seine and camera survey of two

coastal nurseries in Kodiak, AK across 16 sites since 2006. The survey samples are focused on age-0 and age-1 stages of juvenile Pacific cod, but also samples co-occurring juvenile walleye pollock and saffron cod. The Newport laboratory is examining this time-series and its efficacy of predicting year class strength locally (inshore) and more broadly (offshore) across the Gulf of Alaska. Models are also examining variance of sequential year class prediction as a function of habitat (e.g., structure, unstructured), spatial scale (within bay, across bay, regional), time of year (newly vs. late-settled fish) and environment (e.g., temperature, salinity). Mechanisms of such relationships will be examined using available seasonal and annual vital rate information for each species in each system

Vertical Availability of Pacific cod to Survey Bottom Trawls on the Eastern Bering Sea Shelf - RACE GAP

Pacific cod (*Gadus macrocephalus*) are an abundant and commercially valuable bottom fish in Alaska waters (REF). Bottom trawl (BT) surveys are the primary source of fishery independent data for informing stock assessment models about population trends of Pacific cod. Pacific cod occupy both demersal and pelagic habitats, so understanding their vertical availability to BT surveys is critical to the reliability of stock abundance estimates. Results from an archival tag study of Pacific cod suggested that BT survey abundance estimates were negatively biased because the tag data showed that 52.7% of cod resided above the functional height of the survey trawl headrope (2.5 m) making them unavailable to the survey BT gear. By increasing the functional headrope height to 7.0 m the total proportion of cod unavailable to the BT decreased to only 8.4%. Data from the archival tags were representative of the “average” Pacific cod living under natural and undisturbed conditions during daylight hours and did not record the behaviors of Pacific cod responding to external factors which may have affected their vertical distribution, such as presence of a trawl vessel or approaching trawl gear. Other limitations to the archival tag study were a low sample size (n=11) and narrow size range (60-81 cm) of Pacific cod.

There is good evidence that gadoids, in general, dive in response to vessels, trawls, or both. Acoustic echograms from a stationary buoy or from a second vessel in the path of an approaching trawler have shown diving responses for Pacific hake (*Merluccius productus*) and haddock (*Melanogrammus aeglefinus*). From the analysis of 20,000 individual acoustic targets collected by a free-floating buoy in the path of a BT vessel, it was concluded that a dive response in gadoids was triggered by the start-trawling event. In a detailed analysis of BT efficiency using a combination of trawl and acoustic data, it was estimated that walleye pollock (*Gadus chalcogrammus*) within 16 m of the seafloor were vertically herded into a survey trawl having a 2.5 m mean headrope height. The vertical availability of Pacific cod relative to bottom-trawling activity has not been studied and more detailed knowledge is needed in order to understand the precision and reliability of BT survey abundance estimates of Pacific cod used in stock assessment models.

To investigate vertical availability of Pacific cod to the BT, this study used a side-by-side BT experiment and analysis of acoustic data collected during the side-by-side experiment and from other BT surveys. The side-by-side experiment was used to test the null hypothesis that there was no difference in the vertical availability of Pacific cod between a low-opening (2.5 m) and a high-opening (7.0 m) BT. If results from the archival tag study are a typical representation of the vertical structure of Pacific cod from across the Bering Sea shelf, and if vertical availability of Pacific cod to the BT is unaffected by bottom-trawling activity (i.e., diving response), the expectation would be that the low-opening trawl would have approximately half the catch rate of Pacific cod compared to the high-opening trawl. Acoustic data from the experiment and from other historical BT survey tows were also analyzed to investigate whether the vertical structure of Pacific cod and their availability to the BT changed by area, during different times of day, or at different bottom depths. Abundance estimates from the acoustic analyses and the proportion of Pacific cod between the seafloor and 2.5 m and between 2.5 and 7.0 m were compared to corresponding BT abundance estimates to determine if vertical availability of Pacific cod to the BT varies during general survey operations conducted in different areas on the shelf and at different bottom depths. Possible mechanisms for non-varying vertical availability of Pacific cod to the BT survey are also discussed. For more information, contact Bob Lauth, e-mail: bob.lauth@noaa.gov

Local Adaptation in Puget Sound Pacific Cod (*Gadus macrocephalus*): Phenotypic and geneomic differentiation and the conservation of a depleted population in a warming environment

RAD sequencing and SNP discovery

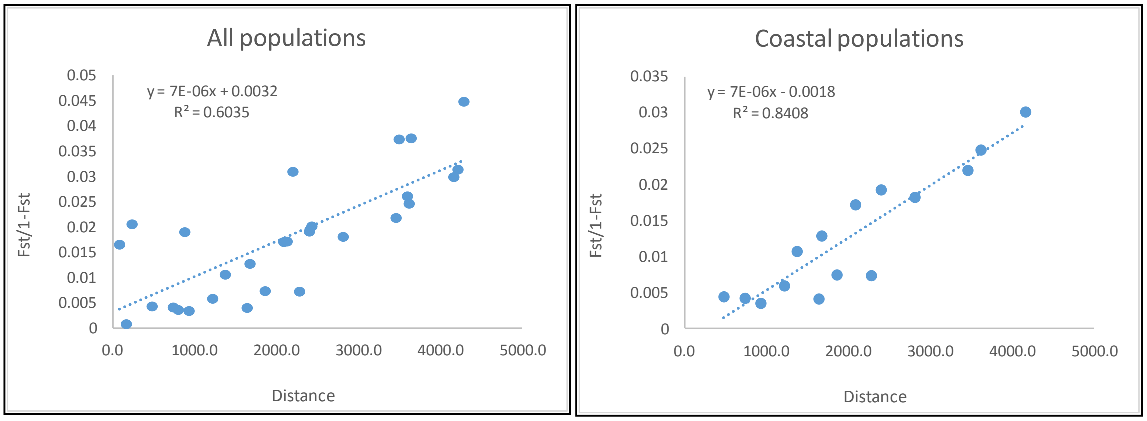
Fin clip samples were collected from spawning and pre-spawning aggregations of Pacific cod at eight locations across the northeastern Pacific Ocean Collection sites included the Washington State coast in 2005 (WC05); Salish Sea region in 2012 and 2013 (JDF12, SS12/13); Hecate Strait in 2004 (HS04); Prince William Sound in 2012 (PWS12); Kodiak Island in 2003 (KOD03), Unimak Pass in 2003 (UP03), and Adak Island in 2006 (AD06). DNA was extracted from up to 48 individuals from each sample (WC05: n = 48, JDF12: n = 21, SS12/13: n = 42, HS04: n = 48, PWS12: n = 48, KOD03: n = 48, UP03: n = 48, and AD06: n = 48) for a total of 351 fish. RAD-tagged libraries were submitted to the University of Oregon Genomics Core Facility (UOGCF) for next-generation DNA sequencing. Compressed data were downloaded and raw reads were quality filtered to minimize physical linkage and sequencing errors and to retain markers in Hardy-Weinberg equilibrium.

Population genetic analyses

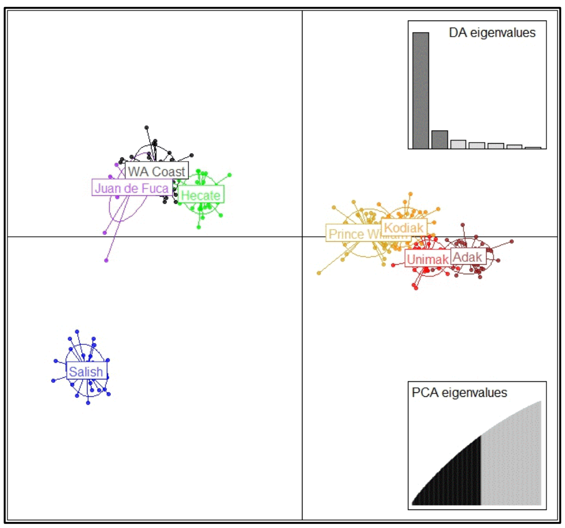
A total of 6,756 loci were retained after filtering. Locus-specific allele frequencies, expected heterozygosity (H_E); Hardy–Weinberg equilibrium (HWE) P-values; F_{IS}, F_{ST}, and F_{IT}; and population pairwise F_{ST} were estimated. Global F_{IS}, F_{ST} and F_{IT} were 0.011, 0.017, and 0.027, respectively. Pairwise F_{ST} values were largely significant, where red indicates significance at the P = 0.05 level:

	JDF12	SS12/13	WC05	HS04	PWS12	KOD03	UP03	AD06
JDF12	0							
SS12/13	0.0168	0						
WC05	0.0003	0.0196	0					
HS04	0.0035	0.0188	0.0034	0				
PWS12	0.0156	0.0310	0.0150	0.0095	0			
KOD03	0.0206	0.0372	0.0193	0.0132	0.0022	0		
UP03	0.0225	0.0369	0.0199	0.0138	0.0036	0.0011	0	
AD06	0.0297	0.0450	0.0276	0.0189	0.0065	0.0042	0.0035	0

Isolation by distance (IBD) was assessed among sampling locations. Results were significant both over all populations (P = 0.005) and just the coastal populations (P = 0.002), excluding JDF12 and SS12/13. Graphs are below:



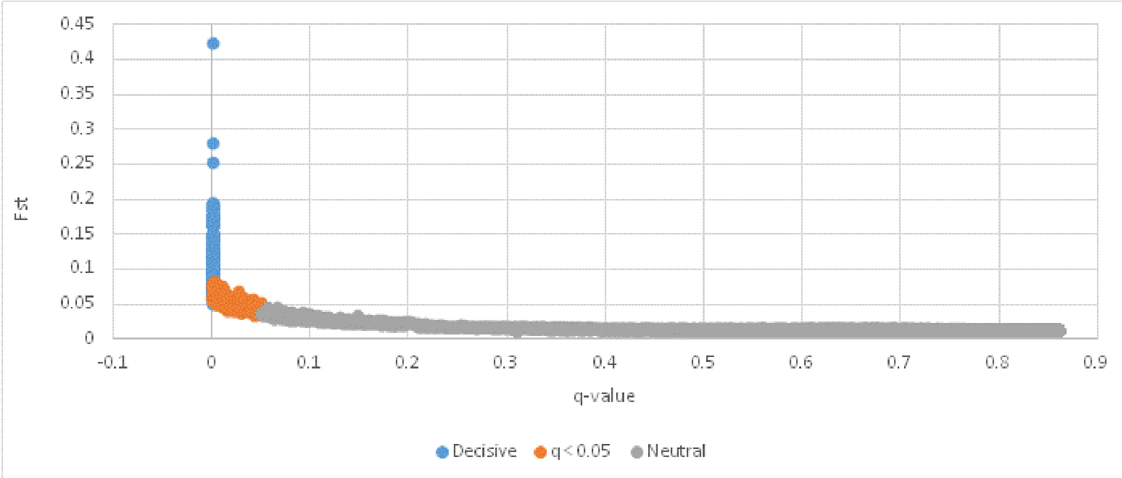
Several individual-based methods, including cluster analysis, PCA, DAPC, and PCoA, were performed. Results were supportive on a large scale of two clusters, with a north/south split between Hecate Straight and Prince William Sound. The Salish Sea sample, which was the only fjord-based population, also tended to separate from the remaining samples as also found in earlier research. PCA is below:



Based on the results from the clustering and multivariate analyses, analyses of molecular variance (AMOVA) were performed on three different population groupings. The first split the populations into two groups, representing the northern and southern populations of the sample range, including 1) PWS12, KOD03, UP03, and AD06 and 2) WC05, JDF12, HS04, and SS12/13. The second split the populations into three groups, representing the northern, southern, and fjord populations, including 1) PWS12, KOD03, UP03, and AD06; 2) WC05, JDF12, and HS04; and 3) SS12/13. The third reflected a potential split within the northern samples and included 1) PWS12 and KOD03; 2) UP03 and AD06; 3) WC05, JDF12, and HS04; and 4) SS12/13.

Individual assignment tests were performed to assess the power of the SNP dataset to correctly assign individuals to their population of origin. A Bayesian method unambiguously assigned 85.6% of individuals, whereas the frequencies-based method assigned 86.3%. The strong performance of SNPs in assignment tests forms the basis for a current proposal to the North Pacific Research Board to track cod movements using genetic tags (SNPs) rather than physical tags.

Finally, a test to identify putative candidate loci under selection was performed. A total of 365 loci exhibit at least “strong” evidence for selection ($q < 0.05$), with 218 of these loci listed as “decisively” (99% probability) under selection. The remaining 6,391 loci were deemed neutral:



Contributed by Lorenz Hauser (UW) and Mike Canino (FOCI)

Pacific cod Dispersal Patterns and Nursery Habitat Use in the Bering Sea - RACE FBEP
The Fisheries Behavioral Ecology program is collaborating with the RACE-Recruitment Processes Program, ABL-Ecosystem Monitoring and Assessment Program, and Oregon State University to examine the dispersal patterns of larval and juvenile Pacific cod and their use of coastal nursery habitats. In 2014, data analysis continued on the basin-wide distribution of age-0 Pacific cod, with future work examining spatial variation in diet and growth rates.

Dispersal patterns:
Pacific cod in the southeastern Bering Sea aggregate at discrete spawning locations but there is little information on patterns of larval dispersal and the relative contribution of specific spawning areas to nursery habitats. Otolith elemental variation can be used as a natural biomarker reflecting patterns of dispersal and mixing. Age-0 Pacific cod from two cohorts (2006 and 2008) were examined to address the following questions: (1) does size, age, and otolith chemistry vary among known capture locations; (2) can variation in elemental composition of the otolith cores (early larval signature) be used to infer the number of chemically distinct sources contributing to juvenile recruits in the Bering Sea; and (3) to what extent are juvenile collection locations represented by groups of fish with similar chemical histories throughout their early life history? Hierarchical cluster (HCA) and discriminant function analyses (DFA) were used to examine variation in otolith chemistry at discrete periods throughout the early life history. HCA identified five chemically distinct groups of larvae in the 2006 cohort and three groups in 2008; however, three sources accounted for 80-100% of the juveniles in each year. DFA of early larval signatures indicated that there were non-random spatial distributions of early larvae in both years, which may reflect interannual variation in regional oceanography. There was also a detectable and substantial level of coherence in chemical signatures within groups of fish throughout the early life history. The variation in elemental signatures throughout the early life history (hatch to capture) indicates that otolith chemical analysis could be an effective tool to further clarify larval sources and dispersal, identify juvenile nursery habitats, and estimate the contributions of juvenile nursery habitats to the adult population within the southeastern Bering Sea.

Pacific cod nursery habitats:
In four years of demersal beam trawling on the southeastern Bering Sea shelf at depths of 20 – 140 m, age-0 Pacific cod were most abundant along the Alaska Peninsula at depths to 50 m. In addition, one year of spatially intensive beam trawl sampling was conducted at depths of 5 – 30 m in a nearshore focal area along the central Alaska Peninsula. In this survey, age-0 cod were more abundant along the open coastline than they were in two coastal embayments, counter to patterns observed in the Gulf of Alaska. Demersal sampling of the shelf and nearshore focal area in 2012 was conducted synoptically with surveys of surface and subsurface waters over the continental shelf. As observed in earlier studies, age-0 cod were captured in pelagic waters over the middle and outer shelf, with maximum catches occurring over depths of 60-80 m. The similar size distributions of fish in coastal-demersal and shelf-surface habitats and the proximity of concentrations in the two habitat types suggests that habitat use in the Bering Sea occurs along a gradient from coastal to pelagic. While capture efficiencies may differ among trawl types, CPUE of age-0 cod in demersal waters along the Alaska Peninsula was 25 times that observed in the highest density pelagic-shelf habitats, demonstrating the importance of coastal nursery habitats in this population. Despite representing a much smaller habitat area, the cumulative contribution of coastal waters along the Alaska Peninsula appears to be markedly larger than those of offshore pelagic and demersal habitats.

b. Stock Assessment

BERING SEA AND ALEUTIAN ISLANDS - REFM
Bering Sea-This is the second year in which separate assessments and OFL/ABC specifications have been made for the Eastern Bering Sea and Aleutian Islands Status and catch specifications (t) of Pacific cod. In prior assessments both regions were combined. Biomass for each year corresponds to the projection given in the SAFE report issued in the preceding year. The OFL and ABC for 2015 and 2016 are those recommended by the Plan Team.

All survey and commercial data series on CPUE, catch at age, and catch at length were updated for the current assessment. The 2015 specifications were based on the same model used in 2011-2013 and is thus a rerun of last year's accepted model (Model 1, the same as the 2011 accepted model) with updated data files. However, the Plan Team expressed serious reservations about this model's poor retrospective performance and continued reliance on a fixed value of survey catchability that is no longer very credible. A different model was requested for next year.

Survey biomass was higher again in 2014, continuing an upward trend that began around 2006 and has been sustained by several good year classes. Spawning stock biomass is now estimated to be at the $B_{40\%}$ level, or 330,000 t and projected spawning biomass in 2015 is 409,000 t. The stock is therefore assigned to Tier 3a. The maximum 2015 ABC in this tier is 295,000 t, but the author and Team recommend that ABC be held at the 2014 level of 255,000 t to compensate for the poor retrospective behavior of the standard model. The Team recommends the same value for the preliminary 2016 ABC. The corresponding OFLs are 346,000 t and 389,000 t.

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

Aleutian Islands- For some years there has been concern that a disproportionate share of the BSAI

TAC was being taken from the Aleutians. The separate specification of EBS and AI OFL/ABC for the AI region, begun last year, is a response to that concern. Both age-structured (Tier 3) and survey-based (Tier 5) assessments have been considered for this area, but the working assessment is Tier 5 for Pacific cod in the Aleutian Islands.

In this region, the survey biomass index has been flat and below the long-term average for the last ten years. The present Tier 5 assessment was reviewed and two age-structured alternatives, both of which displayed poor retrospective performance and estimated biomass on the order of three times the trawl survey swept-area values, which is very high. Thus the Tier 5assessment was again used for 2015 (ABC=17,600 t, OFL=23,400 t) while continuing work on the age-structured models with the aim of moving this assessment up to Tier 3. This stock is not being subjected to overfishing.

GULF OF ALASKA

The 2014 stock assessment updated the fishery catch data series for 1997-2014 (projected for 2014 expected total year catch) and updated the 1997-2012 seasonal and gear-specific catch-at-length. The fishery length composition data were updated for 1997-2014 (preliminary for 2014).
The 2014 GOA Pacific cod assessment evaluated four models. Model 1 is identical to the final model configuration from 2013. Model 2 is identical to Model 1 but uses the recruitment variability multiplier. The two new models (S1a and S1b) also use the recruitment variability multiplier. In addition, these models treat the bottom trawl survey as a single source of data instead of splitting the sub 27 and 27-plus data for lengths and ages, include survey age data as conditional age-at-length data. Instead of incorporating 12 blocks of logistic survey selectivity, Model S1a uses 3 blocks of non-parametric survey selectivity and Model S1b uses cubic spline based survey selectivity.

According to Model S1a, $B_{40\%}$ for this stock is estimated to be 126,600 t, and projected spawning biomass in 2015 is 155,400 t. Estimated age-0 recruitment has been relatively strong since 2005 with the 2008 and 2012 year classes being the strongest over the entire time series since 1978. Stock abundance is expected to be stable in the near term. Models S1a and S1b were preferred over Models 1 and 2 because S1a and S1b used all the survey data instead of only the 27 plus portion. Model S1a was selected by the author as the preferred model primarily because it fit the data better than S1b. The Plan Team agreed with the author's recommendation to use Model S1a as the preferred model. Since 2015 spawning biomass is estimated to be greater than $B_{40\%}$, this stock is in Tier 3a. The estimates of $F_{35\%}$ and $F_{40\%}$ are 0.626 and 0.502, respectively.

The maximum permissible ABC estimate (117,200 t) is a 32% increase from the 2014 ABC. However, The Plan Team recommended that a value lower than the maximum permissible be used for 2015 for the following reasons: Additional age-composition data (2013 GOA bottom trawl survey) was provided after the assessment was completed and a comparative analysis was done by the author to evaluate the impact of these data on results. When incorporated, these data reduced the estimated abundance at age (~ 8% of biomass) relative to the selected model in the assessment without the 2013 survey age data. A retrospective pattern indicates a consistent downward adjustment for the recent years as more data are added. This suggests that estimates tend to be biased high. Therefore, as an intermediate step, the Team recommends that ABC for 2015 be set at a value half way between the maximum permissible ABC in the assessment and the 2014 ABC which is 102,850 t. The approximate F_{ABC} at this level is 0.441.

The stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. In the 2013 assessment, the random effects model (which is similar to the Kalman filter approach, and was recommended in the Survey Average working group report which was presented to the Plan Team in September 2013) was used to apportion the ABC to the geographic regions of the GOA to spread the harvest over the range of Pacific cod.

For further information, contact Dr. Grant Thompson at (541) 737-9318 (BSAI assessment) or Dr. Teresa A'Mar (GOA assessment) (206) 526-4068.

2. Walleye Pollock

a. Research

Seasonal Fish and Oceanographic Surveys to Link Fitness and Abundance of larval and Age-0 Walleye Pollock to Climate Change and Variability on Bering Sea Ecosystems - ABL
The eastern Bering Sea (EBS) shelf is a highly productive ecosystem, where atmospheric forcing, duration and extent of sea ice cover, and transport through ocean passes in the Aleutian Islands dominate the physical processes on the shelf. Inter-annual variability in these processes is believed to influence the distribution, feeding, growth, and recruitment of important fisheries stocks. Physical oceanographic features (e.g. sea surface temperature (SST), fronts, mixed layer depth) and lower trophic level dynamics (e.g. primary production, zooplankton prey availability) also are critical to understanding migration, distribution, and survival of forage fish. Research on the interaction between physical oceanography, plankton, and forage fish such as age-0 walleye pollock (*Gadus chalcogramma*) and juvenile Pacific salmon (*Oncorhynchus spp.*) has been conducted annually by Auke Bay Laboratories Ecosystem Monitoring and Assessment Program researchers in 2000–2012, with biennial surveys planned for 2014 and onward. These surveys are part of a joint effort with other AFSC/NOAA programs, including the Ecosystems and Fisheries Oceanography Coordinated Investigations (EcoFOCI), the RACE Division's Midwater Assessment and Conservation Engineering (MACE) Program, REEM program within REFM Division and ABL's Recruitment Energetics Coastal Assessment (RECA) Program to examine recruitment processes of walleye pollock. Larval and juvenile fish and oceanographic information are collected during spring followed by epipelagic trawl and midwater acoustic surveys during late summer/early fall (August-October). The surveys provide information to assess the abundance and condition of these fish during the larval to juvenile stages and at the end of their early marine growth period, prior to their first winter.

The few large-scale studies of walleye pollock in the Bering Sea have mainly focused on their distribution in relation to sea-ice conditions. In contrast, the seasonal time series on critical life stages of walleye pollock is presently the only shelf-wide data available to examine marine survival from spring to fall in the EBS. This time series provides integrated information on energy density, diet, abundance, and distribution in relation to changing ocean conditions. Such information coupled with an age-0 abundance index provides a unique opportunity to evaluate survival of juvenile walleye pollock relative to the reproductive output estimated from pollock stock assessments. For example, we have found a direct correlation ($r^2 = 0.73$) between the energy content of age-0 pollock (kJ/fish) and the number of age-1 recruits as predicted in the pollock stock assessment. These data are currently being considered for inclusion in the EBS pollock stock assessment to help understand climate and ecosystem variability on pollock recruitment in an effort reduce the uncertainty in recommended total allowable catch .

Our survey results have been used to document the rapidly changing marine conditions in the EBS during the past ten years and provide baselines and analogues for different climate regimes. The EBS SST's underwent large-scale warming from 2002-2005 followed by substantial cooling in 2006-2012. These shifts altered fisheries distributions and have the potential to affect the overall ecology of this region. Coincident with changes in the SST we have observed changes in the energy density (kJ/g) of age-0 pollock. For example, age-0 pollock energy density was low during 2002 to 2005, but significantly increased during 2006 to 2012. These data during the cool period suggest that age-0 pollock have maximized their energy content. Recent warming during 2014 and into 2015 indicate a switch back to lower energy content and higher overwinter mortality for age-0's. The extent of winter sea ice and its rate of retreat influences spring bloom dynamics, secondary production, and the spatial extent of the cold-water pool during the summer. Because most fish growth occurs during the summer, the winter and spring climatic forcing along with summer atmospheric and oceanographic conditions will dramatically affect fish distribution and production. For more information, contact Ed Farley at (907) 789-6085 or ed.farley@noaa.gov.

Salmon, Sea Temperature, and the Recruitment of Bering Sea Pollock - ABL
Chum salmon growth, pink salmon abundances, and sea temperature were used to predict the recruitment of pollock to age-1 in 2014. Chum salmon are incidentally captured in the commercial fisheries for walleye pollock (*Gadus chalcogrammus*) in the Bering Sea (Stram and Ianelli, 2009). We used the intra-annual growth in body weight of these immature and maturing age-4 chum salmon from the pollock fishery as a proxy for ocean productivity experienced by age-0 pollock on the eastern Bering Sea shelf. Adult pink salmon are predators and competitors of age-0 pollock (Coye et al., 2011). We modeled age-1 pollock recruitment estimates from 2001 to 2010 as a function of chum salmon growth, sea temperature, and total production of pink salmon in the Pacific Ocean and used the model parameters and biophysical indices from 2013 to predict age-1 pollock abundances in 2014. Estimates of age-1 pollock abundance were from the stock assessment. Pollock recruitment was highly variable within the 10-year time series, 2001-2010 (Figure 1). A slight alternating year pattern was observed in the time series, with higher recruitment in odd-numbered years at age-1 that corresponds with higher age-0 recruitment in even-numbered years. The lower age-0 recruitment in odd-years may be associated with higher abundances of adult pink salmon (a predator and competitor) in odd-years.

In a multiple regression model, age-1 pollock recruitment was negatively related to spring sea temperatures during their age-1 stage and positively related to chum salmon growth during the pollock age-0 stage ($R^2 = 0.77$; p –value = 0.012). Model residuals had an alternating year pattern. Therefore, we added pink salmon abundances (harvest and escapement) from Asia and North America to the model. The pink salmon abundance predictor variable had a significant negative coefficient and explained an additional 15% of the variation in age-1 pollock recruitment ($R^2 = 0.92$; p-value = 0.004) (Figure 1).

The model parameters (2001-2010) and biophysical indices (2013and 2014) were used to predict the recruitment of Bering Sea pollock in 2014. The 2013 and 2014 biophysical indices (chum salmon growth = 0.969 kg, spring sea temperature = 3.95°C, pink salmon = 493 million) produced a forecast of 6,569 million (3,837 standard error, c.v. = 0.22) age-1 pollock in 2014. The 2013 and 2014 biophysical indices indicated average ocean productivity (chum salmon growth), warm spring sea temperatures (less favorable), and above average predator abundances (pink salmon). These factors are expected to result in below average age-1 pollock recruitment in 2014.

For more information contact ellen.yasumiishi@noaa.gov.

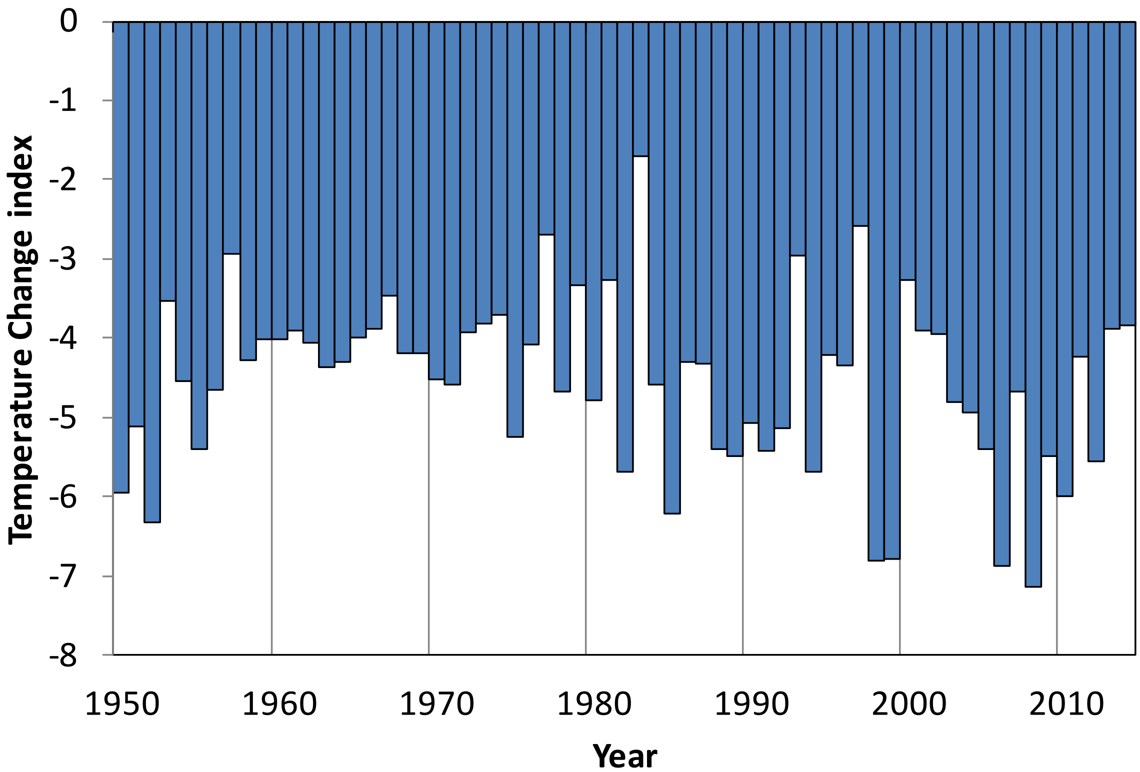


Figure 1: The Temperature Change index values from 1950 to 2014.

Walleye Pollock Ichthyoplankton Dynamics in the Bering Sea - RACE Recruitment Processes

The Eco-FOCI program conducts ongoing work to examine seasonal linkages between spring spawning areas, early summer distribution patterns, and late summer/early fall occurrences of walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea. We conduct annual surveys in spring to assess abundance of eggs and larvae of walleye pollock (*Theragra chalcogramma*) over the eastern Bering Sea shelf, and to describe larval fish assemblages after the late winter spawning season. Data are used to determine how physical and biological factors affect the transport, distribution, recruitment and survival of fish larvae. We have previously documented spatial shifts in the distribution of early life stages to the east (middle domain) under warmer-than-average conditions over the Bering Sea shelf.

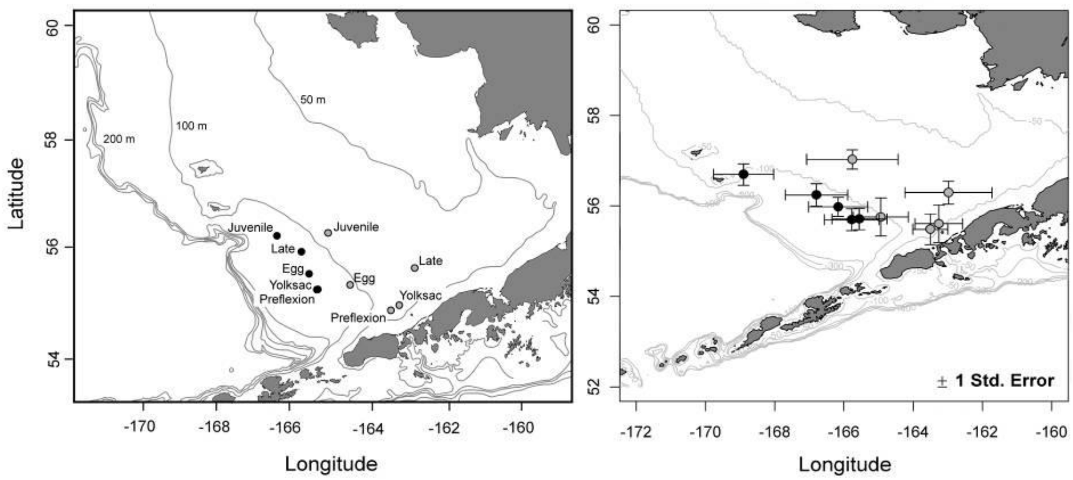


Figure 1. Early life stages of walleye pollock are distributed over the outer shelf during cold periods (filled circles) and over the middle shelf during warm years (open circles). Error bars denote 1 STD.

Most recently individual-based model of pollock early life stages was developed by coupling a hydrodynamic model (ROMS-NEP6) to a particle-tracking model with biology and behavior (TRACMASS). Simulation experiments were performed with the model to investigate the effect of wind on transport, ice presence on time of spawning, and water temperature on location of spawning. This modeling approach benefited from the ability to individually test mechanisms to quantitatively assess the impact of each on the distribution of pollock. Neither interannual variations in advection nor advances or delays in spawning time could adequately represent the observed differences in distribution between warm and cold years. Changes to spawning areas, particularly spatial contractions of spawning areas in cold years, resulted in modeled distributions that were most similar to observations (Figure 2). The location of spawning pollock in reference to cross-shelf circulation patterns is important in determining the distribution of eggs and larvae, warranting further study on the relationship between spawning adults and the physical environment.

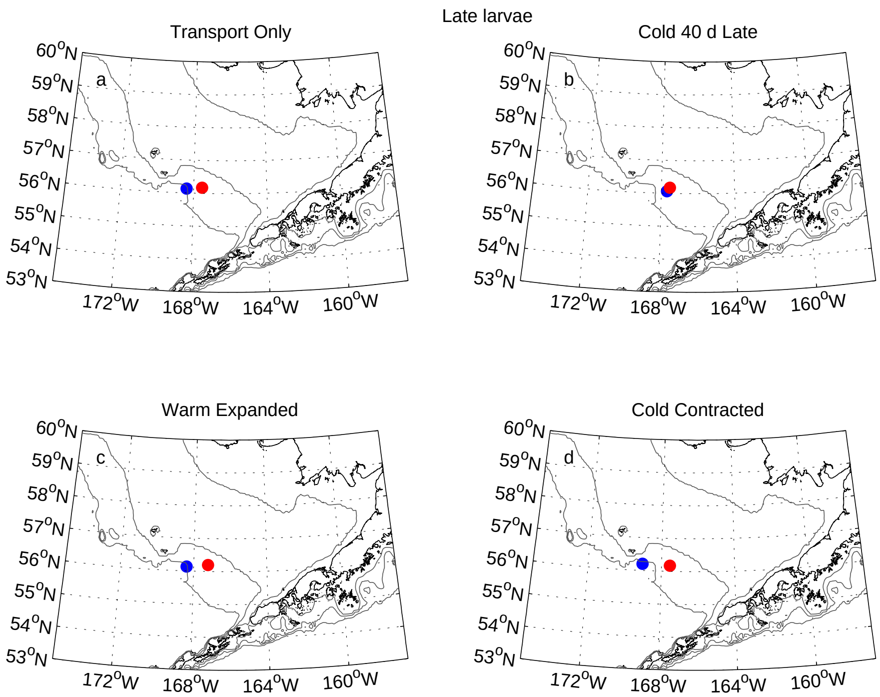


Figure 2. Modeled centers of gravity of pollock larvae (10-40 mm SL) in cold (blue) and warm (red) years for all model scenarios. Transport Only = interannual variations in advection, Cold 40 d Late = spawning delayed by 40 days under cold conditions, Warm Expanded = spawning distribution expanded eastward under warm conditions, Cold Contracted = spawning distribution contracted westward under cold conditions.

Work from seasonal surveys described above is also being utilized to examine variations in ichthyoplankton assemblages and relationships of larval fish communities with climate and oceanographic variables. Data show strong cross-shelf gradients delineating slope and shelf assemblages, an influence of water masses from the Gulf of Alaska on species composition, as well as differences in relative abundances between warm and cold periods. Understanding these variables can elucidate ecosystem-level responses to climate variability, and we are working toward understanding how community-level changes in ichthyoplankton composition reflect species-specific responses to climate change.

Walleye Pollock Age-0 Ecology in the Gulf of Alaska - RACE Recruitment Processes
Eco-FOCI conducts small-mesh midwater trawling cruises, mostly in alternate years, primarily to study the biology and ecology of small neritic forage fishes in the GOA. Due to their commercial importance, research focuses on juvenile walleye pollock. However, capelin and eulachon are studied because these species are poorly covered by groundfish assessments and because their importance in the GOA food web has been underscored by food web modeling.

Eco-FOCI research on these fishes focuses on the western GOA where walleye pollock are prevalent and during late summer and early autumn when age-0 fish are abundant. Our findings indicate that age-0 walleye pollock and capelin are broadly distributed across the shelf during late summer while older walleye pollock (age1+) and eulachon occur in association with elevated current velocity and krill population density. At this time of year, age-0 walleye pollock and capelin exhibit opposite cross-shelf gradients in body size: age-0 walleye pollock are largest near shore and capelin are largest offshore. Considerable overlap in food habits exists, with all species consuming copepods and krill, but capelin and age-0 walleye pollock respond differently to low krill availability. Eulachon are almost singularly dependent on krill, while walleye pollock are flexible zooplanktivores. For age-0 walleye pollock, the area off east Kodiak Island provides greater food-related benefits than the more heavily populated area downstream of Shelikof Strait due to higher krill abundance that is associated with greater oceanic influence (Figure 1).

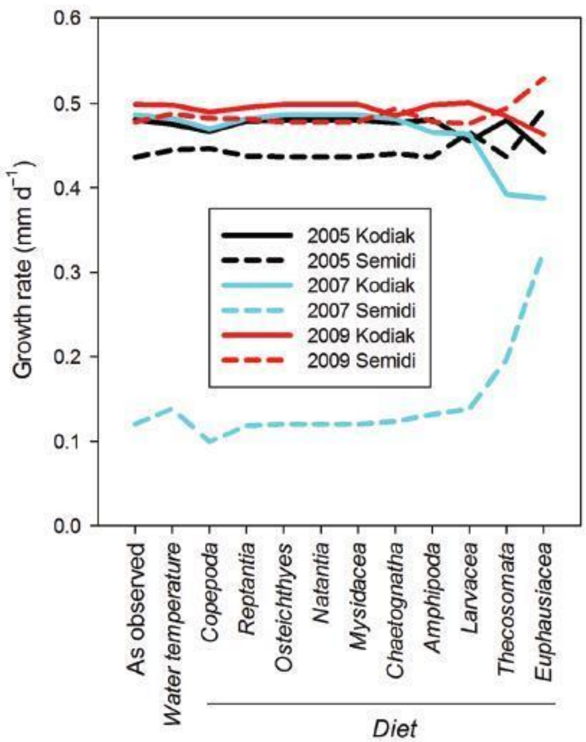


Figure 1. Bioenergetics model-based estimate of growth rate of a 70-mm SL age-0 walleye pollock with the observed weight-based diet at observed water temperatures. Lines show how growth rate estimates were affected when water temperature or the proportion of each dietary component was, in turn, equated between regions (Kodiak, Semidi).

We are investigating spatial and temporal variation in the size of prey consumed by these species to assess whether predator-prey size ratios govern energy flux through marine food webs (including commercially important fishes, protected marine mammals and seabirds). In the GOA, small neritic fishes support a predator-dominated coastal food web. Samples of "forage fishes" collected with small-mesh midwater trawls are dominated by juvenile walleye pollock (*Gadus chalcogrammus*), a gadid, and two smelts (Osmeridae): capelin *Mallotus villosus* and eulachon *Thaleichthys pacificus*. These fishes consume copepods, euphausiids, and other zooplankton depending on predator species and size, and they exhibit species-specific responses to meso-scale spatial and temporal variation in the zooplankton community that relates to bathymetry and hydrography. The availability of body-mass data from these studies should enable us to verify a previously published predator-prey mass relationship, but we will use a broader collection of GOA forage fishes; existing data will also enable us to examine the mass ratio among species over several years and meso-scale geographic regions for evidence that size ratios are resilient to geographic variation in habitat quality and yet sensitive to taxonomic change. Work on this project is being done in consultation with AFSC ecosystem modelers due to its relevance to the REEM Program's FEAST model.

Eco-FOCI has leveraged opportunities to collaborate with other programs that conduct studies that put our late-summer studies into a seasonal context to better understand the spatial-temporal interactions that determine year-class strength. Overwinter samples collected by other programs showed that the benefit to juvenile walleye pollock of rearing off Kodiak Island was restricted seasonally to late summer and only when fish are age-0 juveniles. For age-1 walleye pollock, otolith-based growth trajectories indicate that the growing season lasts almost 7 months with a 0.6 mm/day peak in growth during early July (Figure 2). Onset of the growing season corresponds with vernal lengthening of the photoperiod while autumnal slowing may reflect increased thermal stress.

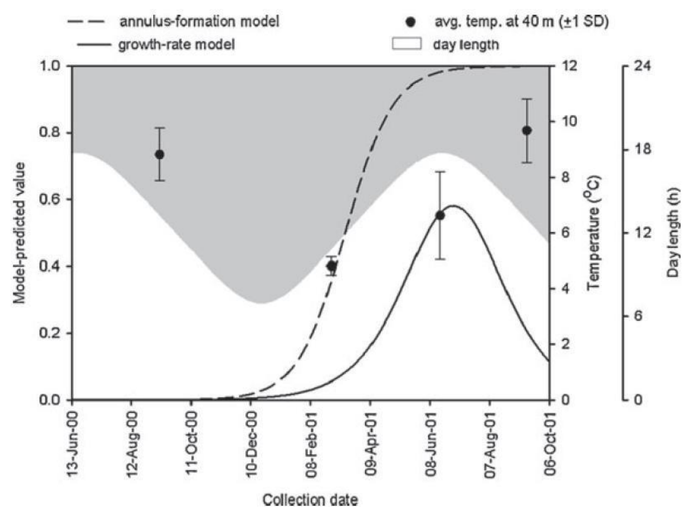


Figure 2. For age-0+ juvenile walleye pollock in the Gulf of Alaska, empirically derived models of first annulus formation and post-annulus growth rate are compared to time series of observed water temperature at 40-m depth and predicted day length.

We are investigating the use of otolith chemistry as a natural tag to identify GOA pollock nurseries, which are areas that contribute substantially to the adult population. This will provide geographic focus to subsequent research and management efforts to understand recruitment and protect essential nursery habitat. Preliminary results indicate that the chemical signature of age-0 juvenile walleye pollock otoliths differ between fish collected off Kodiak Island versus those from farther southwest in the Semidi Bank vicinity. It appears that the Kodiak fish have concentrations of strontium and barium isotopes in recently deposited otolith material that are relatively high and low, respectively. This work is being done in collaboration with experts in otolith elemental composition at Oregon State University and at the AFSC, REFM's Age and Growth Program.

The survey conducted by Eco-FOCI during August-October 2013 to survey neritic fish populations, zooplankton, and physical oceanography encompassed an unprecedented geographic extent in the

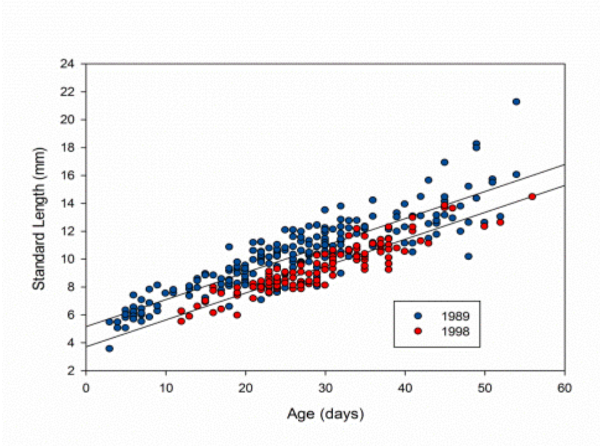
Gulf of Alaska from Unimak Pass to, but not including, Prince William Sound. Although the data and samples are currently being prepared for analysis and archival, preliminary results indicate that the 2013 year class of walleye pollock is likely to be large relative to those observed since 2000. This "early alert" has been included in presentations to the Plan Team on the Gulf of Alaska ecosystem status.

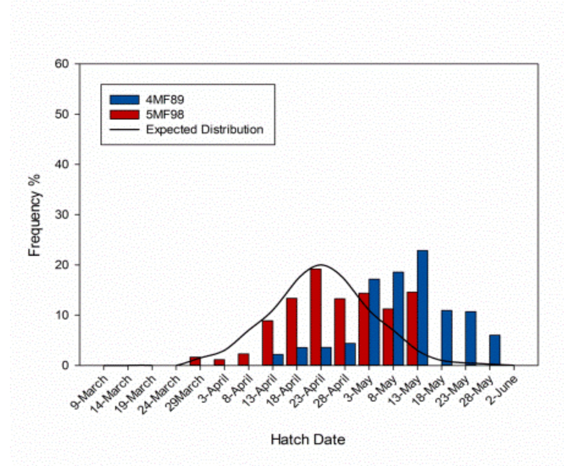
Recently, Eco-FOCI researchers have been tasked with examining the suitability of surface and midwater trawls to conduct assessment surveys of age-0 walleye pollock. Goals are threefold: to compare catch per unit effort of YOY among the gear types, to compare the size ranges of walleye pollock collected, and to compare the community assemblage of fishes collected across gear types. We have accomplished two activities. First, we conducted two paired-tow comparisons, each consisting of replicate tows, between the Cantrawl and the Stauffer (aka anchovy) trawl during the 2013 field season in Kalsin Bay, Kodiak Island, where the sea state was calm enough to safely change between the large Cantrawl doors and the small Stauffer-trawl doors. The catch and length data preliminarily indicate that size ranges of age-0 walleye pollock are similar between the two nets (50-80 mm SL), though greater numbers of the smallest sizes (<60 mm SL) were collected with the Stauffer trawl. Species catch compositions were similar, but absolute numbers collected and species biomass were greater using the Cantrawl. Second, we conducted a gear-trial experiment to investigate whether longer bridles compensate for overspreading of the Stauffer trawl when fished with over-size doors, which may be necessary for conducting paired-tow comparisons in the Bering Sea where the sea state will make door changes unsafe. Gear-trial results indicate that longer bridles mitigate overspreading, but their use resulted in a concerning large and rapid submergence of the trawl when initially deployed; interestingly, over-size doors only marginally decreased trawl mouth vertical opening and it is unknown if this was compensated for in terms of mouth area by increased horizontal spread. These activities were planned and executed in consultation with AFSC scientists in the EMA and MACE Programs.

Temperature Effects on Larval Walleye Pollock (*Gadus chalcogramma*) in the Gulf of Alaska (1987-2010) and Potential Consequences on Recruitment into the Population

Surveys conducted from 1987-2010 by Recruitment Processes/RACE Division in the western Gulf of Alaska sampled late larval walleye pollock (*Gadus chalcogrammus*) whose otoliths were used for age and growth analyses. These analyses revealed shifts in larval length ranges and hatch date distributions, as well as significant differences in growth equations. Temperatures close to and above mean temperatures in March, such as those seen in 1998, resulted in hatch date distributions ranging over a longer time period. Years with temperatures one standard deviation below the mean in March resulted in later hatch date distributions. Cold years such as 1989 resulted in increased survival of larval walleye pollock to the age-1 life stage, which was consistent with MACE/RACE Division acoustic stock assessments and the REFM 2013 SAFE document. Although the complex biological and environmental mechanisms resulting in survival of larval pollock toward their first year are not fully understood, a shift towards later hatching may have given the larvae an initial survival advantage since a delay in development would allow larval fish more time to become in sync with the production of their preferred prey items (copedites).

Contributed by Annette Dougherty , Tiffany Vance, Kathy Mier FOCI; Darin Jones MACE


Standard Length (mm)
Age (days)
1989
1998


4MF89
5MF98
Expected Distribution
Frequency %
Hatch Date
9-March
14-March
19-March
24-March
29March
3-April
8-April
13-April
18-April
23-April
28-April
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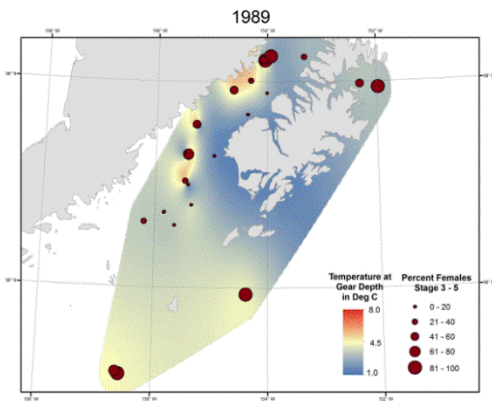
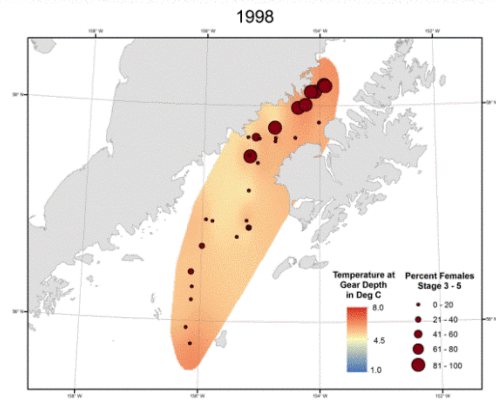
23-May
28-May
2-June


1989
Temperature at Gear Depth in Deg C
Percent Females Stage 3 - 5


1998
Temperature at Gear Depth in Deg C
Percent Females Stage 3 - 5

Climate Induced Changes in Survival and Biogeographic Range Expansion - RACE FBEP
The Fisheries Behavioral Ecology Program examines physiological processes that may control fish and crab responses as oceans warm. The geographic range of fish is largely determined by their thermal preferenda i.e., the temperature at which physiological processes are optimal. These physiological processes include a suite of cellular activities (e.g., biochemical homeostasis, energy conversion efficiency, muscle performance, etc.) but are manifested collectively in terms of growth and condition of the animal. In the Bering Sea and Gulf of Alaska, walleye pollock (*Gadus chalcogrammus*) and Pacific cod (*Gadus macrocephalus*) represent two of the most important fisheries in terms of landings and value and there is growing interest in whether walleye pollock will expand their range northward as temperatures continue to increase or whether resident Arctic species (Arctic cod (*Boreogadus saida*) and saffron cod (*Eleginus gracilis*)) will hold their 'thermal niche' in polar regions. The Newport laboratory is conducting a standardized series of laboratory experiments to quantify optimal thermal habitats for walleye pollock and other gadid populations in Alaska. Projected thermal habitats will be based on optimal growth and condition (energy storage) of juvenile gadids exposed to broad, temperature ranges in the laboratory (0 – 16ºC). Thus far, Arctic cod demonstrate a cold-water, stenothermic response in that there was relatively high growth at 0°C, limited growth beyond 5°C and negative impacts on condition, activity, growth and survival above 9°C. In contrast, juvenile walleye pollock and can grow 2 – 3 times faster than Arctic gadids across a relatively broad temperature range (i.e., 5 – 12°C), but cannot maintain growth at temperatures below 1°C.

Effects of Ocean Acidification on Walleye Pollock-RACE FBEP
The Fisheries Behavioral Ecology Program has been evaluating the impacts of ocean acidification on the early life history stages of these critical resource species. This includes three lines of research examining: a) the effects of OA on the growth of early life stages; and b) the effects of OA on behavioral responses of walleye pollock; and c) evaluation of the impact of OA on Alaskan communities.

Two papers present the results obtained in experiments with walleye pollock. Eggs, larvae, and juveniles of walleye pollock were reared at ambient and elevated CO_2 levels (to ~ 2100 µatm). In walleye pollock, there were no significant differences in hatch rates, larval or juvenile growth rates across multiple independent trials with each life stage. As observed in other species, hypercalcification of otoliths occurred in juvenile pollock held at high CO_2 levels. New experiments conducted with larval northern rock sole produced similar results, but suggest possible negative effects of OA in later larval stages as fish undergo metamorphosis. These results suggest a general resiliency of physiological capacity for growth in these species due to population acclimation or adaptation, while demonstrating the necessity of examining responses in multiple life stages.

Elevated CO_2 has been shown to disrupt sensory and behavioral responses in some tropical reef fish species, even when growth was not disrupted. In a separate experiment, we examined the behavioral responsiveness of juvenile walleye pollock, 58-97 mm, to prey scent cues under elevated CO_2. Baseline activity levels were not significantly different among CO_2 treatments, but fish reared at high CO_2 (> 800 µatm) were less likely to respond to injections of prey scent cues than fish reared at ambient CO_2 levels (~ 400 µatm). Future experiments are planned to examine the sensitivity of other behavioral responses in walleye pollock and provide species contrasts with Pacific cod. Such sensory and behavioral responses will be a significant determinant of how acidification affects the functioning of marine ecosystems.

The experimental information on the potential direct effects of OA on groundfishes and other animals harvested for commercial and subsistence purposes was incorporated into an evaluation of the vulnerability of Alaskan communities to Ocean Acidification. The project, led by researchers at NOAA's Pacific Marine Environmental Laboratory, used a variety of biological, economic, and social science data to evaluate the overall risk to each region of the state based on degree of the hazard, exposure to the hazard, and vulnerability to the hazard.

b. Stock Assessment

GULF OF ALASKA - REFM

The age-structured assessment model used for the GOA (west, central and western Yakutat areas) pollock assessment implemented several model changes relative to the model used for the 2013 assessment based on the 2012 CIE review, SSC, and Plan Team comments, and other considerations. The 2014 model implemented the following changes, each added to sequential models in a cumulative manner 1) starting the model in 1970 rather than 1964 and removing fishery length composition data for 1964-1971, 2) removing summer bottom trawl surveys in 1984 and 1987 and Shelikof Strait acoustic surveys in 1981-1991, 3) estimating summer bottom trawl catchability using a prior rather than fixing catchability and modeling selectivity with an asymptotic curve, 4) using a random walk for changing fishery selectivity parameters rather than time blocks, 5) using an age-specific mortality schedule with higher juvenile mortality, and 6) modeling age-1 and age-2 pollock in the winter acoustic surveys as separate indices. All composition data sets were "tuned" so that input sample sizes were close to the harmonic mean of effective sample size. Many of these changes were implemented following SSC and Plan Team recommendations, including age-specific mortality, removing older data that had been difficult to fit, and estimating summer bottom trawl catchability. To obtain an age-specific natural mortality schedule, an ensemble approach was used which averaged the results for six methods, three multispecies models and three "theoretical empirical" methods, and then rescaled the age-specific values so that natural mortality for fish greater than or equal to age 5 was equal to 0.3, the value of natural mortality used in previous pollock assessments. The Plan Team accepted the authors' recommended final model configuration that incorporated all of these changes. The authors also explored using a net selectivity correction for acoustic surveys calculated from field experiments using pocket nets. However, additional model exploration is needed before this model can be implemented. In addition, the method for making the net selectivity correction to the historical surveys needs to be reviewed prior to incorporating the revised estimates in the model.

This year's pollock assessment features the following new data: 1) 2013 total catch and catch-at-age from the fishery, 2) 2014 biomass and age composition from the Shelikof Strait acoustic survey, 3) 2013 age composition from the NMFS bottom trawl survey, 4) 2014 biomass from the ADFG crab/groundfish trawl survey, 5) total catch for all years was re-estimated from original sources, and 6) fishery catch at age and weight at age were re-estimated for 1975-1999. Model fits to fishery age composition data are adequate in most years. The largest residuals tended to be at ages 1-2 of 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 are similar to previous assessments, and general trends in survey time series are fit reasonably well. It is difficult for the age-structured model to fit the rapid increase in the Shelikof Strait acoustic survey and the NMFS survey in 2013. In contrast, the model expectation is close to the ADFG survey in 2013 and

2014. The fit to the age-1 and age-2 acoustic indices appeared adequate though variable. There is an indication of non-linearity in the fit to age-1 index that needs to be explored further.

The model estimate of spawning biomass in 2015 is 309,869 t, which is 39.7% of unfished spawning biomass (based on average post-1977 recruitment) which is just below the $B_{40\%}$ estimate of 312,000 t. The 2014 biomass estimate for Shelikof Strait is 842,138 t, which is a 6% decrease from 2013, but is still larger than any other biomass estimate in Shelikof Strait since 1985. The ADFG crab/groundfish survey 2014 biomass estimate is close to the 2013 estimate (2% lower). The estimated abundance of mature fish is projected to remain stable near $B_{40\%}$ or to increase over the next five years. From 2009-2013 the stock has shown an upward trend from 24% to 47% of unfished stock size, but declined to 38% of unfished stock size (spawning biomass) in 2014.

The assessment author recommended to reduce F_{ABC} from the maximum permissible using the "constant buffer" approach (first accepted in the 2001 GOA pollock assessment). Since the model projection of female spawning biomass in 2015 is below $B_{40\%}$, the W/C/WYAK Gulf of Alaska pollock stock is in Tier 3b. The projected 2015 age-3+ biomass estimate is 1,883,920 t (for the W/C/WYAK areas). Markov Chain Monte Carlo analysis indicated the probability of the stock being below $B_{20\%}$ will be negligible in the near future.

The 2015 ABC for pollock in the Gulf of Alaska west of 140° W lon. (W/C/WYAK) is 191,309 t. This is an increase of 14% from the 2014 ABC. In 2016, the ABC based on an adjusted $F_{40\%}$ harvest rate is 250,824 t. The OFL is 256,545 t in 2015 and 321,067 t in 2016. The 2015 Prince William Sound (PWS) GHL is 4,783 t (2.5% of the 2015 ABC of 191,309 t); the 2016 PWS GHL is 6,271 t (2.5% of the 2016 ABC of 250,824 t).

For pollock in southeast Alaska (East Yakutat and Southeastern areas), the ABC for both 2015 and 2016 is 12,625 t and the OFL for both 2015 and 2016 is 16,833 t. These recommendations are based on a Tier 5 assessment using the estimated biomass in 2015 and 2016 from a random effects model fit to the 1990- 2013 bottom trawl survey biomass estimates in Southeast Alaska, and are unchanged from last year. The Gulf of Alaska pollock stock is not being subjected to overfishing and is neither overfished nor approaching an overfished condition.

The assessment was updated to include the most recent data available for area apportionments within each season (Appendix C of the GOA pollock chapter) and are most likely to represent the current biomass distribution.

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

EASTERN BERING SEA - REFM

Spawning biomass in 2008 was at the lowest level since 1980, but has increased by 75% since then, with a 3% decrease projected for next year. The 2008 low was the result of extremely poor recruitments from the 2002-2005 year classes. Recent and projected increases are fueled by above average recruitment from the 2006 year class and very strong recruitment from the 2008 year class, along with reductions in average fishing mortality (ages 3-8) from 2009-2010. Spawning biomass is projected to be 39% and 32% above B_{MSY} in 2015 and 2016, respectively.

New data in the 2014 assessment included the following: 1) 2014 summer bottom trawl survey abundance at age. 2) 2014 summer acoustic-trawl survey abundance at age. 3) updated 2013 summer acoustic-trawl survey abundance at age (data using an age-length key from that survey replaced those in last year's assessment that were based on an age-length key from the bottom trawl survey). 4) updated catch at age and average weight at age from the 2013 fishery. 5) updated total catch, including a preliminary value for 2014. There were no changes in the authors' recommended assessment model.

The SSC has determined that EBS pollock qualifies for management under Tier 1 because there are reliable estimates both for B_{MSY} and the probability density function for F_{MSY}. The Plan Team concurred with the SSC's conclusion that the Tier 1 reference points continue to be reliably estimated. The updated estimate of B_{MSY} from the present assessment is 1.948 million t, down 8% from last year's estimate of 2.122 million t. Projected spawning biomass for 2015 is 2.714 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 0.512, up 9% from last year's value of 0.469. The harvest ratio of 0.512 is multiplied by the geometric mean of the projected fishable biomass for 2015 (5.669 million t) to obtain the maximum permissible ABC for 2015, which is 2.9 million t, up 15% and 19% from the maximum permissible ABCs for 2014 and 2015 projected in last year's assessment.

However, as with other recent EBS pollock assessments, the authors recommend setting ABCs well below the maximum permissible levels. They list three reasons for doing so in the SAFE chapter: 1) A single year class (2008) accounts for more than half of the spawning biomass. 2) In 2014, the fleet achieved good catch rates and low salmon bycatch with an ABC far below the maximum permissible level. 3) Current low roe recovery rates may be indicative of reduced reproductive potential. During the period 2010-2013 the ABC recommendations were based on the most recent 5-year average fishing mortality rate. This year, the authors instead based their 2015 and 2016 ABC recommendations on a "replacement yield" strategy, giving a value of 1.35 million t for both years. The Team agreed that an ABC well below the maximum permissible value is appropriate, but felt that stock conditions had improved sufficiently that an increase in the ABC harvest rate was appropriate. Specifically, basing the 2015 and 2016 ABCs on the harvest rate associated with Tier 3, the stock's Tier 1 classification notwithstanding, giving values of 1.637 million t and 1.554 million t, respectively.

The OFL harvest ratio under Tier 1a is 0.587, 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 2015 determines the OFL for 2015, which is 3.33 million t. The current projection for OFL in 2016 given a 2015 catch equal to the Team's recommended ABC is 3.319 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 - REFM

The new data in the model consist of updated catch information and the addition of 2014 Aleutian Islands survey data. There was one minor change in the assessment methodology, the inclusion of age one pollock in the model. This year's assessment estimates that spawning biomass reached a minimum level of about $B_{29\%}$ in 1999 and then has generally increased, with a projected value of $B_{34\%}$ for 2015. The increase in spawning biomass since 1999 has resulted more from a marked decrease in harvest than from good recruitment, as there have been no above-average year classes spawned since 1989. Spawning biomass for 2015 is projected to be 70,012 t.

The SSC has determined that this stock qualifies for management under Tier 3and last year's model was used for evaluating stock status and recommending ABC. The model estimates $B_{40\%}$ at a value of 83,042 t, placing the AI pollock stock in sub-tier "b" of Tier 3. The model estimates the values of $F_{35\%}$ as 0.40 and $F_{40\%}$ as 0.31. Under Tier 3b, with the adjusted value of $F_{40\%}$=0.25, the maximum permissible ABC is 29,659 t for 2015. The Team recommended setting the 2015 ABC at this level. Following the Tier 3b formula with the adjusted value of $F_{35\%}$=0.32, OFL for 2015 is 36,005 t. If the 2015 catch is 1,237 t (i.e., equal to the five year average for 2009-2013), the 2016 maximum permissible ABC would be 31,900 t and the 2016 OFL would be 38,699 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 District
A Bogoslof pollock acoustic-trawl survey was conducted in 2014. The 2014 Bogoslof pollock acoustictrawl survey resulted in a biomass estimate of 112,070 t, which was an increase from the 2012 estimate of 67,100 t. The 2012 estimate was the lowest since the survey began in 1988. Survey biomass estimates since 2000 have all been lower than estimates prior to 2000, ranging from a low of 67,063 t in 2012 to a high of 301,000 t in 2000.

The SSC has determined that this stock qualifies for management under Tier 5. The maximum permissible ABC value for 2014 would be 15,900 t (assuming M = 0.2 and F_{ABC} = 0.75 x M = 0.15): ABC = B_{2014} x M x 0.75 = 106,000 x 0.2 x 0.75 = 15,900 t. The projected ABC for 2016 was also set at 15,900 t. Following the Tier 5 formula with M=0.20, OFL for 2015 is 21,200 t. The OFL for 2016 was set at the same level. The walleye pollock stock in the Bogoslof district is not being subjected to overfishing. It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

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

3. Dusky Rockfish

a. Stock Assessment

GULF OF ALASKA - 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 2014, a projection model was used with updated catch data. For the 2015 GOA fishery, a maximum allowable ABC for dusky rockfish was set at 5,109 t. This ABC is a 7% decrease from the 2014 ABC of 5,486 t. The stock is not overfished, nor is it approaching overfishing status.

For more information, contact Chris Lunsford, ABL, at (907) 789-6008 or chris.lunsford@noaa.gov.

4. Slope Rockfish

a. Research

Long-term Survival and Healing of a Deep-water Rockfish After Barotrauma and Subsequent Recompression in Pressurized Tanks - ABL

Movement patterns and stock structure of deep-water rockfish (*Sebastes spp*.) are difficult to study because rockfish are physoclystic, i.e. their gas bladders are closed off from the gut, and so they often suffer internal injuries from rapid, internal air expansion when caught. From 2011-2013, we tagged and released 184 blackspotted rockfish fish at ~150-225 m and 60 others were recompressed in portable pressure tanks and slowly brought back to surface pressure. All fish exhibited some signs of barotrauma including exophthalmia ("pop-eye") (89%), everted esophagus (95%), subcutaneous emphysema (gas bubbles under the skin) (57%), ocular emphysema (air bubble under the cornea) (83%), and emphysema in the pharyngeal-cleithral membrane (99%). After re-pressurization in the tanks, the great majority of fish no longer had any external signs of barotrauma.

In 2011, 50% of fish recompressed survived long term in the lab, 60% in 2012, and 78% in 2013. This increase in survival was likely related to experience with tanks and a longer decompression schedule in 2013. When using pressurized tanks to recompress fish, it is important that adequate time is taken to depressurize fish back to surface pressure. This is species specific. For blackspotted rockfish, acute observations of fish health post-barotrauma would not be adequate. Mortalities typically occurred while fish were being recompressed (70% within 2-4 days) but 30% of mortalities occurred afterward; 17% were within a week after recompression and 13% died 3-12 months later. Of fish that survived long-term in the lab (61.6%), 41% had evidence of a previously ruptured swim bladder. This indicates that gas was released into the body cavity through ruptures in other tissues. For example, following the path of least resistance, it has been reported that gas often first fills the orbital space behind the eye. Overall, mortality increased with increasing fish length. This may be related to changes in body morphology with growth.

In 2013 a cage equipped with video capability was used to release fish at 75 m. Fish were all oriented downward when released and were capable of swimming: 33% drifted away in the current and 67% swam away. In March, 2014 a fish was recaptured in the Pacific halibut fishery 59 km away from the release location a year and a half later, demonstrating that fish can survive in the wild post capture. Since all dissected fish were immature and caught and released in inside waters, they may be less likely to be intersected by fisheries. It is possible that recaptures will increase in the coming years as fish mature. A paper is being prepared for publication.

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

Deepwater Rockfish Tagging – ABL

In the Gulf of Alaska, Aleutian Islands, and Bering Sea, commercial rockfish (*Sebastes* spp.) landings have exceeded 43,500 t annually since 2002. A large percentage of these landings are attributed to Pacific ocean perch (POP) *S. alutus*, northern rockfish *S. polyspinis*, dusky rockfish *S. variabilis*, rougheye rockfish *S. aleutianus*, and shortraker rockfish *S. borealis*. These species occupy deep water on the continental shelf and slope and are taken in directed fisheries as well as in non-directed fisheries as bycatch. Both fixed and mobile gears, including longlines and bottom trawls, are used to catch rockfish in these fisheries. Despite the value of these fisheries, many life history and biological characteristics of the fish remain poorly understood by scientists and managers.

Since rockfish are physoclystic, i.e., their swim bladder is not directly connected with their gut, rockfish often suffer barotrauma injuries when brought up from depth. These injuries occur because rockfish cannot rapidly eliminate expanding gas from internal spaces during ascent. The gas expansion can cause everted stomachs, exophthalmia (pop-eye), and damage to internal tissues. Because of these barotrauma-induced injuries, post-release survival of many rockfish species has previously been assumed to be negligible and large-scale deep-water rockfish tagging efforts have therefore not been undertaken. Without tagging studies, research avenues that elucidate rockfish movement and migration patterns, behavior, and stock structure are limited. However, recent research at the Alaska Fisheries Science Center in Juneau, Alaska, and elsewhere, has demonstrated that deep-water rockfish can survive barotrauma injuries if the fish are recompressed soon after capture. If substantial numbers of rockfish were captured, tagged, and released quickly, information on movement and stock structure could be generated from subsequent tag recoveries. This information is important for understanding rockfish biology and ultimately for managing rockfish stocks. Furthermore, if this method of tagging is successful, this protocol could be used to study not only deep-water rockfish in Alaska, but other physoclystic fish in oceans worldwide.

The objective of this project is to investigate vertical and horizontal movement patterns, distribution, stock structure, and life history parameters of three deep-water rockfish species — Pacific ocean perch, northern rockfish, and dusky rockfish. We propose to trawl in the Gulf of Alaska near Kodiak Island with a livebox (aquarium codend) attached to a midwater trawl. Rockfish caught in the trawl will pass into the livebox and will be shunted into a calm, water-filled compartment. This compartment will protect the fish from being crushed while the net is pulled through the water and while the livebox is retrieved onto the deck of the vessel. Once on deck, rockfish will be removed from the livebox, quickly measured and tagged. Tagged fish will be loaded into a release cage, lowered to a depth at which they will be sufficiently recompressed and negatively buoyant, approximately 80 m, and the fish will be released at depth. All fish will be tagged with numbered external spaghetti tags and a subset will be tagged with either archival tags or pop-off satellite tags. Data for spaghetti- and archival-tagged fish will be recovered within the fishery, whereas, data from satellite-tagged fish will be uploaded autonomously after a preprogrammed pop-off date. This work will be completed in areas that receive substantial commercial fishing effort near Kodiak Island. By tagging in these areas, the probability of recovering spaghetti and archival tags, and thus data, will be maximized.

In 2015, we plan to tag up to 5,000 rockfish with spaghetti tags. Tag recovery data will allow us to describe rockfish movements between release and recapture locations and will elucidate distribution and migration patterns. This information is critical for understanding stock composition and habitat requirements. Additionally, spaghetti tag recoveries will allow for growth calculations which are important for stock assessments. Pop-off satellite and archival tag recoveries will provide detailed information, including time and date, temperature, depth, and location, thereby allowing a thorough description of vertical and horizontal movements and greatly enhancing our ability to describe rockfish distribution and habitat utilization.

For more information, contact Patrick Malecha at (907) 789-6415 or pat.malecha@noaa.gov.

Predicting the Abundance and Distribution of Pacific Ocean Perch in the Aleutian Islands - RACE GAP

Work was continued examining which habitat characteristics best predict the abundance of POP in the Aleutian Islands. POP have been observed living in association with a variety of epibenthic invertebrates during juvenile and adult life stages, and adult POP have been observed schooling over sea whip forests, and juvenile abundance has been correlated to total sponge and coral biomass. We used generalized additive models (GAMs) to predict juvenile and adult *S. alutus* distribution and conditional abundance in Aleutian Islands bottom trawl surveys from both the occurrence of biogenic structures (i.e., sponges, corals, and bryozoans) and selected environmental parameters (e.g., depth, temperature, local slope, and tidal velocity). For our analyses we separated sponges into distinct morphological groups using gross shapes like vase, fan, or ball.

Based on the six surveys conducted between 1997 and 2010, GAMs explained 25-28% of the observed deviance in juvenile and adult distribution and 40-44% of the deviance in conditional abundance. The GAMs predicted increased probability of encountering *S. alutus* as well as increasing abundance over the study period consistent with the increasing biomass trend observed for *S. alutus* in the Aleutian Islands since 1997; the greatest predicted increases were in the major Aleutian passes. Our results indicate that the probability of encountering both adult and juvenile *S. alutus* increased in the presence of fan and ball shaped sponges over moderate slopes within life-stage-specific depth ranges and decreased in the presence of strong currents. Longitude and depth had the greatest explanatory power in the GAMs, but combinations of epibenthic invertebrates, sponge morpho-groups, local slope, and tidal current also contributed significantly to predictions of *S. alutus* distribution and conditional abundance. Among other findings, this research suggests that some types of upright sponges and epibenthic invertebrates likely support higher abundances of *S. alutus* juveniles and adults, possibly indicating that these structures provide a form of refuge for this species. For further information contact Ned Laman (Ned.Laman@noaa.gov).

Rockfish Reproductive Studies - RACE GAP

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. Preliminary 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 2012 and additional samples will be collected through at least the 2015 reproductive season.

Rougheye and Blackspotted Rockfish-GAP Kodiak

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. Preliminary results from this study indicate age and length at 50% maturity for rougheye rockfish are 15.5 years and 43.9 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. Preliminary results indicate length at 50% maturity for blackspotted rockfish is 44.3 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.

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

Shortraker rockfish (in collaboration with Charles Hutchinson, AFSC age and growth laboratory)

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 49.5 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.

Blackspotted and rougheye rockfish field identification project – ABL in collaboration with RACE

There is difficulty in accurate at-sea field identification between the two species. Previous studies have found that, when compared to genetic identifications, field scientists had a misidentification rate of approximately 46% (samples in eastern GOA near Yakutat), while the expert (Jay Orr) had misidentification rates of 9%. In addition, if differences in growth and maturity exist, one species may be at greater risk to overfishing than the other.

In response to these concerns, special projects were initiated during the 2009 and 2013 GOA bottom trawl survey. The goals of these projects were to collect relevant biological and genetic data to improve at-sea identification, adjust the species-specific biomass estimates based on misidentification rates, and examine differences in life history characteristics between the two species. Field scientists collected length, weight, and muscle tissue (2009) or fin clips (2013) from most rougheye and blackspotted rockfish sampled for otoliths. Additionally, most of the unidentified rougheye/blackspotted specimens were sampled for genetics.

For the 2009 survey, 895 fish were genetically identified in the lab. Overall (not including hybrids or fish unidentified in the field) these results show a 23% misidentification rate. This is a substantial improvement over previous studies. Of the genetically identified rougheye rockfish (n=307), only 6% were incorrectly identified in the field as blackspotted rockfish and 1% were unidentified. Of the genetically identified blackspotted rockfish (n=577), 31% were incorrectly identified in the field as rougheye rockfish and 3% were unidentified. Hybrids existed between the two species (n=11). These hybrids were mostly identified as rougheye rockfish in the field (82 %).
Trawl survey data were adjusted for species misidentification rates to compute species specific biomass estimates and age compositions. For the 2009 survey the adjusted data indicated that 47%, 51%, and 2% of the estimated biomass was comprised of rougheye, blackspotted, and hybrids, respectively. Prior to this adjustment the estimated biomass was 63% rougheye and 37% blackspotted rockfish.

Data from the 2013 trawl survey have been analyzed for species misidentification rates, but ages have not been determined. Preliminary analysis of the 2013 survey data show that there have been some continued improvements in species identification with overall misidentification rates of 13% compared to 23% from the 2009 survey. The identification of blackspotted rockfish improved substantially compared to 2009. Of the genetically identified blackspotted rockfish (n=424), only 15% were incorrectly identified in the field as rougheye rockfish compared to 31% in 2009. The identification of rougheye rockfish somewhat worsened compared to 2009. Of the genetically identified rougheye rockfish (n=429), 11% were incorrectly identified in the field as rougheye rockfish compared to 6% in 2009.

Trawl survey age compositions for 2009 corrected for misidentification rates indicated that the average age was 20 years for blackspotted rockfish and 15 years for rougheye rockfish (see figure below). The majority of the age composition for rougheye rockfish was less than 20 years old whereas blackspotted rockfish had a more uniform age composition. The 2009 genetically identified and aged fish (n=878, hybrids=11) found differences in growth between the two species. Rougheye rockfish grow faster and typically attain a greater maximum size than blackspotted rockfish (Figure 1).

The estimated Von Bertalanffy growth parameters for the two species based on the samples taken in the 2009 bottom trawl survey were as follows (Figure 2):

	Rougheye	Blackspotted
Sample Size	298	570
L_∞ (mm)	536	519
κ	0.109	0.065
t_0	0.250	0.250

In the future, we would like to extend this sampling to commercial fisheries as a special project requested of the Observer Program. When combined with accurate species-specific catch and survey data, such information will help determine the utility of a split-species complex model or separate species models for examining if one species may be at greater risk to overfishing. At present, the area-specific harvest rates for RE/BS rockfish have been on average low and catches have consisted of approximately half the ABC in recent years.

For further information please contact Jon Heifetz (907) 789-6054 or jon.heifetz@noaa.gov

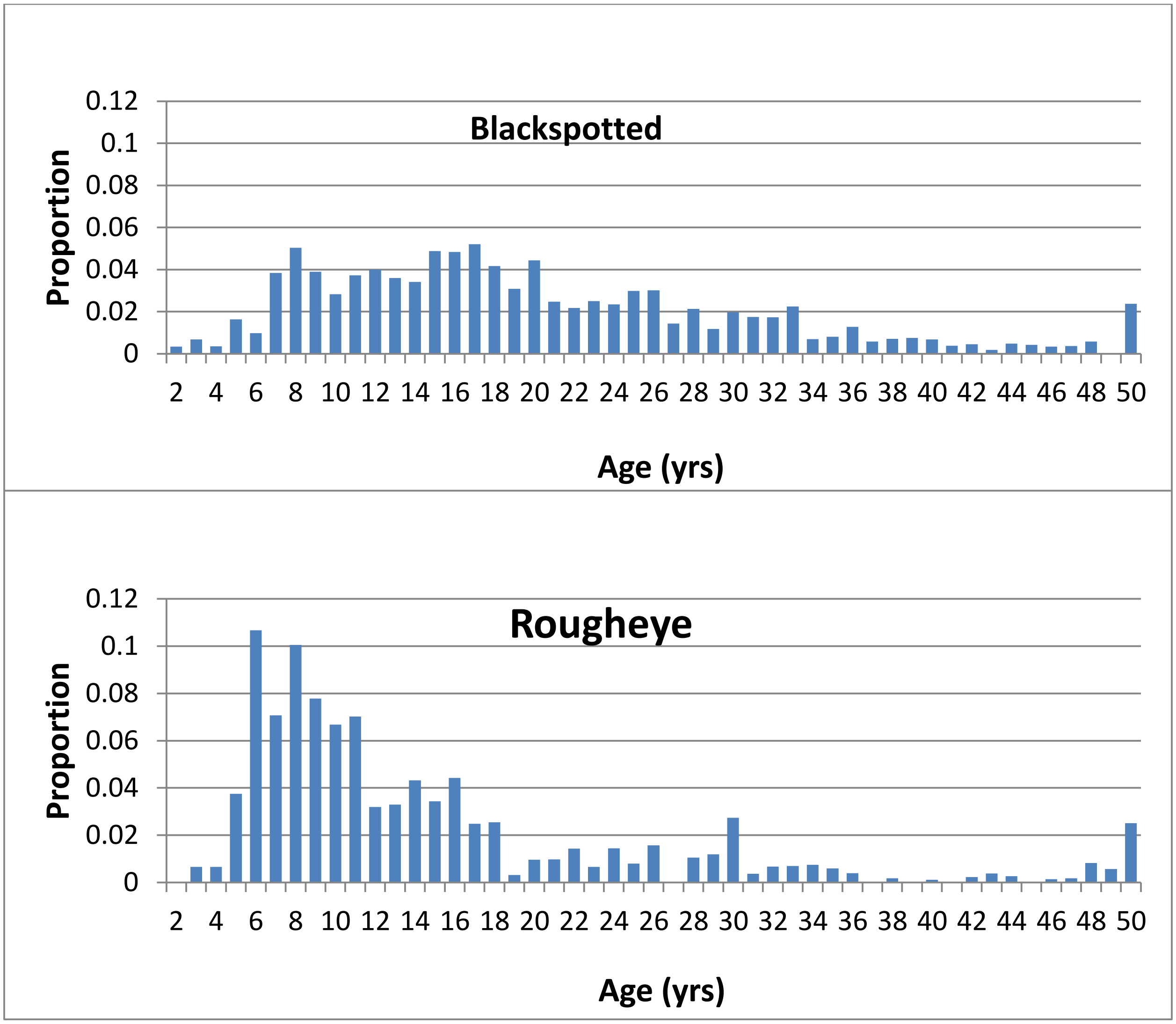


Figure 10. Age composition of rougheye and blackspotted rockfish from the 2009 trawl survey.

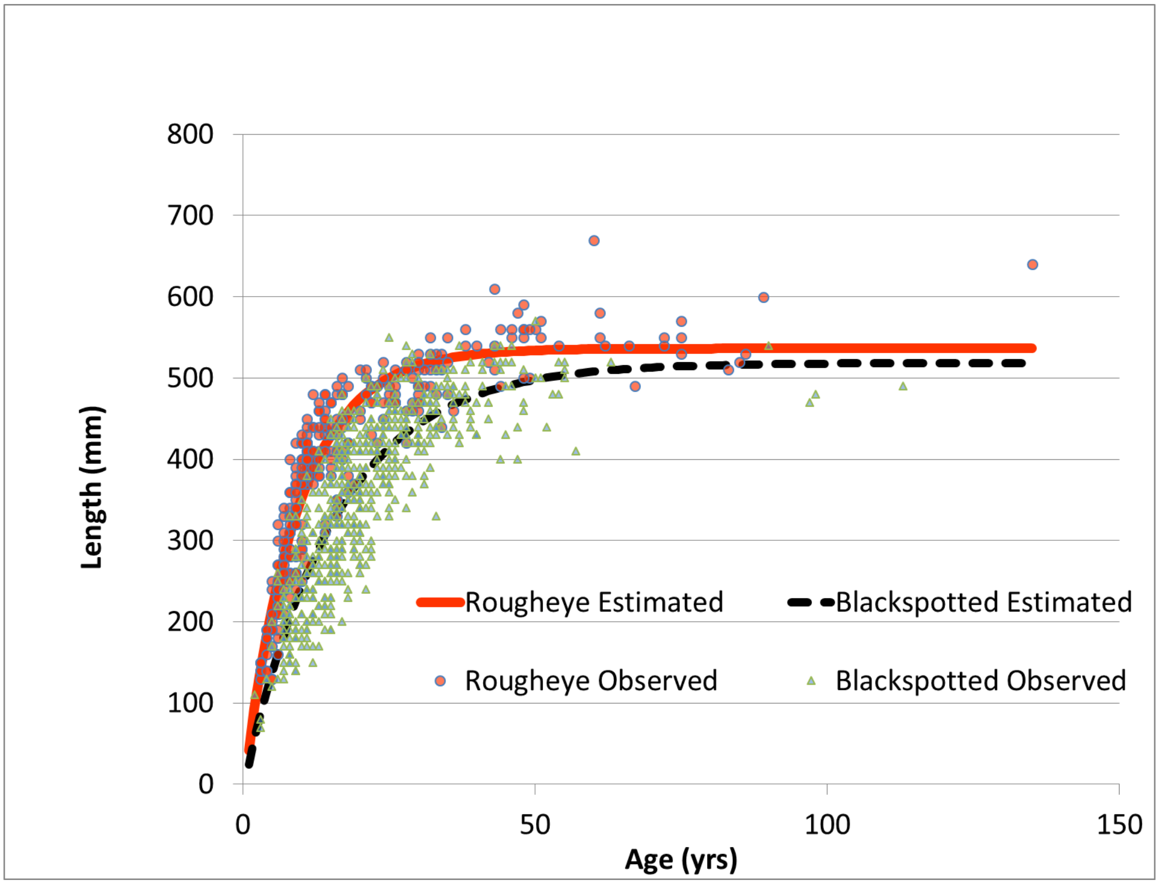


Figure 2. Estimated Von Bertalanffy growth curves for genetically identified rougheye and blackspotted rockfish from the 2009 trawl survey.

b. Stock Assessment

Pacific Ocean Perch (POP)

BERING SEA AND ALEUTIAN ISLANDS - REFM
Pacific ocean perch (POP) assessments are conducted on a two-year cycle to coincide with planned Aleutian Islands surveys. Since the Aleutian Islands were surveyed in 2014, a full assessment was conducted to determine the 2015 harvest.

The survey biomass estimates and age composition data from the U.S.-Japan cooperative survey in 1980, 1983, and 1986 were removed from the assessment. The 2014 AI survey biomass estimate and length composition were included in the assessment as well as the 2012 AI survey and 2013 fishery age compositions and the 2012 fishery length composition. The length-at-age, weights-at-age, and age-to-length conversion matrix were updated based on data from the NMFS AI trawl survey beginning in 1991.

The 2014 AI survey biomass is large and consistent with the survey biomass estimates in 2010 and 2012, and the size composition data continue to show relatively strong cohorts from 1994 to 2000. A bicubic spline model was used to estimate fishery selectivity as a function of year and age. The multinomial input sample sizes for the age and length composition data were changed using an iterative reweighting procedure that ensures that the standard deviation of the normalized residuals for each composition data type is 1.

Spawning biomass is well above the $B_{40\%}$ reference point and projected to be 234,426 t in 2015 and to decline to 223,744 t in 2016. Large recruitments in the late 1990s have driven up recent estimates of stock abundance. The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, thereby qualifying Pacific ocean perch for management under Tier 3. The current estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ are 169,203 t, 0.089, and 0.0109 respectively. Spawning biomass for 2015 (234,426 t) is projected to exceed $B_{40\%}$, thereby placing POP in sub-tier “a” of Tier 3. The 2015 and 2016 catches associated with the $F_{40\%}$ level of 0.089 are 34,988 t and 33,550 t, respectively, and were the authors’ and Plan Team’s recommended ABCs. The 2015 and 2016 OFLs are 42,558 t and 40,809 t.

A random effects model was used to regionally set ABC based on the proportions of model-based estimates of ending year survey biomass that were for 2015: BS = 8,771 t, Eastern Aleutians (Area 541) =8,312 t, Central Aleutians (Area 542) = 7,723 t, and Western Aleutians (Area 543) = 10,182 t. The recommended OFL for 2015 and 2016 is not regionally apportioned. Pacific ocean perch is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

GULF OF ALASKA - ABL

Pacific ocean perch (POP), *Sebastes alutus*, is the dominant fish in the slope rockfish assemblage and has been extensively fished along its North American range since 1940. Since 2005, Gulf of Alaska rockfish have been moved to a biennial stock assessment schedule to coincide with the biennial AFSC trawl survey that occurs in this region. In even years (such as 2014’s assessment for the 2015 fishery) there is no new trawl survey data available, and usually a projection model is run to provide forecast estimates of abundance. However, in 2014 a full assessment was performed in order to include new maturity data into the assessment. This new information indicated a younger age at 50% maturity than in previous assessments. For the 2015 fishery, we recommended the maximum permissible ABC of 21,012 t. This ABC was a 9% increase from the 2014 ABC of 19,309 t. Overfishing was not occurring, the stock was not overfished, and it was not approaching an overfished condition.

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

Northern Rockfish

BERING SEA AND ALEUTIAN ISLANDS - REFM

Northern rockfish are assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. Since the Aleutian Islands were surveyed in 2014, a full assessment was presented for catch advice in 2015.

Catch was updated through October 11, 2014. The survey biomass estimates and age composition data from the U.S.-Japan cooperative surveys in 1980, 1983, and 1986 were removed from the assessment. The 2014 AI survey biomass estimate and length composition were included in the assessment. The 2012 AI survey age composition was included in the assessment. The 2012 and

2013 fishery length compositions were included in the assessment. The length-at-age, weights-at-age, and age-to-length conversion matrix were updated based on data from the NMFS AI trawl surveys beginning in 1991. The multinomial input sample sizes for the age and length composition data were obtained by an iterative reweighting procedure that ensures that the standard deviation of the normalized residuals for each composition data type is 1.

The 1980s cooperative surveys had low biomass estimates relative to the remainder of the time series, and removal of these data increased the estimated population size. Spawning biomass has been increasing slowly and almost continuously since 1977 until recent years, where it appears to be leveling off. Female spawning biomass is projected to be 94,873 t and 93,540 t in 2015 and 2016, values well above $B_{40\%}$.. Recent recruitment has generally been below average.
The Plan Team agreed with the author's recommended changes to the model. The SSC has determined that this stock qualifies for management under Tier 3 due to the availability of reliable estimates for $B_{40\%}$ (57,768 t), $F_{40\%}$ (0.070), and $F_{35\%}$ (0.088). Because the projected female spawning biomass of 94,873 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 2015 is 12,488 t, which was the recommendation for the 2015 ABC. Under Tier 3a, the 2014 OFL is 15,337 t for the Bering Sea/Aleutian Islands combined. The Plan Team recommended setting a combined BSAI OFL and ABC. The Team recommendation for 2016 ABC is 12,295 t and the 2016 OFL is 15,100 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

GULF OF ALASKA-ABL
The northern rockfish, *Sebastes polyspinis*, is a locally abundant and commercially valuable member of its genus in Alaskan waters. As implied by its common name, northern rockfish has one of the most northerly distributions among the 60+ species of *Sebastes* in the North Pacific Ocean. Since 2005, Gulf of Alaska (GOA) rockfish have been moved to a biennial stock assessment schedule to coincide with the AFSC trawl survey. An age-structured assessment (ASA) model is used to assess northern rockfish in the GOA; the data used in the ASA model includes the trawl survey index of abundance, trawl survey age and length composition, fishery catch biomass, and fishery age and length composition. Updated catch data is the only data available in even years, while in odd years a full assessment is run that includes both updated survey and catch data since the last full assessment. In 2014 a projection model was performed with new catch data implemented to determine ABC. The result was a recommended ABC for 2015 of 4,999 t; this ABC was 6% less than the 2014 ABC of 5,324 t. The GOA northern rockfish stock is not subjected to overfishing, is not currently overfished, and is not approaching a condition of overfishing.

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

Shortraker Rockfish

BERING SEA AND ALEUTIAN ISLANDS - REFM
A full assessment was made for shortraker rockfish in 2014 due to the completion of the Aleutian Islands survey. The 2014 biomass estimate is based on the Aleutian Island survey data through 2014 as well as the 2002-2012 eastern Bering Sea slope survey data. The EBS slope survey data had not been included in previous biomass estimates for this species. Catch data have been revised

and updated through October 31, 2014. For estimation of biomass, the assessment methodology was changed from a Kalman filter version of the Gompertz-Fox surplus production model to a simple random effects model.

The 2015 estimated shortraker rockfish biomass is 23,009 t, increasing from the previous estimate of 16,447 t primarily due to the inclusion of the 2002-2012 EBS slope survey biomass estimates. The modern EBS slope survey time series began in 2002. For the period 2002-2014, EBS slope survey biomass estimates ranged from a low of 2,570 t in 2004 to a high of 9,299 in 2012 (which was the year of the most recent EBS slope survey). For the period 1991-2014, the AI survey biomass estimates ranged from a low of 12,961 t in 2006 to a high of 38,497 t in 1997. According to the random effects model, total biomass (AI and EBS slope combined) from 2002-2014 has been very stable, ranging from a low of 20,896 t in 2006 to a high of 23,938 t in 2002. The time series from the random effects model is much smoother than the time series for the raw data, due to large standard errors associated with the data.

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 Plan Team recommended basing the biomass estimate on the random effects model. The recommended F_{ABC} was set at the maximum permissible level under Tier 5, which is 75 percent of M. The accepted value of M for this stock is 0.03 for shortraker rockfish, resulting in a $maxF_{ABC}$ value of 0.0225. The ABC is 518 t for 2015 and 2016 and the OFL is 690 t for 2015 and 2016.

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.

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 2014. Catch data were updated.

Shortraker rockfish has always been classified into “tier 5” in the North Pacific Fishery Management Council’s (NPFMC) definitions for ABC and overfishing level, in which the assessment is mostly based on averaging the exploitable biomass from the three most recent trawl surveys (presently the 2009, 2011, and 2013) to determine the recommended ABC. For an off-cycle year, there is no new survey information for shortraker rockfish; therefore, the 2013 estimates are rolled over. Estimated shortraker biomass is 58,797 mt, which is identical to the 2013 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 1,323 t for the 2015 fishery. Gulfwide catch of shortraker rockfish was 730 t in 2013 and estimated at 559 t in 2014. Shortraker rockfish in the GOA is not being subjected to overfishing, It is not possible to determine whether this stock is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

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Blackspotted/rougheye Rockfish Complex

BERING SEA AND ALEUTIAN ISLANDS - REFM

A full stock assessment was completed for 2014, the first since 2012. The assessment features an age-structured statistical model for the Aleutian Islands (Tier 3) and a Tier 5 assessment for the Bering Sea component of the stock. New data in this assessment included: updated catch for 2013 and catch for 2014 through October 11, 2014 fishery length composition data were included for 2012 and 2013 the 2014 AI survey biomass estimate and length composition was included the 2012 AI survey age composition was included. The survey biomass estimates and age composition data from the U.S.-Japan cooperative survey in 1980, 1983, and 1986 were removed from the assessment. The length-at-age, weights-at-age, and age-to-length conversion matrices were updated based on data from the NMFS AI trawl survey beginning in 1991. Two major changes were made in the age-structured model for the AI component of this stock complex: After evaluating several alternative methods of parameterizing selectivity, the recommended model uses a double logistic curve to model fishery selectivity. Multinomial input sample sizes for the age and length composition data were obtained by an iterative reweighting procedure that ensures that the standard deviation of the normalized residuals for each composition data type is 1.

A simple random effects model was used to estimate current biomass for the EBS component of this stock complex. Total biomass for the AI component of the stock in 2015 is projected to be 40,327 t which is an increase from last year's projected 2014 value of 29,087 t. For the period 1977-2014, the current (2014) estimate of female spawning biomass is the all-time high. Female spawning biomass is projected to increase further to 7,921 t in 2015 and 8,993 t in 2016. These projected increases are fueled by extremely large year classes spawned in 1998, 2002, and 2006. Application of the random effects model produces an estimated biomass for the SBS area of 1,339 t for 2015, a small decrease from last year's estimate of 1,389 t.

As was the case with the two most recent full assessments in 2010 and 2012, there was a concern about the appropriate range of year classes to use when estimating average recruitment. This year, the authors recommended using year classes up through 1998, but the Team recommends using year classes up through 1996 only, as this would correspond to the result of the formula recommended by the recruitment working group. The difference in the recommended range of year classes causes the Team's $B_{40\%}$ estimate to differ from that of the authors, which in turn affects the recommended ABCs. The values listed in this summary correspond to the Plan Team's estimate of $B_{40\%}$. For the Aleutian Islands, 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 2015 of 7,921 t is greater than $B_{40\%}$, (5,535 t) the stock qualifies as Tier 3a and the adjusted $F_{ABC} = F_{40\%}$ values for 2015 and 2016 are 0.047 and 0.058, respectively. The maximum permissible ABC for the Aleutian Islands is 615 t, which is the authors' and Team's recommendation for the AI portion of the 2015 ABC.

Under Tier 3a, the 2015 OFL is 799 t for the combined BSAI region. The apportionment of 2015 ABC to subareas is 445 t for the Western and Central Aleutian Islands and 203 t for the Eastern Aleutian Islands and Eastern Bering Sea. The Team recommends an overall 2016 ABC of 702 t and a 2016 OFL of 865 t. Given on-going concerns about fishing pressure relative to biomass in the Western Aleutians, the SSC requested that the potential apportionment by sub-area be calculated and presented. The blackspotted and rougheye rockfish complex is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

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. However, due to the 2013 government shutdown, we presented an executive summary in 2013, similar to an off-cycle year, to recommend harvest levels for the next two years. Because of the availability of new longline survey data and additional aging data in 2014, we conducted a full assessment for the 2015 fishery. New and updated data added to this model include updated catch estimates for 2011-2013, new catch estimates for 2014-2016, new fishery ages for 2009 and 2012, new fishery lengths for 2010 and 2011, a new trawl survey estimate for 2013, updated trawl survey ages for 2009, new trawl survey ages for 2011, and fully revised longline survey abundance estimates and length frequencies (1993-2014). We now use the time series of relative population numbers (RPNs) rather than relative population weights (RPWs) to represent the longline survey abundance. Use of the RPNs follows what is done for the sablefish assessment model. New biological data on growth and aging error were used to update the weight-at-age estimates, the size-at-age conversion matrix, and the aging error matrix. For the 2015 fishery, we recommended the maximum allowable ABC of 1,122 t from the updated projection model. This ABC is 10% less than last year's ABC of 1,244 t and similarly less than last year's projected 2015 ABC of 1,262 t. The stock is not overfished, nor is it approaching overfishing status.

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Other Rockfish Complex

BERING SEA AND ALEUTIAN ISLANDS - REFM

New data in the 2014 assessment included updated catch and fishery lengths for 2014. Biomass estimates, CPUE, and length frequency compositions were also included from the 2014 Aleutian Island trawl survey, and the 2013 and 2014 eastern Bering Sea shelf survey. There was no Bering Sea slope survey in 2014. Of the new data, only the survey biomass estimate is used in computing recommended ABCs and OFLs. In previous assessments, a 4-6-9 weighted average of three most recent surveys for each region (Aleutian Islands, Bering Sea shelf, and Bering Sea slope) had been used to calculate the BSAI other rockfish biomass estimate. To remain consistent with other Tier 5 assessments, a random effects model was used for each region to calculate the biomass estimate for the entire BSAI area.

Trends in spawning biomass are unknown for the species of the "Other rockfish" complex. The 2014 assessment reported that biomass of other rockfish was at an all-time high in both the most recent EBS slope survey (2012) and this year's AI survey. F_{ABC} was set at the maximum allowable under Tier 5 ($F_{ABC} = 0.75M$). The accepted values of M for species in this complex are 0.03 for shortspine thornyheads and 0.09 for all other species. Multiplying these rates by the best biomass estimates of shortspine thornyhead and other rockfish species in the "other rockfish" complex yields 2015 and 2016 ABCs of 695 t in the EBS and 555 t in the AI. The Team recommends that OFL be set for the entire BSAI area, which under Tier 5 is calculated by multiplying the best estimates of total biomass for the area by the separate natural mortality values and adding the results, which yields an OFL of 1,667 t for 2015 and 2016.

The “other rockfish” complex is not being subjected to overfishing. It is not possible to determine whether this complex is overfished or whether it is approaching an overfished condition because it is managed under Tier 5.

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

GULF OF ALAKSA - ABL

The Other Rockfish complex in the Gulf of Alaska (GOA) is comprised of 25 species, but the composition of the complex varies by region. The species that are included across the entire GOA are the 15 rockfish species that were previously in the “Other Slope Rockfish” category together with yellowtail and widow rockfish, formerly of the “Pelagic Slope Rockfish” category. Northern rockfish are included in the Other Rockfish complex in the eastern GOA and the Demersal Shelf rockfish species are included west of the 140 line (i.e. all of the GOA except for NMFS area 650). The primary species of “Other Rockfish” in the GOA are sharpchin, harlequin, silvergray, and redstripe rockfish; most of the others are at the northern end of their ranges in Alaska and have a relatively low abundance here. Rockfish in the GOA have been moved to a biennial stock assessment schedule to coincide with data from the AFSC biennial trawl surveys in the GOA. The next full assessment will be completed in the fall of 2015.

All species in the group are classified into “tier 5” or “tier 4” (only sharpchin rockfish is “tier 4”) in the NPFMC definitions for acceptable biological catch (ABC) and overfishing level (OFL), in which the assessment is mostly based on biomass estimates from trawl surveys, instead of modeling. As in previous assessments since 1994, an average of the Gulf-wide biomass from the three most recent trawl surveys (presently the 2009, 2011, and 2013 surveys) is used to determine current exploitable biomass. This results in a current exploitable biomass of 83,383 t for Other Rockfish. Applying either an $F_{ABC} \leq F_{40\%}$ rate for sharpchin rockfish or an $F_{ABC} \leq 0.75M$ (*M* is the natural mortality rate) for the other species to the exploitable biomass for Other Rockfish results in a recommended ABC in the GOA of 4,079 t for 2014 and 2015. This is an increase of 1% compared to the 2013 ABC of 4,045 t for Other Rockfish. While the overall survey biomass was similar to the previous survey (85,774 t in 2011), the composition of the species included changed. The Demersal Shelf Rockfish species had not previously been included in the biomass calculations. With the inclusion of the new species, the large decline in biomass observed for silvergray rockfish did not impact the overall exploitable biomass substantially. Gulfwide catch of Other Rockfish was 818 t and 988 t in 2013 and 2014, respectively. Other rockfish is not considered overfished in the Gulf of Alaska, nor is it approaching overfishing status. However, the apportioned ABC for the Western GOA has often been exceeded. Beginning in 2014, the Western and Central GOA apportioned ABCs were combined. This was not deemed a conservation concern because the combined catch of the Western and Central GOA does not always exceed the combined ABC of the two areas, nor is the catch of Other Rockfish approaching the complex ABC.

Catch composition is quite different from survey composition. There are three species which are poorly sampled by the survey, but occur in the catch, and ABC was exceeded in the last two years (harlequin, widow, and yelloweye). Widow rockfish is a species with relatively low biomass in the complex and the ABC = 2 t, but annual catch averages ~ 16 t. Catch of harlequin and yelloweye rockfish average ~ 450 t and 156 t, respectively, exceeding the ABCs of 365 t and 20 t, respectively. These species tend to inhabit untrawlable habitat, and thus, the biomass indices are likely an underestimate. Yelloweye rockfish is mostly caught in hook and line fisheries, as well as Alaska state fisheries, thus catch in the federal assessment may not capture all sources of catch. Harlequein, on the other hand, are the major species caught in the Other Rockfish complex and are mostly caught in the rockfish trawl fishery. This could be a conservation concern because it unknown to what degree the trawlable/untrawlable habitat impacts the survey biomass estimates. Species specific ABCs are not used for management, they are summed to create a complex ABC/OFL, which is used for management.

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5. Thornyheads

a. Stock Assessment

GULF OF ALAKSA - ABL
Gulf of Alaska thornyheads (*Sebastolobus* species) are assessed as a stock complex under Tier 5 criteria using the assessment methodology introduced in 2003. We use the exploitable biomass from the most recent trawl survey to determine the recommended ABC for thornyheads. This complex is assessed on a biennial stock assessment schedule to coincide with the availability of new survey data. For Gulf of Alaska thornyheads, 2014 was an even year that has no new survey data available, so we presented an executive summary that rolls over the same recommendations from the 2013 assessment. The total estimated biomass of 81,816 t results in a recommendation of maximum allowable ABC of 1,841 t for thornyhead rockfish. Catch levels remain below the TAC and the stock was not being subjected to overfishing last year.

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6. Sablefish

a. 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 2014. Total sablefish tag recoveries for the year were around 700. Twenty nine percent of the recovered tags in 2014 were at liberty for over 10 years. About 40 percent of the total 2014 recoveries were recovered within 100 nautical miles (nm; great circle distance) from their release location, 34 percent within 100 – 500 nm, 17 percent within 500 – 1,000 nm, and 9 percent over 1,000 nm from their release location. The tag at liberty the longest was for approximately 36 years, and the greatest distance traveled of a 2014 recovered sablefish tag was 1,998 nm. Two adult sablefish and two juvenile sablefish tagged with archival tags were recovered in 2014. 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 and blackspotted rockfish are also maintained in the Sablefish Tag Database. Twenty four thornyhead, one blackspotted rockfish, and one archival Greenland turbot tag were recovered in 2014.

Releases in 2014 totaled 2,778 adult sablefish, 123 juvenile sablefish, 738 shortspine thornyheads, and five greenland turbot. Pop-up satellite tags (PSAT) were implanted on 43 sablefish and three blackspotted rockfish. For more information, contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

Juvenile Sablefish Studies - ABL

Juvenile sablefish studies have been conducted by the Auke Bay Laboratories in Alaska since 1984 and were continued in 2014. A total of 123 juvenile sablefish were caught and tagged and released in St John Baptist Bay near Sitka, AK over 4 days (July 15th – July 18th) with 90 rod hrs. A biologist from the Alaska Department of Fish and Game participated for one of the days. Total catch-per-unit-effort (CPUE) equaled 1.36 sablefish per rod hour fished. This was down significantly from 2013 (2.29) and lower than the 5-year average. Juvenile sablefish had a mean length of 33 cm fork length (95% CI, 29-36 cm). The St. John Baptist Bay juvenile sablefish tagging cruise will likely be conducted again in 2015 at the end of May. Due to reports of high young of the year presence reported in 2014, tagging may also be conducted in other areas in summer 2015 such as Prince William Sound or Kodiak.

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Age at maturity, Skipped Spawning, Fecundity, and Site Fidelity of Female Sablefish - ABL

It is preferable to gauge maturity status (if a fish will spawn in the future spawning season) just prior to spawning when oocytes are easily discernable. Sablefish were sampled in December of 2011, immediately before the spawning season nearby Kodiak Island, which is near the center of their Alaska distribution. Skipped spawning was documented in sablefish for the first time. These could be identified by the combination having only immature oocytes and a much thicker ovarian wall than immature fish, measured from histological slides (Figure 1). These characteristics indicated that sablefish exhibit the resting type of skipped spawning, where vitellogenic oocytes (containing yolk) are not produced. Age at maturity estimates were heavily influenced by whether these skipped spawners were classified as mature or immature; the age at 50% maturity when skipped spawners were classified as mature was 6.8 years and 9.9 when classified as immature. Skipped spawning fish were identified primarily on the shelf (19 of 22 skip spawning fish were on the shelf, total study sample size = 394). Weight specific fecundity was not related to fish size or age, indicating that relative reproductive output stays constant, verifying the assumption made in the stock assessment that total egg productions is linearly related to female spawning biomass. Four satellite tags were deployed during the cruise and programmed to pop-off after a month to two months. Despite being highly migratory throughout their lives, all four of the sablefish exhibited sight fidelity within the spawning season; the two tagged on the slope remained on the slope and the two caught on the slope and released on the shelf, moved back to where they were caught on the slope.

This year a project was funded to sample the same area that was sampled in 2011 during the summer and winter of 2015. Since skipped spawning sablefish did not produce vitellogenic oocytes, they can be identified during the summer when fish that will spawn have developed vitellogenic oocytes. It is currently unknown when during the summer this occurs. Energy reserves are linked to skipped spawning in other species. The liver synthesizes vitellogenin and so the ratio of liver weight to body weight may be a good predictor of whether a female sablefish will spawn. Goals of this project include acquiring more data on the distribution and prevalence of skipped spawning, relating energy reserves to whether a fish will spawn, improving determinations of maturity during the summer, and evaluating methods to incorporate skipped spawning into maturity ogives for sablefish.

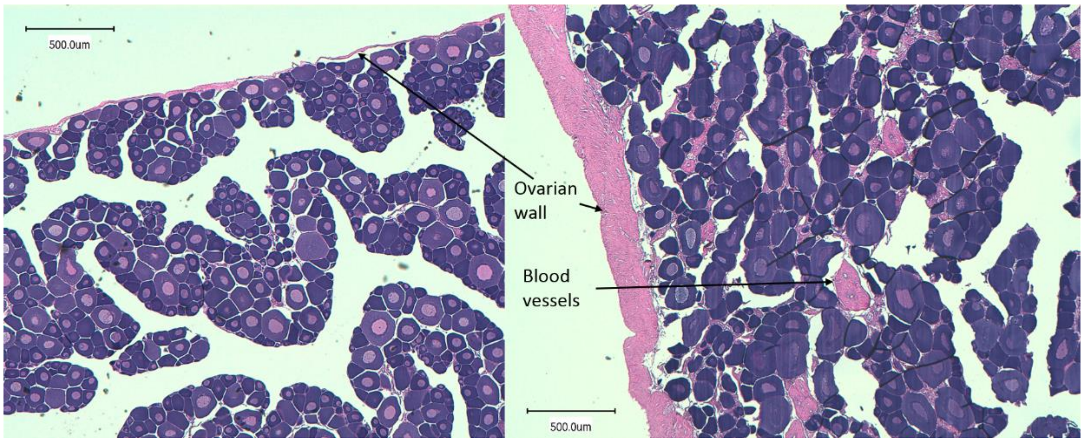

Figure 1. Images of histology slides made from an ovarian section from an immature female sablefish (left) and a skipped spawning female (right).

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

Juvenile Sablefish Ecology – ABL and UAF

Juvenile sablefish are commonly found in nearshore waters; however, the characteristics that make this habitat preferable are not well understood. This joint study between ABL and UAF investigated the diet composition of juvenile sablefish, quantified seasonal and ontogenetic shifts in diet, and assessed nearshore habitat use.

Pulsed resources create an influx of energy that can provide individual and population level benefits to their consumers. As consumers, sablefish experience strong seasonal pulses in prey resources during their period of juvenile growth in the nearshore marine environment. This study described temporal patterns in diet composition of sablefish (N=1,081) ranging in size from 226 mm to 455 mm FL during summer and fall, 2012-2013, in St. John Baptist Bay, Alaska. Juvenile sablefish exploited a large variety of prey taxa characteristic of a generalist predator, with significant diet shifts among sampling periods revealing seasonal and interannual variation in resource use (ANOSIM; Global R=0.278, p<0.001). Diets were more diverse in 2012, when more invertebrate taxa were consumed, compared to 2013, when diets were dominated by Pacific herring and salmonid offal. In September of 2012 and 2013, spawning pink salmon (*Oncorhynchus gorbuscha*) were observed within the study area and juvenile sablefish capitalized on this high energy subsidy, with salmon carcasses among the top contributors to their diets by weight. However, sablefish also exploited lower energy in situ prey, such as benthic invertebrates, suggesting that they are not entirely reliant on seasonally pulsed, high energy prey. This study emphasizes the significance of salmon as a vector of energy across ecosystems and is one of the first to document a marine teleost species scavenging on adult salmon carcasses in coastal marine waters.

Describing fine-scale movements of juvenile sablefish can provide insight into their mechanisms for survival in nearshore habitats. Juvenile sablefish have been found to eat benthic and pelagic prey, implying potential vertical migration off the bottom to forage, however little is known about their fine-scale movement. This study assessed the vertical movement patterns of juvenile sablefish in relation to daylight and tidal cycles using acoustic telemetry. Thirteen juvenile sablefish were implanted with acoustic transmitters and monitored by 2 acoustic receivers from 5 Oct to 14 Nov 2003 within St. John Baptist Bay, Baranof Island, Alaska. The six fish that remained within range of the receivers spent the majority of time near the bottom, but made periodic vertical excursions. Generalized linear mixed models were used to determine the relationship between excursion frequency and environmental factors. Excursions were influenced by tide and diel conditions, with a higher excursion frequency at dawn and during slack and flood stages and a lower excursion frequency at night. Flood and slack tide may create an influx of pelagic prey resources, which could lead to the more frequent vertical movement of juvenile sablefish during these tide stages. Higher probability of excursions at dawn may be due to factors such as predator avoidance or increased prey movement at crepuscular periods. To date, this is the first study describing vertical migration of juvenile Sablefish in the wild and reveals that environmental conditions have the potential to affect the fine-scale movements of juvenile sablefish within nearshore habitats.

For more information, contact Patrick Malecha at (907) 789-6415 or pat.malecha@noaa.gov.

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 2013-2014, data analysis will resume in 2015 or 2016. For more information, contact Mike Sigler mike.sigler@noaa.gov or Pete Hulson pete.hulson@noaa.gov.

Sablefish Satellite Tagging - ABL

The third year of extensive tagging of sablefish with pop-up satellite tags (PSATs) was conducted on the AFSC annual longline (LL) survey in 2014. Pop-off satellite tags were deployed on 43 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 on 1 January 2015 and 1 February 2015, 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 2014 released tags join the 27 tags that were released in the GOA on the LL survey in 2013, the 48 tags that were released throughout the GOA and AI on the 2012 longline survey, and 4 tags that were released during a sablefish winter maturity cruise in December 2011. With just three years of data acquired from summer survey released tags and still in the early stages of analysis of the data that has been received, 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.

We had about a 50% success rate of the 2014 released PSATs, the highest of all three years of sampling. Success means that the tag stayed on the fish until the programmed release date, and successfully reported the pop-off location as well as archived data collected while on the fish. Tags were on the fish anywhere from 6 – 9 months, depending on when the fish was tagged on the LL survey in the summer. Data is still being processed and analyzed, but both long and short migrations were observed within the 6 - 9 months of tracking. For more information, contact Katy Echave at (907) 789-6006 or katy.echave@noaa.gov.

Sablefish – Whale depredation research -ABL

Sperm whales in the Gulf of Alaska depredate (remove or damage fish caught on fishing gear) on the annual National Marine Fisheries Service Alaska longline survey. Sperm whale depredation can reduce sablefish catch rates and increase the uncertainty of estimates of sablefish abundance and biomass derived from the longline survey. Prior studies that estimated the effect of sperm whale depredation were all fixed-effects models. However, the occurrence of whale depredation is sporadic – creating unbalanced data – and analysis of unbalanced designs using fixed-effects models can results in poor estimation and inference compared to mixed-effects models. In addition, the data within and among longline survey stations is likely correlated, which is also better handled with random effects. We compared inferences across several fixed effects and mixed-effects models of sperm whale depredation. We used these results and simulations to select an appropriate model for inference. We evaluated approaches for improved accounting of whale depredation in the sablefish stock assessment and sablefish management.

From 1998-2012, a total of 1154 year/station combinations were examined in sperm whale depredation models. Overall, 241 (21%) combinations were flagged for depredation based on sperm whale sightings as a proxy for depredation, while only 149 (13%) were flagged based on depredation evidence (damaged fish). Mixed effects models to estimate the sperm whale depredation effect performed better (based on simulations and comparison of point estimates and standard errors) than fixed effects models, likely due to the unbalanced nature and variation in the depredation data. Area-specific model results for sperm whale depredation varied by area; the greatest reductions in sablefish catch rates were generally seen in the West Yakutat and East Yakutat/Southeast areas (~17% - 23% reductions, $p < 0.05$). Models did not perform as well in regions with fewer data points, such as the Western Gulf of Alaska; therefore, mixed effects across-area models were selected as the most effective method for application in the annual sablefish stock assessment. Using the results of the area-wide model estimated expansions of catches at longline stations with sperm whales present by 1.14 and by 1.18 at stations where there was evidence of depredation. Because there were fewer incidents of evidence of depredation than presence, the effect on the all Alaska abundance index was similar for both variables and was an increase of 1-5% from 1998-2012. Compared to previous fixed effect studies, the use of mixed effect modelling and the longer time series of data showed that the effect of both presence and evidence of depredation had a significant effect on catch rates of sablefish on the Alaska longline survey.

Correcting for sperm whale depredation in the stock assessment resulted in an increase in estimated female spawning biomass of 3-4% in the terminal year which would yield an 8% higher quota recommendation. However, accounting for sperm whale depredation in the assessment should be done in concert with estimating the increase in mortality caused by depredation in the fishery. Current work is focused on estimating additional mortality caused by sperm whale depredation in the fishery.

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

Biophysical indices from surveys and fisheries were used to predict the recruitment of sablefish to age-2 from 2013 to 2015. The southeast coastal monitoring project is an annual survey of oceanography and fish conducted in inside and outside waters of northern southeast Alaska. Oceanographic sampling included, but was not limited to, sea temperature and chlorophyll *a*. These data are available from documents published through the North Pacific Anadromous Fish Commission website from 1999 to 2012 (www.npafc.org) and from Emily Fergusson at ABL. These oceanographic metrics may index sablefish recruitment, because sablefish use these waters as rearing habitat early in life (late age-0 to age-2). Estimates of age-2 sablefish abundance are from the sablefish stock assessment. We modeled age-2 sablefish recruitment estimates from 2001 to 2012 as a function of sea temperature, chlorophyll *a*, and pink salmon productivity in southeast Alaska.

Age-2 sablefish recruitment was described as a function of late August sea temperature, late August chlorophyll *a*, and juvenile pink salmon productivity index during the age-0 stage (based on adult salmon returns to southeast Alaska during the age-1 stage) in a multiple regression model (Figure 1; Table 1). Chlorophyll *a* during the age-0 phase was most strongly correlated with sablefish recruitment ($R^2 = 0.80$; p-value = 0.00003) with a three-fold increases in chlorophyll *a* in 2000 and recruitmentin 2002. Sea temperature and pink salmon productivity explained an additional 15% of the variation in sablefish recruitment ($R^2 = 0.950$; p-value = 0.00001).

Warmer sea temperatures were associated with high recruitment events in sablefish. 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.

The model parameters (2001-2012) and biophyscial indices (2011-2013) were used to predict the recruitment of Gulf of Alaska sablefish (2013-2015). Below average recruitment events for age-2 sablefish are expected in 2013 and 2015, and a slightly above-average recruitment event is expected in 2014 due to the high juvenile pink salmon productivity in 2013.

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b. Stock Assessment

BERING SEA, ALEUTIAN ISLANDS, AND GULF OF ALASKA - ABL
A full sablefish stock assessment was produced for the 2015 fishery. We added relative abundance

and length data from the 2014 AFSC longline survey, relative abundance and length data from the 2013 longline and trawl fisheries, age data from the 2013 longline survey and 2013 fixed gear fishery, updated historical catches from 2006 – 2013, and projected 2014- 2016 catches.

The fishery abundance index decreased 13% from 2012 to 2013 (the 2014 data are not available yet). The longline survey abundance index increased 15% from 2013 to 2014 following a 25% decrease from 2011 to 2013. Spawning biomass is projected to decrease from 2015 to 2018, and then stabilize. Sablefish are currently slightly below the spawning biomass limit reference point and well below the target, which automatically lowers the potential harvest rate. We recommend a 2015 ABC of 13,657 t. The maximum permissible ABC for 2015 is very similar to the 2014 ABC of 13,722 t. The 2013 assessment projected a 10% decrease in ABC for 2015 from 2014. This smaller decrease is supported by a moderate increase in the domestic longline survey index from the all-time low in 2013 that offset the lowest value of the fishery abundance index seen in 2013. The fishery abundance index has been trending down since 2007. The 2013 IPHC GOA sablefish index was not used in the model, but also declined 21% from 2012. The 2008 year class showed potential to be above average in previous assessments based on patterns in the age and length compositions. However the estimate in this year's assessment is only average because it is heavily influenced by the recent large overall decrease in the longline survey and trawl indices.

Spawning biomass is projected to decline through 2018, and then is expected to increase; assuming average recruitment is achieved in the future. ABCs are projected to decrease in 2016 to 12,406 t and 12,292 t in 2017 (see Table 3.18). Projected 2015 spawning biomass is 35% of unfished spawning biomass. Spawning biomass has increased from a low of 32% of unfished biomass in 2002 to 35% of unfished biomass projected for 2015 but is trending downward in projections for the near future. The 1997 year class has been an important contributor to the population; however, it has been reduced and is predicted to comprise less than 7% of the 2015 spawning biomass. The 2000 year class is still the largest contributor, with 16% of the spawning biomass in 2015. The 2008 year class is average and will comprise 10% of spawning biomass in 2015 even though it is only 60% mature.

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7. Yellowfin sole

a. Stock Assessment

BERING SEA - REFM
The 2014 EBS bottom trawl survey resulted in a biomass estimate of 2.51 million t, compared to the 2013 survey biomass of 2.28 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 (63% above 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 26 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 is a contributor to the reservoir of female spawners. The 2014 catch of 156,700 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).

New data for this year's assessment include:
2013 fishery and survey age compositions
2014 trawl survey biomass point estimate and standard error
estimates of the discarded and retained portions of the 2013 catch
estimate of total catch through the end of 2014.

The current assessment model allows for the input of sex-specific estimates of fishery and survey age composition and weight-at-age and provides sex-specific estimates of population numbers, fishing mortality, selectivity, fishery and survey age composition and allows for the estimation of sex-specific natural mortality and catchability. It also features the inclusion of estimates of time varying fishery selectivity, by sex.

The projected female spawning biomass estimate for 2015 is 644,200 t. Projected spawning biomass for 2015 through 2020 indicates an increasing trend and a slow decline thereafter. The upward trend in the population biomass is due to strong recruitment from the 2003 year class.

The SSC has determined that reliable estimates of B_{MSY} and the probability density function for F_{MSY} exist for this stock. Accordingly, yellowfin sole qualify for management under Tier 1. The estimate of B_{MSY} from the present assessment is 391,000 t. Corresponding to the approach used in recent years, the 1978-2006 stock-recruitment data 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 0.117. 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 2015 biomass estimate produced 2015 ABC of 248,800 t recommended by the author and Team, and the corresponding product using the OFL harvest ratio produces the 2015 OFL of 266,400 t. For 2016, the corresponding quantities are 245,500 t and 262,900 t, respectively.

Yellowfin sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition. As in previous years, this assessment contains an ecosystem feature that represents catchability of the EBS shelf trawl survey as an exponential function of average annual bottom temperature.

8. Northern Rock Sole

a. Research

Habitat availability for age-0s as a leading indicator of northern rock sole recruitment? RACE Recruitment Processes

Recruitment Processes and GAP researchers from the AFSC studied the relationships between annual spatial distribution and relative abundance of small (≤ 11 cm FL) juvenile Northern Rock Sole and summer bottom temperatures using data from a time series of eastern Bering Sea summer trawl surveys from 1982 through 2012. Latitudinal distributions of age-2 and age-3 fish were correlated most strongly with eastern Bering Sea mean summer bottom temperatures (range of 0.8–3.8 °C) two and three years prior to the survey year, during the time that the fish would have been age-0. Thus, temperature in the age-0 year may affect spatial distribution for the first few years of life. Distribution of small juveniles shifted northwards two years following the beginning of a warming trend from 1999 to 2003, and shifted southwards two years following a cooling trend from 2004 through 2010. Northerly distributions were correlated with high abundances (Figure 1). Density dependence was ruled out as a reason for northward shifts in distribution given a lack of correlation between annual latitudinal centers of distributions and the annual abundances within the southern part of the distribution. The vast spatial extent of age-0 nursery habitat in the north may produce large cohorts of Northern Rock Sole that contribute disproportionately to the recruiting population, and temperature related use of this habitat during the age-0 year may regulate recruitment to the overall population. Bottom temperature in the age-0 year may affect later adult distribution and abundance in the eastern Bering Sea. Results suggest that availability of nursery habitat during the age-0 year could be a useful leading indicator of Northern Rock Sole recruitment.

Contributed by Dan Cooper (FOCI) and Dan Nichol (GAP)

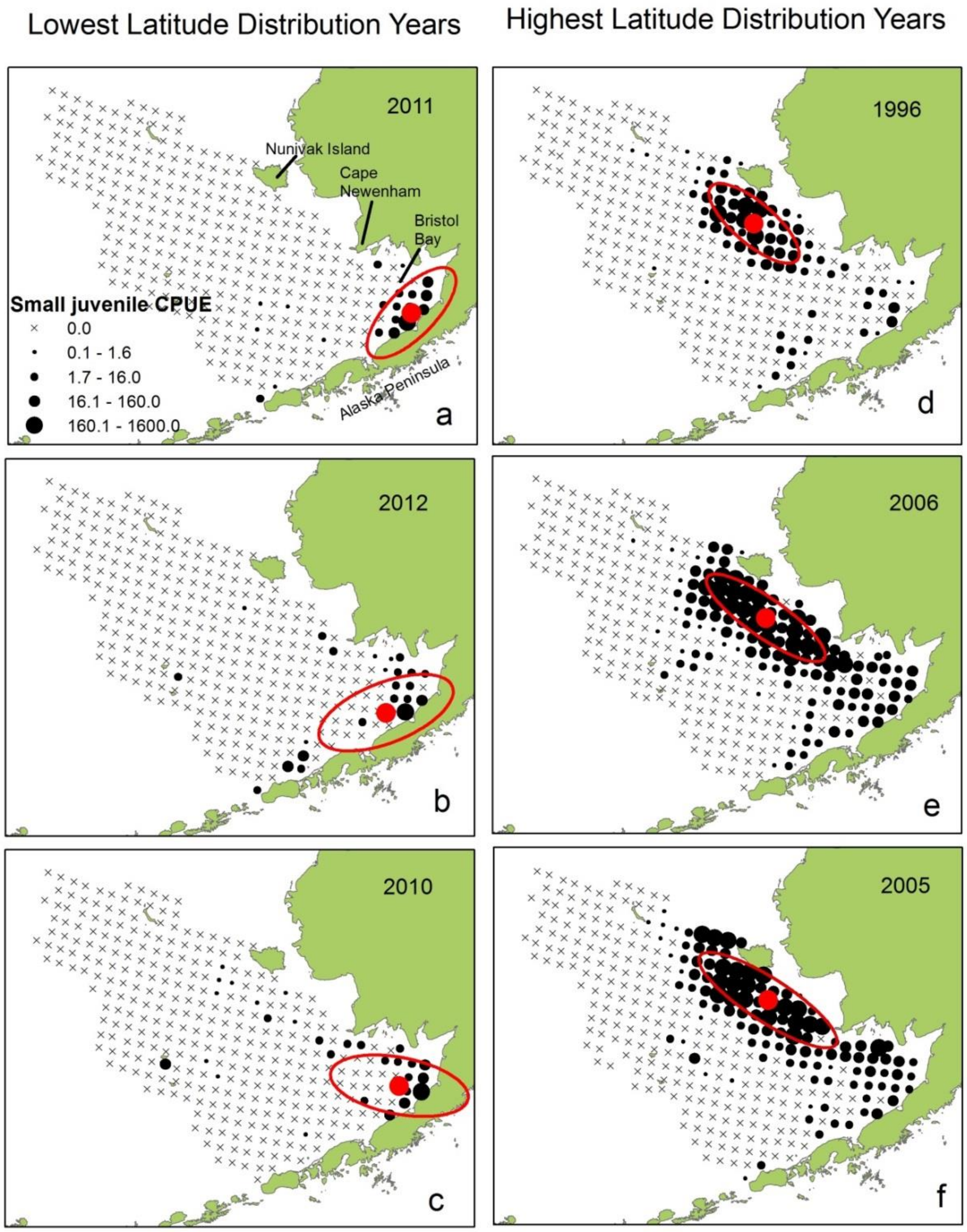

Figure 1. Variability in latitudinal distribution of Northern Rock Sole small juveniles (≤11 cm) for six years with the three highest and three lowest latitudinal centers of distribution from the summer AFSC EBS trawl survey. Catch per unit effort (CPUE) at each survey station (number of fish per hectare) are shown with variably sized black circles. Mean geographic center of distribution weighted by CPUE for each year is shown with a solid red circle. Red ellipses encompass the area of approximately 68% of the catch in each survey year. a-c) The three years with the lowest latitude centers of distribution and d-f) the three years with the highest latitude centers of distribution from 1982–2012.

Age-0 yr Northern Rock Sole Habitat Studies Around Kodiak, Alaska - RACE FBEP
The Fisheries Behavioral Ecology Program, located in Newport Oregon, in cooperation with staff members from the Kodiak Laboratory, conduct research and test hypotheses designed to better understand annual recruitment of juvenile northern rock sole to coastal nursery areas in the Gulf of Alaska around Kodiak using a combination of field and laboratory studies. Laboratory studies focus upon specific habitat features which promote settlement and survival in these species, while field research focuses the recruitment of juvenile northern rock sole and their distribution among habitats. In addition, the program continues an annual survey (11-years in 2014) of juvenile recruitment that may ultimately prove useful in understanding annual variability in habitat features that control nursery production, subsequent year-class strength, and eventual adult recruitment to the fishery. In 2013 a study was completed that documented inter-annual variability in the depth distribution of juvenile northern rock sole on their nursery grounds around Kodiak Island, Alaska. This study evaluated whether this variability was a response to inter-annual changes in the availability of habitat created by polychaete tubes; principally *Sabellides sibirica*. Worm tubes may constitute an alternative refuge and/or feeding habitat for juvenile flatfish. Accordingly, it was hypothesized that during years of low worm abundance, fish would concentrate in the shallows (< 10 m depth) where they would find refuge from predation, but would move to greater depths (> 15 m, where the worms occur) during years when the worms were abundant. Using data on worm abundance and fish density over 5 yr, this hypothesis was tested at 2 Kodiak nursery embayments. Whether worms were abundant in a given year or embayment had no influence on overall fish abundance, however, worm abundance did influence juvenile flatfish depth distributions. At one site, where worms tended to be scarce, fish were typically concentrated in shallow water. However, during the 1 year when worms were abundant, fish were concentrated in deeper water. At another site, where worms are more regularly found, fish tended to concentrate in deeper water, the exception being the one year when worms were nearly absent. Regression analysis for both sites and all years indicated that the percent of fish occupying shallow water (< 10m) decreased with increasing worm abundance. When worms were prevalent, fish were most commonly found on bottom with sparse to moderate worm cover, but avoided bottom where the worms were so dense as to form a 'turf'. These results demonstrate that the geographic and inter-annual variation in worm tube abundance has significant influence over the distribution of juvenile northern rock sole.

b. Stock Assessment

BERING SEA - REFM
The northern rock sole stock is currently at a high level due to strong recruitment from the 2001, 2002 and 2003 year classes which are now contributing to the mature population biomass. The 2014 bottom trawl survey resulted in a biomass estimate of 1.86 million t, 6% higher than the 2013 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 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 2003. The stock is currently estimated at over twice the B_{MSY} level.

New information for the 2014 analysis include:

1) 2013 fishery age composition. 2) 2013 survey age composition. 3) 2014 trawl survey biomass point estimate and standard error. 4) updated fishery discards through 2014. 5) fishery catch and discards projected through the end of 2014.

Northern rock sole are managed as a Tier 1 stock using a statistical age-structured model as the primary assessment tool. Model results indicate that spawning biomass increased almost continuously from a low of 54,981 t at the beginning of the model time series in 1975 to a peak of 758,648 t in 2001. Spawning biomass then declined to 491,611 t in 2009, but has increased continuously since then, reaching 632,502 t in 2014. The 2000-2005 year classes are all estimated to be above average, with the 2002 year class estimated to be at about twice the long-term average. The stock assessment model projects a 2015 spawning biomass of 622,300 t. This was slightly less than the 2015 value projected in last year's assessment. The projected spawning biomass for 2016 is 589,800 t.

The SSC has determined that northern rock sole qualifies for management under Tier 1. Spawning biomass for 2015 is projected to be well above the B_{MSY} estimate of 260,000, placing northern rock sole in sub-tier "a" of Tier 1. The Tier 1 2015 ABC harvest recommendation is 181,700 t (F_{ABC} = 0.143) and the 2015 OFL is 187,600 t (F_{OFL} = 0.152). The 2016 ABC and OFL values are 164,800 t and 170,100 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 3.5 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.

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. An executive summary for shallow water flatfish was presented which included updated 2013 catch and the partial 2014 catch as well as projections using the updated results from the northern and southern rock sole assessment. 2014 catches of southern rock sole were substantially lower than catches in 2013.

The shallow water complex is comprised of northern rock sole, southern rock sole, yellowfin sole, butter sole, starry flounder, English sole, sand sole and Alaska plaice. Northern and southern rock sole are assessed with an-age structured model. Changes to the rock sole assessment model input data included updating the fishery catches for 2013 and 2014, including catch-at-length for 2014, adding GOA bottom trawl survey age compositions data from 2013 and compiled survey age data by length to accommodate the option for model fitting based on conditional age-at-length. The fishery catch data was portioned 50% to each of the northern and southern analyses (rather than 60% for both assessment models in 2013). Several changes were made to the technical implementations of the rock sole stock assessment models in response to SSC and Team recommendations from 2013. These included estimation of natural mortality rates separately for males (females were fixed at 0.2), a change in both models from using selectivity-at length to selectivity-at-age and using the number of trips or hauls as the primary input sample size (rather than the number of fish). Both models internally estimated the growth and selectivity parameters.

The rock sole species assessment model estimates are used for trend and spawning biomass estimates whereas the remaining species in this complex are based on the NMFS bottom trawl surveys. The most recent survey was 2013. Survey abundance estimates for the entire shallow-water complex were lower in 2013 compared to 2011; decreasing by 35,156 t. Model estimates of northern and southern rock sole spawning biomass have also shown slight declines in recent years.

Northern and southern rock sole are in Tier 3a while the other species in the complex are in Tier 5. An updated projection model for northern and southern rock sole was run this year; the remaining shallow water flatfish biomass estimates are from the 2013 survey. The Team noted that changes in the growth parameter estimates (relative to the externally estimated values used in the previous assessment) led to large changes in the *F* reference points for northern rock sole, as well as the total biomass in the southern rock sole assessment.

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 44,205 t and OFL of 54,207 t for 2015. For 2016, the combined ABC is 39,205 t and the OFL is 48,407 t. The assessment authors recommended the maximum permissible ABC for 2015. Information is insufficient to determine stock status relative to overfished criteria for the complex. For the rock sole species, the assessment model indicates they are not overfished nor are they approaching an overfished condition. Catch levels for this complex remain below the TAC and below levels where overfishing would be a concern.

9. Flathead Sole

a. Stock Assessment

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 2014 shelf trawl biomass estimate increased 6% from 2013 for flathead sole. Survey estimates indicate high abundance for both stocks for the past 30 years. The 2007 year class is estimated to be above average, but it follows 3 years of poor recruitment. The assessment employs an age-structured stock assessment model.

New for the 2014 assessment are 1) 2014 catch biomass was added to the model, 2) 2013 catch biomass was updated to reflect October – December 2013 catches, 3) 2012 fishery age composition data were added and 2011 fishery age composition data were updated to reflect changes made to the observer database, 4) 2013-2014 fishery length composition data were added to the model, 5) 2013-2014 Eastern Bering Sea (EBS) shelf survey biomass and 2014 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, which resulted in updating the entire time series,6) 2013-2014 survey bottom temperatures were added to the model, 7) 2013 survey age composition data were added to the model,8) 2014 survey length composition data were added to the model, and 9) Minor changes in the historical survey catch were made to the eastern Bering Sea shelf bottom trawl survey database, as a result of Pacific halibut data reconciliation between RACE and the IPHC. The most common error was an incorrect application of an expansion factor to the Pacific halibut catch sample. In hauls where the catch was subsampled, this change in expansion for halibut affected the catch proportion of the other species in the catch to a minor degree. No changes were made to the assessment methodology.

Model estimates indicated that spawning biomass increased continuously from a low of 17,654 t in

1979 to a high of 319,400 t in 1997, and has been quite stable since 2005, with biomasses ranging between 234,130 t and 252,320 t. The 1998, 2001-2003, and 2011 year classes are all estimated to be well above average. The projected spawning stock biomass for 2015 is 233,736 t. Flathead sole are abundant and only lightly exploited.

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 $B_{40\%}$=127,682 t, $F_{40\%}$=0.28, and $F_{35\%}$=0.35. Because projected spawning biomass for 2015 (233,736 t) is above $B_{40\%}$, flathead sole is in sub-tier “a” of Tier 3. ABCs for 2015 and 2016 were set at the maximum permissible values under Tier 3a, which are 66,130 t and 63,711 t, respectively. The 2015 and 2016 OFLs under Tier 3a are 79,419 t and 76,504 t, respectively. Flathead sole is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

GULF OF ALASKA - REFM
Flathead sole are 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 presented. The projection model was run using updated 2013 catch and new estimated total year catches for 2014-2016. The 2015 spawning biomass estimate (83,818 t) is above $B_{40\%}$ (35,532 t) and projected to be stable through 2016. Total biomass (3+) for 2015 is 254,602 t and is projected to slightly increase in 2016. Flathead sole are determined to be in Tier 3a. The 2015 ABC was set at the maximum permissible ABC of 41,349 t from the updated projection. The F_{OFL} is set at $F_{35\%}$ (0.61) and gives an OFL of 50,792 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.

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10. Alaska Plaice

a. Stock Assessment - REFM
The Alaska plaice resource continues to be estimated at a high and stable level with very light exploitation. The 2014 survey biomass was 451,600 t is a 10% decrease over 2013 and is largely consistent with estimates from resource assessment surveys conducted since 1985. The combined results of the eastern Bering Sea shelf survey and the northern Bering Sea survey indicate that 38% of the Alaska plaice biomass was found in the northern Bering Sea in 2010. The stock is expected to remain at a high level in the near future due to the presence of a strong year class estimated from 2002. Exploitation occurs primarily as bycatch in the yellowfin sole fishery and has averaged only 1% from 1975-2014.

The last full assessment was in November 2012, therefore changes to input data in this analysis include: 1) Estimated 2014 fishery catch and updated 2013 fishery catch, 2) 2013 and 2014 trawl survey biomass estimate and standard error, 3) 2014 survey length composition, 4) 2012 and 2013 survey age composition, 5) 2013 fishery length composition, 6) 1975 and 1979-1981 survey biomass data were excluded, 7) New maturity schedule estimated from histological analysis of samples collected in 2012. The assessment methodology was unchanged.

The stock assessment model estimates a 2015 spawning biomass of 215,300. This was slightly less than the 2015 value of 246,300 projected in last year's assessment. The projected spawning biomass for 2016 is 201,300. Above average recruitment strength in 1998 and exceptionally strong recruitment in 2001 and 2002 have contributed to recent highs level of female spawning biomass. Reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock, therefore qualifying it for management as a Tier 3 stock. The updated point estimates are $B_{40\%}$ = 142,100 t, $F_{40\%}$ = 0.143, and $F_{35\%}$ = 0.175. Given that the projected 2015 spawning biomass of 215,300 t exceeds $B_{40\%}$, the ABC and OFL recommendations for 2015 were calculated under sub-tier "a" of Tier 3. Projected harvesting at the $F_{40\%}$ level gives a 2015 ABC of 44,900 t and a 2016 ABC of 42,900 t. The OFL was determined from the Tier 3a formula, which gives a 2015 value of 54,000 t and a 2016 value of 51,600 t. Alaska plaice is not being subjected to overfishing, is not overfished, and is not approaching an overfished condition.

11. Greenland Halibut (Turbot)

a. Stock Assessment

The 2014 Greenland turbot assessment was updated as follows: 1) updated 2014 catch data, including a 433 t decrease in the catch estimate for 2003 from last year, 2) 2014 EBS shelf survey biomass, 3) 2014 ABL longline survey RPN 4) 2014 EBS shelf survey and ABL longline age and length composition estimates, 5) Shelf survey age and length composition data now include the expanded northern strata from 1987 onward, 6) Updated fishery catch-at-length data for longline and trawl gear from 2014, 7) For Model 2 (see below), the 2006 and 2007 trawl fishery length composition data were removed as the sample sizes were deemed too small, 8) Updated fishery catch-at-length data for longline and trawl gear from 2014, 9) Length of females at 50% mature was changed from 55 to 60 cm per D'yakov (1982).

Two models (Models 1 and 2) were presented for review with Model 2 accepted for use in the 2014 assessment. Model 1 was identical to Model 1 from 2013 except for the addition of new female maturity parameters. Model 2 differed from Model 1 (from 2014) by the addition of a recruitment autocorrelation parameter, fixing of catchability for shelf and slope surveys at 0.62 and 0.57, respectively; and inclusion of an additional selectivity bin (2010 - 2014) for the longline fishery length composition data.

The projected 2015 female spawning biomass is 30,853 t. This is a 12% increase from the 2015 spawning biomass of 27,624 t projected in last year's assessment. Spawning biomass is projected to increase to 38,848 t in 2016. While spawning biomass continues to be near historic lows, increases have been estimated or are projected for the years following 2013, and large 2008 and 2009 year classes are being observed in both the survey and fishery size composition data. These year classes are both estimated to be stronger than any other year class spawned since the 1970s.

The SSC has determined that reliable estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ exist for this stock. Greenland turbot therefore qualifies for management under Tier 3. Updated point estimates of $B_{40\%}$, $F_{40\%}$, and $F_{35\%}$ from the present assessment are 52,049 t, 0.176, and 0.218, respectively. The stock remains in Tier 3b. The maximum permissible value of F_{ABC} under this tier translates into a maximum permissible ABC of 3,172 t for 2015 and 5,248 t for 2016, and an OFL of 3,903 t for 2015 and 6,453 t for 2016. These are the accepted ABC and OFL recommendations.

The authors' and Team's recommended 2015 and 2016 ABCs in the EBS are 2,448 t and 4,050 t, respectively. The authors' and Team's recommended 2015 and 2016 ABCs in the AI are 724 t and 1,198 t, respectively. 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.

12. Arrowtooth Flounder

a. Stock Assessment

BERING SEA AND ALEUTIAN ISLANDS- REFM
The following new data was included in the model: 1) Survey size compositions from the 2013 and 2014 Eastern Bering Sea shelf surveys and the 2014 Aleutian Islands survey, 2) Biomass point estimates and standard errors from the 2013 and 2014 Eastern Bering Sea shelf surveys and the 2014 Aleutian Islands survey, 3) Fishery size compositions for 2012, 2013, and 2014. Fishery size composition data were also added for 1992-1999, which were not previously included, 4) Estimates of catch through October 10, 2014, 5) Age data from the 2010 Bering Sea shelf and 2010 Aleutian Islands surveys, as well as the 2004 shelf survey, which also was not previously included.

The age-structured assessment model is similar to the model used for the 2012 and 2013 assessments. The 2014 model implemented the following changes based on Plan Team and SSC comments: 1) Fishery selectivity is estimated non-parametrically rather than using a 2-parameter logistic function, and 2) An additional likelihood component was added to incorporate the Aleutian Islands age data.

The projected age 1+ total biomass for 2015 is 908,379 t, a decrease from the value of 995,494 t projected for 2015 in last year's assessment. The projected female spawning biomass for 2015 is 533,731 t which is a decrease from the previous estimate of 632,319 t. The recommended 2015 ABC is 80,547 t based on a $F_{40\%}$=0.153 harvest rate and the 2015 overfishing level is 93,856 t based on a F_{OFL}=0.180 harvest rate.

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 last year's assessment were 231,015 t and 0.156, respectively; from this year's assessment, they are 222,019 t, 0.153, respectively. The projected 2015 spawning biomass is far above $B_{40\%}$ in both last year's and this year's assessments, thus ABC and OFL recommendations for 2015 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, which results in 2015 and 2016 ABCs of 80,547 t and 78,661 t, respectively, and 2015 and 2016 OFLs of 93,856 t and 91,663 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.

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 is 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.

GULF OF ALASKA - REFM
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 2014, and updated 2013 catch were used to make projections for ABC and OFL estimates.

Female spawning biomass in 2015 was estimated at about 2 million t and is expected to decrease slightly in 2016. The 2014 catch of arrowtooth was the highest on record. This is partially due to recent changes to regulations (Amendment 95) of the halibut trawl prohibited species catch (PSC) limits. For the Amendment 80 fleet in the GOA, unused halibut PSC limits are now allowed to be rolled from one season to the next, which allows catcher processors to spend more time targeting arrowtooth flounder without constraints due to halibut PSC. In addition, new regulations have moved the deep-water flatfish fishery closure date later in the year for all trawl vessels. These changes will likely result in continued higher arrowtooth flounder catches than previous years, similar to the current year.

Arrowtooth flounder is estimated to be in Tier 3a. Projections are based on an estimated 2014 catch (39,744 t) that is also used for 2015 and 2016. The 2015 ABC ($F_{40\%}$=0.172) is 192,921 t, which is a slight decrease from the 2014 ABC of 195,358 t. The 2015 OFL ($F_{35\%}$=0.204) is 226,390 t. The 2016 ABC is 185,352 t and OFL is 217,522 t. The stock is not overfished nor approaching an overfished condition. Catch levels for this stock remain below the TAC and below levels where overfishing would be a concern.

13. Other Flatfish

a. Stock Assessment

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 2014 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. The biomass of the other flatfish complex on the eastern Bering Sea shelf was relatively stable from 1983-1995, averaging 54,274 t, and then increased from 1996 to 2003, averaging 84,137 t. Since 2003, the biomass estimates have been at a higher level, averaging 125,800 t. The 2014 shelf and Aleutian Islands (slope survey not conducted in 2014) surveys combined estimate of 143,000 t is at the highest level of the past 7 years and third highest overall for the time-series. The estimated increases from the past five years are primarily due to the higher estimates of starry flounder on the Eastern Bering Sea shelf. Sakhalin sole biomass, which has no pattern in fluctuation, had a high of 1,410 t in 1997 and a low of 37 t in 2012. 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 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) in the GOA SAFE document are used, along with a value of 0.15 for all other species in the complex. For 2014, a random effects model was used to estimate the complex biomass for ABC purposes. Projected harvesting at the 0.75 *M* level (average F_{ABC} = 0.093) gives a 2015 ABC of 13,250 t for the "other flatfish" complex. The corresponding 2015 OFL (average F_{OFL} = 0.124) is 17,700 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.

GULF OF ALASKA Deep-water flatfish - REFM

The deepwater flatfish complex is comprised of Dover sole, Greenland turbot, and deepsea sole. This complex 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 presented. Dover sole are assessed as a Tier 3a species and the projection model was run using updated 2013 catch and new estimated catches for 2014- 2016. 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 the purpose of calculating complex-level OFLs and ABCs.

The model estimate of 2015 spawning stock biomass for Dover sole is 67,156 t, which is well above $B_{40\%}$ (28,218 t). Spawning stock biomass and total biomass are expected to remain stable through 2016. Stock trends for Greenland turbot and deepsea sole are unknown.

Since the Dover sole stock has been assessed using an age-structured model and $B_{2015} > B_{40\%}$, it is determined to be in Tier 3a. Both Greenland turbot and deepsea sole are determined to be in Tier 6. The 2015 and 2016 Dover sole ABCs are 13,151 t and 12,994 t, respectively. The Tier 3a 2015 and 2016 OFLs are 15,749 t and 15,559 t, respectively. The Tier 6 calculation (based on average catch from 1978–1995) for the remaining species in the deepwater flatfish complex ABC is 183 t and the OFL is 244 t for 2015 and 2016. The GOA Plan Team agreed with the authors' recommendation to use the combined ABC and OFL for the deepwater flatfish complex for 2015 and 2016. This equates to a 2015 ABC and OFL of 13,334 t and 15,993 t respectively for deepwater flatfish. The ABC is equivalent to the maximum permissible ABC.

Gulf of Alaska Dover sole is not being subjected to overfishing and is neither overfished nor approaching an overfished condition. Information is insufficient to determine stock status relative to overfished criteria for Greenland turbot and deepsea sole. Catch levels for this complex remain well below the TAC and below levels where overfishing would be a concern.

14. Sharks and Skates

a. Research

Spiny Dogfish Ecology and Migration - ABL

A total of 183 satellite pop-off tags have been deployed on spiny dogfish since 2009. Data has been successfully recovered from 153 tags. Five tags have been physically recovered and complete data sets are being downloaded from them. Six spiny dogfish tagged in Puget Sound were tagged with acoustic tags in addition to the pop-off tags, to attempt to compare the light based geolocation with known positions from the acoustic receivers. Recovered data from the pop-off tags, which includes temperature, depth, and geographic location, 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 near 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 near shore, with the near shore 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. For more information, contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

Spiny Dogfish Improved Aging Methods - ABL

Staff from ABL, AFSC REFM Division, and the University of Alaska Fairbanks are wrapping up a North Pacific Research Board funded project to investigate alternative ageing methods for spiny dogfish. The project objectives were to compare the previous method of ageing the dorsal fin spines with a new technique developed that uses the vertebrae. Sample processing and ageing criteria were standardized and a manual has been created which is currently under review for peer review publication. Preliminary results suggest that the vertebrae may be suitable for ageing, however, more research is necessary before that method can be supported (e.g., validating ages). This project has been discussed at workshops at the last two CARE meetings (2013 and 2015), and presented at many scientific conferences. The NPRB final report has been submitted, and manuscripts are in preparation (one submitted). For more information, contact Cindy Tribuzio at (907) 789-6007 or cindy.tribuzio@noaa.gov.

Population Genetics of Pacific Sleeper Sharks - ABL

Two species of the subgenus *Somniosus* are considered valid in the northern hemisphere: *S. microcephalus*, or Greenland shark, found in the North Atlantic and Arctic, and *S. pacificus*, or Pacific sleeper shark, found in the North Pacific and Bering Sea. The purpose of this study was to investigate the population structure of sleeper sharks in Alaskan waters. Tissue samples were opportunistically collected from 141 sharks from 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. A minimum spanning haplotype network separated the 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%. Greenland sharks were found to diverge from the 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. The consistent divergence from multiple sites within the mtDNA between the two groups of Pacific sleeper sharks indicates a historical physical separation. There appears to be no phylogeographic pattern, as both types were found throughout the North Pacific and Bering Sea. 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.

b. Stock Assessment

Sharks - ABL

The shark assessments in the Bering Sea/Aleutian Islands (BSAI) and the Gulf of Alaska (GOA) were moved to biennial cycles. The GOA assessment coincides with the biennial trawl survey in odd years and the BSAI assessment is in even years. A full assessment for the GOA sharks and an executive summary for the BSAI sharks is planned for the fall of 2015.

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. Catch estimates from 2003-2014 were updated from the NMFS Alaska Regional Office's Catch Accounting System. In the GOA, total shark catch in 2014 was 1,525 t, which is down from the 2013 catch of 2,169 t (the greatest catch of the full time series). Substantial changes to the observer program (referred to as "observer restructuring") likely affected the catch estimates for shark species. Smaller vessels are now subject to observer coverage, and this includes vessels fishing halibut IFQ, which were previously exempt from coverage. The increase in 2013 can be attributed mostly to an increase in the catch estimate of spiny dogfish in the Pacific halibut target fishery, which was 675 t, up ~450 t from the average catch from 2003 – 2012, but was still within the range of catches from this target fishery. An additional impact of observer restructuring 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 has increased. In the last two years, the average Pacific sleeper shark and spiny dogfish catch in NMFS areas 649 and 659 has been 87 t and 79 t, respectively, compared to the historical average of < 1 t and ~14 t average (SD = 23), respectively. There was 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 2014 would be 1,703 t, which is still below the recommended acceptable biological catch (ABC) for the shark complex.

Survey biomass was updated for the 2013 GOA assessment. The trawl survey biomass estimates are only used for spiny dogfish. The 2013 survey biomass estimate (160,384 t, CV = 40%) is nearly four times greater than the 2011 biomass estimate of 41,093 t (CV = 22%); this variability is typical for spiny dogfish. The 3 – year average biomass from the trawl survey that is used in calculating the ABC and over fishing level (OFL) declined from 79,979 t (2007, 2009 and 2011 surveys) to 76,452 t (2009, 2011 and 2013 surveys) with the inclusion of the new survey data. The 2007 survey biomass estimate (161,965 t, CV = 35%) dropped out of the calculations, but because the 2013 estimate was nearly equal to the 2007 estimate, the average had only minimal change.

In the BSAI, estimates of shark catch from the Catch Accounting System from 2014 were 137 t which exceeded the TAC, but not the ABC. Pacific sleeper shark are the primary species caught. These catch estimates do incorporate the restructured observer program, but the impact appears to be minimal for BSAI sharks. The survey biomass estimates on the BSAI are highly uncertain and not informative for management purposes.

For the GOA assessment, spiny dogfish are a "Tier 6" species, but a "Tier 5" calculation is used (this is due to the "unreliable" nature of the biomass estimates) and all other sharks a "Tier 6" species. The 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 ABC=5,989 t and OFL= 7,986 t for 2014. In the BSAI, all shark species are considered "Tier 6" with the 2015 ABC = 1,020 t and OFL = 1,360 t.

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

15. Other Species

a. Research

Otolith Morphology, Speciation, Stock Structure, and Microchemistry of Giant Grenadier – ABL (MESA and Genetics), REFM (Age and Growth)

Three very different shapes of otoliths have been observed in giant grenadier. A review of the literature and world-wide experts revealed that such variability in otolith shape is highly unusual for an individual fish species. Otolith morphology differences could be related to speciation or stock structure. Tagging studies are a traditional way to determine migration patterns and spatial stock structure for fish. However, these studies are not possible for giant grenadier because the fish do not survive the pressure difference when caught at depth and brought to the surface. Genetic and otolith microchemistry studies are an alternative means for examining stock structure and speciation, i.e. if giant grenadier are actually two or more species. In 2013, tissue and otoliths samples were collected on the AFSC longline survey in the eastern, central, and western Gulf of Alaska, and the Bering Sea. Otoliths have been measured for a quantitative comparison of shapes in relation to genetic differences. Ageing will be completed in spring of 2015. Samples of each otolith shape in each area are being sequenced at the cytochrome c oxidase subunit 1 (COI) mitochondrial region to look for genetic variation. Additionally, microsatellite markers are being employed to look for stock structure.

It is unknown where juvenile giant grenadier reside; the youngest fish that has been aged is 14 years old. This spring, an undergraduate student at the University of Washington is examining otolith microchemistry in a small number of samples to determine if giant grenadier make large migrations (geographically or depth) at certain times during their long lives (maximum age is at least 58 years and age at 50% maturity for females is 22). Adults are found at depths from 600-1,000+ in great abundance.

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

Octopus Delayed Discard Mortality - RACE GAP

Octopus are caught incidentally in trawl, longline, and pot fisheries; however, the majority of the catch comes from Pacific cod pot fisheries. There is concern that the establishment of annual catch limits (ACLs) for this group may unnecessarily constrain this and other commercial fisheries. During 2011, in the Bering Sea/Aleutian Islands regions the total allowable catch (TAC) for octopus was reached in August 2011 and octopus retention was prohibited starting September 1, 2011. The overfishing limit (OFL) for octopus was reached October 21, 2011 and directed fishing for Pacific cod pot gear was closed for the remainder of the year. Due to the lack of reliable abundance estimates and life history information about octopus in the Gulf of Alaska it is appropriate that they be managed conservatively, however better scientific data will ensure the most appropriate values are used for discard mortality rates for this assemblage. Observer data have documented the short term mortality of octopus captured within these pot fisheries is very low. Data on delayed or long-term mortality of this species will enable scientists to develop a gear-specific discard mortality factor. During three fishing seasons 60 octopus were collected for long term mortality studies from commercial fishing vessels utilizing pot gear. To date these octopus have exhibited low mortality rates and these data support the development of a gear specific discard mortality factor. Field collections for this project are completed and data analyses will be completed within the next year.

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

Blue King Crab Modeling in the Bering Sea - RACE Recruitment Processes

Eco-FOCI personnel are involved in modeling of blue king crab (BKC) in the Bering Sea in a project funded by NOAA's FATE program. We are adapting an existing individual-based model (IBM) of snow crab larval drift, for BKC. The snow crab IBM has been used to demonstrate connectivity patterns for snow crab across the eastern Bering Sea. BKCs are found in widely-separated populations in the Bering Sea, and stock structure is largely unknown. Population trends are very different between the Pribilof Islands regions and the St. Matthew region, however, there are no apparent barriers to adult dispersal between the regions. They are, however, infrequently taken in NMFS trawl surveys between those islands suggesting limited post-settlement dispersal as adults. General current structure in the region suggests that there may be a possible source-sink relationship of planktonic larvae released in the Pribilof Islands region that could settle in the St. Matthew region, but also potential retention in the area around the Pribilofs.

The objectives of the FATE project is to adapt a biophysical individual-based model (IBM) to determine connectivity between larval release and benthic settlement areas for eastern Bering Sea BKC populations. The study is examining the likelihood of exchange via larval drift among populations of BKC in different regions of the eastern Bering Sea, from near the Alaska Peninsula, the Pribilof Islands and St Matthew Island. Connectivity, or the lack of it, between these regions can shed light on populations structure of BKC in the Bering Sea.

The results of this study will directly inform the assessment and management of the Pribilof Islands and St. Matthew BKC stocks. Currently, stock boundaries are established based on geographical features and fishing practices without any information on stock overlap or connectivity. Information on larval drift and likely impacts of environmental conditions and habitat availability on settling locations may inform the management boundaries. This would affect the estimation of biomass, determination of removals, and subsequent definitions of stock status. An extreme yet possible outcome of the changes in boundary definitions might lead to the aggregation of the Pribilof Islands and St. Matthew stocks for overfishing determinations. This would obviously have dramatic impacts on the overfishing status of BKC in the eastern Bering Sea and have potentially lasting impacts on the Pribilof Islands ecosystem.

Contributed by S. Hinckley, e-mail: Sarah.Hinckley@noaa.gov

Distribution and Migration of Morphometrically Mature Male Snow Crab in the Eastern Bering Sea - RACE GAP

Tagging of adult male snow crab (*Chionoecetes opilio*) in the eastern Bering Sea, using pressure and temperature recording data storage tags, was conducted during 2010 and 2011 in an effort to determine the occurrence and extent of seasonal migrations. The research was designed to address the question of whether or not morphometrically mature males undergo a migration from offshore wintering areas northwest of the Pribilof Islands where the fishery occurs to more inshore areas where mature females reside. Fishery managers have recognized a spatial mismatch among larger commercial-sized (≥ 102 mm carapace width) snow crab males, which are found over the middle

EBS shelf (< 100 m bottom depth) during annual summer bottom trawl surveys, but appear centered over the outer shelf (100 - 150 m bottom depth) during winter where the fishery occurs. Part of this mismatch occurs because, upon reaching morphometric maturity, adult males undergo an offshore migration during winter. Although this movement into deeper water during is firmly established, the timing and other particulars of a return migration (which might contribute to the mismatch), have not been demonstrated. Since mature females are thought to remain in the shallower areas throughout the year, the specifics of this return migration are also important because they are critical to understanding whether males continue to participate in breeding throughout their lives.

A total of 277 adult males were tagged and 33 were recovered by the fishery between 2011 and 2012. Analyses of the tag depth records indicated that most of these males underwent some limited inshore movements during spring, but that the timing and extent of these movements were highly variable among individuals. Comparisons of tag depth records with distributions of adult female snow crab during the two years in which tagged males were at liberty, indicated that inshore movements were likely made for the purpose of mating. However, the timing and extent of these migrations were such these males could only mate with females that had already released a brood in a prior years (multiparous), and not with those that were holding their first brood (primiparous).

For more information, contact Dan Nichol, e-mail: dan.nichol@noaa.gov

b. Assessment

Grenadiers - ABL

The Secretary of Commerce approved Amendments 100/91 on August 6, 2014, which added the grenadier complex into both FMPs as Ecosystem Components. Under this rule, they are not allowed to be targeted, but there is an 8% Maximum Retainable Allowance (MRA). There are no OFL, ABC, and TACs. It is recommended that an Ecosystem Component be monitored for overfishing, but no definition of overfishing exists for this group and a SAFE report is not required. The only other Ecosystem Component is forage fish. An unofficial assessment has been conducted annually since 2006. An abbreviated full SAFE was prepared in 2014 that presented unofficial ABC and OFL values using tier 5 calculations. A random effects model was used for an updated estimate of GOA biomass. The great majority of grenadier biomass is below 700 m and no trawl surveys have sampled from 700-1,000 m since 2009. The model is used to estimate biomass in three depth strata separately and then three are summed for a total biomass estimate. Since there was no trawl survey in the GOA in 2014, the estimate for 2013 is used as the most recent value of exploitable biomass. There was no EBS slope trawl survey in 2014 and so the biomass estimate remained the same. Estimated catch is not close to approaching unofficial ABCs and so we conclude that overfishing is not occurring in the BSAI or the GOA. The Plan Team and the Scientific and Statistical Committee of the NPFMC have requested an abbreviated assessment, like the one prepared in 2014, every other year with no executive summary report in off years.

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

D. Other Related Studies

Fisheries Resource Pathology Program – RACE

During the 2013 survey season, the Fisheries Resource Pathobiology sub-task continued its monitoring effort of potentially important diseases of a number of species found in the Bering Sea shelf region. As part of an ongoing study, non-lethal hemolymph withdrawals were collected from *Chionoecetes opilio, Chionoecetes bairdi*, *Paralithodes camtschaticus*, and *Paralithodes platypus* to determine the prevalence and distribution of bitter crab syndrome caused by *Hematodinium sp*., a parasitic dinoflagellate.

As a disease program, we frequently get inquiries regarding the nature of encountered anomalies. It is our goal to develop a web-based reference site or information center. Therefore, we inspected numerous fish and shellfish for assorted visual anomalies during the 2013 EBS RACE survey. Abnormalities were photographed, excised, and placed in fixative for subsequent microscopic diagnosis and for genetic characterization of the respective etiological agent. Species analyzed included Alaska plaice, yellowfin sole, northern rock sole, Pacific cod, flathead sole, and walleye Pollock.

For further information, contact Dr. Pam Jensen, (206) 526-4122.

Systematics Program - RACE GAP

Several projects on the systematics of fishes of the North Pacific have been completed or were underway during 2014. A taxonomic revision, based on molecular and morphological data, of the sandlance genus *Ammodytes* of the North Pacific was published (Orr et al., 2015), recognizing two species in the eastern North Pacific (*A. hexapterus* in the Bering Sea and north; *A. personatus* in the southern Bering Sea and south) and describing and naming a new species from Japan. We (Orr and Wildes) are continuing our work on sandlances by including Atlantic species in a global analysis and conducting more detailed population-level studies in the eastern Pacific. A paper documenting the genetic diversity of lumpsuckers (Cyclopteridae) across the North Pacific and marginal seas (Kai et al., 2014) was published, as well as a range extension documenting the presence of two species of manefishes (Caristiidae) in Japanese waters (Okamoto et al., 2014) and a manuscript clarifying the taxonomy and distribution of sculpins of the genus *Malacocottus*, including recognition of *M. aleuticus* as a juvenile form of *M. zonurus* and *M. kincaidi* (Stevenson, 2015). A guide to cods and cod-like fishes (Gadiformes) is complete and being formatted for distribution (Hoff, Orr, and Stevenson, in press). A taxonomic revision of snailfishes in the *Careproctus rastrinus* species complex, including the description of a new species from the Beaufort Sea, was completed and tentatively accepted (Orr et al., in review). An additional study testing the hypothesis of cryptic speciation in northern populations of the eelpout genus *Lycodes* (Stevenson) is underway. Also in progress are studies 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); and a partial revision of the lumpsucker genus *Eumicrotremus* (Stevenson). A description of two new species of snailfishes from the Aleutian Islands is in preparation (Orr) and work on the morphology of the pectoral girdle (Orr, with UW), and other new species continues. In addition to taxonomic revisions, descriptions of new taxa, and guides, RACE systematists have collaborated with molecular biologists at the University of Washington and within AFSC to identify snailfish eggs in king crabs (Gardner, Orr, Stevenson, Somerton, and Spies, in review) and to examine population-level genetic diversity in the skates

Bathyraja parmifera, related to its nursery and undertaken with NPRB support (Hoff, Stevenson, Spies, and Orr). Molecular and morphological studies on *Bathyraja interrupta* (Stevenson, Orr, Hoff, and Spies), *Eumicrotremus* (Kai and Stevenson), and *Lycodes* (Stevenson and Paquin) are also underway. In addition to systematic publications and projects, RACE systematists have been involved in works on the zoogeography of North Pacific fishes, including collaborations with the University of Washington on a checklist of the fishes of the Salish Sea (Pietsch and Orr, in press) and notes on new records and range extensions of other fishes (Paquin et al., in press).

With the support of NPRB and JISAO, an annotated checklist of the marine macroinvertebrates of Alaska comprising over 3500 species has been tentatively accepted (Drumm et al., in review). As a result of this checklist and following Stevenson and Hoff's (2009) for the Bering Sea shelf, a processed report providing species-level confidence identification matrix for the Gulf of Alaska and Aleutian Islands and another on species of the Bering Sea slope were published (Orr et al., 2014a,b). A report on a pilot study to collect coral bycatch data from the Alaska commercial fishing fleet was also completed (Stone et al., in press).

Salmon Excluders – RACE Conservation Engineering (CE)

We continued our collaboration with industry on new designs for salmon excluders. Efforts have focused on testing and improving a new design that would allow escape from both above and below, resulting from a previous flume tank workshop. We began by participating in a model testing/development workshop at the flume tank in St. Johns, Newfoundland. The North Pacific Fisheries Research Foundation placed a technician aboard Gulf of Alaska vessels to demonstrate correct tuning and operation of the new excluder design to promote transfer of this technology to that fleet. The AFSC provided the camera systems used by this technician from our CE "loaner pool." This work was conducted both in the Bering Sea and the Gulf of Alaska Pollock trawl fisheries. Tests in 2013 and 2014 of the new over/under design in the Gulf of Alaska trawl fleet show escapement rates for salmon between 35-54%. Pollock escape was insignificant at less than 1%. Because the new excluder system includes more and larger escape portals, escapes are being monitored with video instead of the more cumbersome recapture nets. The CE program developed a much more compact camera system for this work and up to six of these have been used during the same tow. This new camera system is expected to see wide use on Alaska fishing vessels. The most recent design is currently being tested in 2015 in the Bering Sea.

Develop Alternative Trawl Designs to Effectively Capture Pollock Concentrated Against the Seafloor While Reducing Bycatch and Damage to Benthic Fauna – RACE 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 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%. We are still working on analyzing the data to determine impacts to benthic structure forming organisms. CE cooperative research moving forward includes work with industry to adapt the prototype footropes tested in 2014 for regular commercial use and full scale tests of the resulting designs to confirm commercial effectiveness.

Provide Underwater Video Systems to Fishermen and Other Researchers to Facilitate Development of Fishing Gear Improvements – RACE 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 of fishing gear operation and quicker development of improvements is being realized. While the existing camera systems have been maintained, a significant advance in this area has been the development and testing of much more compact and inexpensive camera systems for use on commercial fishing gear. All camera system components are enclosed in a single 3.5 inch diameter acrylic tube mounted on a plastic plate. The entire system measures 21 x 9 x 5 inches and is of nearly neutral buoyancy in water. These systems have been in use for about 2 years now and have proven to be very easy to use, durable and flexible. Six new systems will be built for our use and as replacements of the older 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.

APPENDIX I - AFSC GROUNDFISH-RELATED PUBLICATIONS AND DOCUMENTS

Published January 2014 through December 2014 (AFSC authors in bold text)

BAKER, **M. R.**, and **A. B. HOLLOWED**.
2014. Delineating ecological regions in marine systems: Integrating physical structure and community composition to inform spatial management in the eastern Bering Sea. Deep-Sea Res. II 109:215-240.

BARBEAUX, **S. J.**, **J. K. HORNE**, and **J. N. IANELLI**.
2014. A novel approach for estimating location and scale specific fishing exploitation rates of eastern Bering Sea walleye pollock (*Theragra chalcogramma*). Fish. Res. 153:69-82.

BOGRAD, S. J., E. L. HAZEN, E. A. HOWELL, and **A. B. HOLLOWED**.
2014. The fate of fisheries oceanography: Introduction to the special issue. Oceanography 27(4):21-25.

BUSBY, **M. S.**, **J. T. DUFFY-ANDERSON**, **K. L. MIER**, and **L. G. De FOREST**.
2014. Spatial and temporal patterns in summer ichthyoplankton assemblages on the eastern Bering Sea shelf 1996–2007. Fish. Oceanogr. 23:270-287.

CAHALAN, **J.**, J. GASPER, and J. MONDRAGON. 2014. Catch sampling and estimation in the federal groundfish fisheries off Alaska, 2015 edition. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-286, 46 p. Online. (.pdf, 664 KB).

CONN, **P. B.**, **D. S. JOHNSON**, **L. W. FRITZ**, and **B. S. FADELY**.
2014. Examining the utility of fishery and survey data to detect prey removal effects on Steller sea lions (*Eumetopias jubatus*). Can. J. Fish. Aquat. Sci. 71:1229-1242.

CONRATH, **C. L.**, and **M. E. CONNERS**.
2014. Aspects of the reproductive biology of the North Pacific giant octopus (*Enteroctopus dofleini*) in the Gulf of Alaska. Fish. Bull., U.S. 112:253-260. Online. (.pdf, 1 MB).

De FOREST, **L.**, **J. T. DUFFY-ANDERSON**, **R. A. HEINTZ**, **A. C. MATARESE**, **E. C. SIDDON**, **T. I. SMART**, and **I. B. SPIES**.
2014. Taxonomy of the early life stages of arrowtooth flounder (*Atheresthes stomias*) and Kamchatka flounder (*A. evermanni*) in the eastern Bering Sea, with notes on distribution and condition. Deep-Sea Res. II 109:181-189.

De ROBERTIS, **A.**, and **K. TAYLOR**.
2014. *In situ* target strength measurements of the scyphomedusa *Chrysaora melanaster*. Fish. Res. 153:18-23.

De ROBERTIS, **A.**, **D. McKELVEY**, **K. TAYLOR**, and **T. HONKALEHTO**.
2014. Development of acoustic-trawl survey methods to estimate the abundance of age-0 walleye pollock in the eastern Bering Sea shelf during the Bering Arctic Subarctic Integrated Survey (BASIS). U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-272, 46 p. Online (.pdf, 2.39 MB).

FAUNCE, **C.**, **J. CAHALAN**, J. GASPER, **T. A'MAR**, **S. LOWE**, **F. WALLACE**, and R. WEBSTER.
2014. Deployment performance review of the 2013 North Pacific Groundfish and Halibut Observer Program. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-281, 74 p. Online (.pdf, 4.15 MB).

FELTHOVEN, **R.**, J. LEE, and K. SCHNIER.
2014. Cooperative formation and peer effects in fisheries. Mar. Resour. Econ. 29:133-156.

FISSEL, **B. E.**
2014. Economic indices for the North Pacific groundfish fisheries: Calculation and visualization. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-279, 47 p. Online (.pdf, 756 KB).

FOWLER, **C. W.**, and S. M. LUIS.
2014. We are not asking management questions. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-267, 48 p. Online (.pdf, 1.26 MB).

FOWLER, **C. W.**, R. D. REDEKOPP, V. VISSAR, and J. OPPENHEIMER.
2014. Pattern-based control rules for fisheries management. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-268, 116 p. Online (.pdf, 1.6 MB).

GODDARD, P., **R. LAUTH**, and **C. ARMISTEAD**.
2014. Results of the 2012 Chukchi Sea bottom trawl survey of bottomfishes, crabs, and other demersal macrofauna. U. S. Dep. Commer., NOAA-TM-AFSC-278, 110 p. Online (.pdf, 8.74 MB).

GUYON, **J. R.**, **C. M. GUTHRIE III**, A. R. MUNRO, J. JASPER, and W. D. TEMPLIN.
2014. Extension of genetic stock composition analysis to the Chinook salmon bycatch in the Gulf of Alaska walleye pollock (*Gadus chalcogrammus*) trawl fisheries, 2012. U. S. Dep. Commer., NOAA-TM-AFSC-285, 26 p. Online. (.pdf, 725 KB).

HAWKYARD, M., **B. LAUREL**, and C. LANGDON.
2014. Rotifers enriched with taurine by microparticulate and dissolved enrichment methods influence the growth and metamorphic development of northern rock sole (*Lepidopsetta polyxystra*) larvae. Aquaculture 424-42:151-157.

HELSER, **T. E.**, **C. R. KASTELLE**, and H-L. LAI.
2014. Modeling environmental factors affecting assimilation of bomb-produced $\Delta 14^{C}$ in the North Pacific Ocean: Implications for age validation studies. Ecol. Model. 277:108-118.

HOLLOWED, **A.**, and S. SUNDBY.
2014. Change is coming to the northern oceans. Science 344:1084-1085.

HUGHES, K., M. KAISER, S. JENNINGS, **R. McCONNAUGHEY**, R. PITCHER, R. HILBORN, R. AMOROSO, J. COLLIE, J. HIDDINK, A. PARMA, and A. RIJNSDORP.
2014. Investigating the effects of mobile bottom fishing on benthic biota: A systematic review protocol. Environ. Evid. 3:23. (Open Access). Online. (.pdf, 504 KB).

KAMIN, L. M., K. J. PALOF, **J. HEIFETZ**, and A. J. GHARRETT.
2014. Interannual and spatial variation in the population genetic composition of young-of-the-year Pacific ocean perch (*Sebastes alutus*) in the Gulf of Alaska. Fish. Oceanogr. 23:1-17.

KOTWICKI, **S.**, **J. N. IANELLI**, and A. E. PUNT.
2014. Correcting density-dependent effects in abundance estimates from bottom-trawl surveys. ICES J. Mar. Sci. 71:1107–1116.

LAUTH, **R. R.**, and **J. CONNER**.
2014. Results of the 2011 Eastern Bering Sea continental shelf bottom trawl survey of groundfish and invertebrate fauna. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-266, 176 p. Online (.pdf, 8 MB).

LEHNERT, H., and **R. P. STONE**.
2014. Aleutian Ancorinidae (Porifera, Astrophorida): Description of three new species from the genera *Stelletta* and *Ancorina*. Zootaxa 3826:341-355.

LEHNERT, H., **R. P. STONE**, and **D. DRUMM**.
2014. *Geodia starki* sp. nov. (Porifera, Demospongiae, Astrophorida) from the Aleutian Islands, Alaska, USA. J. Mar. Biol. Assoc. UK 94:261-265.

LOEFFLAD, **M. R.**, **F. R. WALLACE**, J. MONDRAGON, J. WATSON, and **G. A. HARRINGTON**.
2014. Strategic plan for electronic monitoring and electronic reporting in the North Pacific. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-276, 52 p. Online. (.pdf, 1 MB).

MATEO, I., and **D. H. HANSELMAN**.
2014. A comparison of statistical methods to standardize catch-per-unit-effort of the Alaska longline sablefish. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-269, 71 p. Online (.pdf, 3 MB).

McBRIDE, M. M., P. DALPADADO, K. F. DRINKWATER, O. R. GODØ, A. J. HOBDAY, **A. B. HOLLOWED**, T. KRISTIANSEN, E. J. MURPHY, **P. H. RESSLER**, S. SUBBEY, E. E. HOFMANN, and H. LOENG.
2014. Krill, climate, and contrasting future scenarios for Arctic and Antarctic fisheries. ICES J. Mar. Sci. 71:1934-1955.

McCLATCHIE, S., **J. DUFFY-ANDERSON**, J. C. FIELD, R. GOERICKE, D. GRIFFITH, D. S. HANISKO, J. A. HARE, J. LYCZKOWSKI-SHULTZ, W. T. PETERSON, W. WATSON, E. D. WEBER, and G. ZAPFE.
2014. Long time series in U.S. fisheries oceanography. Oceanography 27(4):48-67.

McCONNAUGHEY, **R. A.**, and **S. E. SYRJALA**.
2014. Short-term effects of bottom trawling and a storm event on soft-bottom benthos in the eastern Bering Sea. ICES J. Mar. Sci. 71:2469-2483. Online. (.pdf, 521 KB).

MOORE, S. E., **E. A. LOGERWELL**, **L. EISNER**, E. V. FARLEY, Jr., L. A. HARWOOD, K. KULETZ, J. LOVVORN, J. R. MURPHY, and L. T. QUAKENBUSH.

2014. Marine fishes, birds and mammals as sentinels of ecosystem variability and reorganization in the Pacific Arctic region, p. 337-392. *In* J. M. Grebmeier and W. Maslowski (editors), The Pacific Arctic Region: Ecosystem Status and Trends in a Rapidly Changing Environment. Springer, Dordrecht.

OKAMOTO, M., **D. E. STEVENSON**, and H. MOTOMURA.
2014. First record of *Paracaristius maderensis* from the central North Pacific and a second specimen of *Platyberyx rhyton* (Perciformes: Caristiidae). Biogeography 16:23-29.

OVERDICK, **A.**, **M. BUSBY**, and **D. BLOOD**.
2014. Descriptions of eggs of snailfishes (family Liparidae) from the Bering Sea and eastern North Pacific Ocean. Ichthyol. Res. 61:131-141.

PAQUIN, **M. M.**, **T. W. BUCKLEY**, **R. E. HIBPSHMAN**, and **M. F. CANINO**.
2014. DNA-based identification methods of prey fish from stomach contents of 12 species of eastern North Pacific groundfish. Deep-Sea Res. I 85:110-117.

PAQUIN, **M. M.**, A. N. KAGLEY, K. L. FRESH, and **J. W. ORR**.
2014. First records of the night smelt, *Spirinchus starksi*, in the Salish Sea, Washington. Northwest. Nat. 95:40-43.

PUNT, A. E., and **M. W. DORN**.
2014. Comparisons of meta-analytic methods for deriving a probability distribution for the steepness of the stock recruit relationship. Fish. Res. 149:43-54.

PUNT, A. E., D. POLJAK, M. G. DALTON, and **R. J. FOY**.
2014. Evaluating the impact of ocean acidification on fishery yields and profits: the example of red king crab in Bristol Bay. Ecol. Model. 285:39-53.

PUNT, A. E., C. S. SZUWALSKI, and **W. STOCKHAUSEN**.
2014. An evaluation of stock–recruitment proxies and environmental change points for implementing the US Sustainable Fisheries Act. Fish. Res. 157:28-40.

PUNT, A. E., **T. A'MAR**, N. A. BOND, D. S. BUTTERWORTH, C. L. De MOOR, J. A. A. De OLIVEIRA, M. A. HALTUCH, **A. B. HOLLOWED**, and C. SZUWALSKI.
2014. Fisheries management under climate and environmental uncertainty: Control rules and performance simulation. ICES J. Mar. Sci. 71:2208-2220.

RAND, **K. M.**, **P. MUNRO**, **S. K. NEIDETCHER**, and **D. G. NICHOL**.
2014. Observations of seasonal movement from a single tag release group of Pacific cod in the eastern Bering Sea. Mar. Coastal Fish. 6:287-296.

RESSLER, **P. H.**, **A. De ROBERTIS**, and **S. KOTWICKI**.
2014. The spatial distribution of euphausiids and walleye pollock in the eastern Bering Sea does not imply top-down control by predation. Mar. Ecol. Prog. Ser. 503:111-122.

RIEUCAU, G., K. M. BOSWELL, **A. De ROBERTIS**, G. J. MACAULAY, and N. O. HANDEGARD.

2014. Experimental evidence of threat-sensitive collective avoidance responses in a large wild-caught herring school. PLoS ONE 9(1): e86726. Online. (.pdf, 750 KB).

RIEUCAU, G., **A. De ROBERTIS**, K. M. BOSWELL, and N. O. HANDEGARD.
2014. School density affects the strength of collective avoidance responses in wild-caught Atlantic herring *Clupea harengus*: a simulated predator encounter experiment. J. Fish Biol. 85:1650-1664.

RIVERA, K. S., L. T. BALLANCE, L. BENAKA, E. R. BREUER, S. G. BROOKE, **S. M. FITZGERALD**, P. L. HOFFMAN, N. LeBOEUF, and G. T. WARING.
2014. Report of the National Marine Fisheries Service's National Seabird Workshop: Building a National Plan to Improve the State of Knowledge and Reduce Commercial Fisheries Impacts on Seabirds. September 9–11, 2009, Alaska Fisheries Science Center, Seattle, WA. U.S. Dept. of Commer., NOAA Tech. Memo. NMFS-F/SPO-139, 78 p.

ROOPER, **C. N.**, **M. ZIMMERMANN**, M. M. PRESCOTT, and A. J. HERMANN.
2014. Predictive models of coral and sponge distribution, abundance and diversity in bottom trawl surveys of the Aleutian Islands, Alaska. Mar. Ecol. Prog. Ser. 503:157-176.

SCHOBERND, Z. H., N. M. BACHELER, and **P. B. CONN**.
2014. Examining the utility of alternative video monitoring metrics for indexing reef fish abundance. Can. J. Fish. Aquat. Sci. 71:464-471.

SHEFFIELD GUY, L., **J. DUFFY-ANDERSON**, **A. C. MATARESE**, C. W. MORDY, **J. M. NAPP**, and P. J. STABENO.
2014. Understanding climate control of fisheries recruitment in the eastern Bering Sea: Long-term measurements and process studies. Oceanography 27(4):90-103.

SHOTWELL, **S. K.**, **D. H. HANSELMAN**, and I. M. BELKIN.
2014. Toward biophysical synergy: Investigating advection along the Polar Front to identify factors influencing Alaska sablefish recruitment. Deep-Sea Res. II 107:40-53.

SIGLER, **M. F.**, P. J. STABENO, **L. B. EISNER**, **J. M. NAPP**, and F. J. MUETER.
2014. Spring and fall phytoplankton blooms in a productive subarctic ecosystem, the eastern Bering Sea, during 1995-2011. Deep-Sea Res. II 109:71-83.

SMITH, **K. R.**, and **C. E. ARMISTEAD**.
2014. Benthic invertebrates of the eastern Bering Sea: a synopsis of the life history and ecology of the sea star *Asterias amurensis*. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-273, 60 p. Online (.pdf, 4.5 MB).

STACHURA, M. M., T. E. ESSINGTON, N. J. MANTUA, **A. B. HOLLOWED**, M. A. HALTUCH, **P. D. SPENCER**, T. A. BRANCH, and M. J. DOYLE.
2014. Linking Northeast Pacific recruitment synchrony to environmental variability. Fish. Oceanogr. 23:389-408.

STONE, **R. P.**
2014. The ecology of deep-sea coral and sponge habitats of the central Aleutian Islands of Alaska. NOAA Professional Paper NMFS 16, 52 p.

STONE, **R. P.**, K. W. CONWAY, **D. J. CSEPP**, and J. V. BARRIE.
2014. The boundary reefs: Glass sponge (Porifera: Hexactinellida) reefs on the international border between Canada and the United States. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-264, 31 p. Online. (.pdf, 10 MB).

THOMPSON, K. A., S. S. HEPPELL, and **G. G. THOMPSON**.
2014. The effects of temperature and predator densities on the consumption of walleye pollock (*Theragra chalcogramma*) by three groundfish in the Gulf of Alaska. Can. J. Fish. Aquat. Sci. 71:1123-1133.

THOMPSON, L. A., T. R. SPOON, C. E. C. GOERTZ, **R. C. HOBBS**, and T. A. ROMANO.
2014. Blow collection as a non-invasive method for measuring cortisol in the beluga (*Delphinapterus leucas*). PLoS One 9(12):e114062. Online. (html page)

TORRES, M., and **R. FELTHOVEN**.
2014. Productivity growth and product choice in catch share fisheries: the case of Alaska pollock. Mar. Policy 50:280-289.

TRIBUZIO, **C. A.**, J. R. GASPER, and **S. K. GAICHAS**.
2014. Estimation of bycatch in the unobserved Pacific halibut fishery off Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-265, 506 p. Online. (.pdf., 8 MB).

VESTFALS, C. D., L. CIANNELLI, **J. T. DUFFY-ANDERSON**, and C. LADD.
2014. Effects of seasonal and interannual variability in along-shelf and cross-shelf transport on groundfish recruitment in the eastern Bering Sea. Deep-Sea Res. II 109:190-203.

VULSTEK, **S. C.**, **C. M. KONDZELA**, **C. T. MARVIN**, **J. WHITTLE**, and **J. R. GUYON**.
2014. Genetic stock composition analysis of chum salmon bycatch and excluder device samples from the 2012 Bering Sea walleye pollock trawl fishery. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-271, 35 p. Online. (.pdf., 972 KB).

WALDEN, J., J. AGAR, **R. FELTHOVEN**, A. HARLEY, **S. KASPERSKI**, J. LEE, T. LEE, A. MAMULA, J. STEPHEN, A. STRELCHECK, and E. THUNBERG.
2014. Productivity change in U.S. catch shares fisheries. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-F/SPO-146, 137 p.

WALLER, R. G., **R. P. STONE**, J. JOHNSTONE, and J. MONDRAGON.
2014. Sexual reproduction and seasonality of the Alaskan red tree coral, *Primnoa pacifica*. PLoS ONE 9(4): e90893. doi:10.1371/journal.pone.0090893. Online. (.pdf, 5.39 MB).

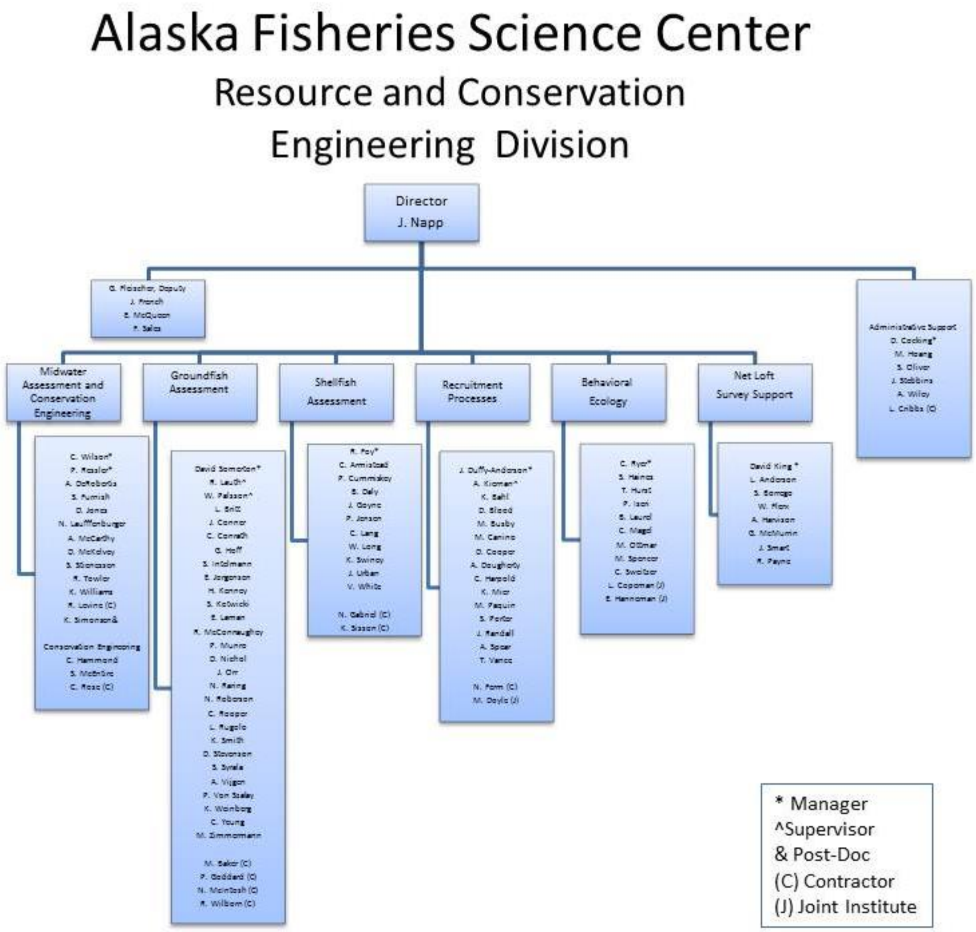
WEST, J. E., **T. E. HELSER**, and S. M. O'NEILL.
2014. Variation in quillback rockfish (*Sebastes maliger*) growth patterns from oceanic to inland waters of the Salish Sea. Bull. Mar. Sci. 90:747–761.

WHITEHOUSE, **G. A.**, **K. AYDIN**, T. E. ESSINGTON, and G. L. HUNT, Jr.
2014. A trophic mass balance model of the eastern Chukchi Sea with comparisons to other high-latitude systems. Polar Biol. 37:911-939.

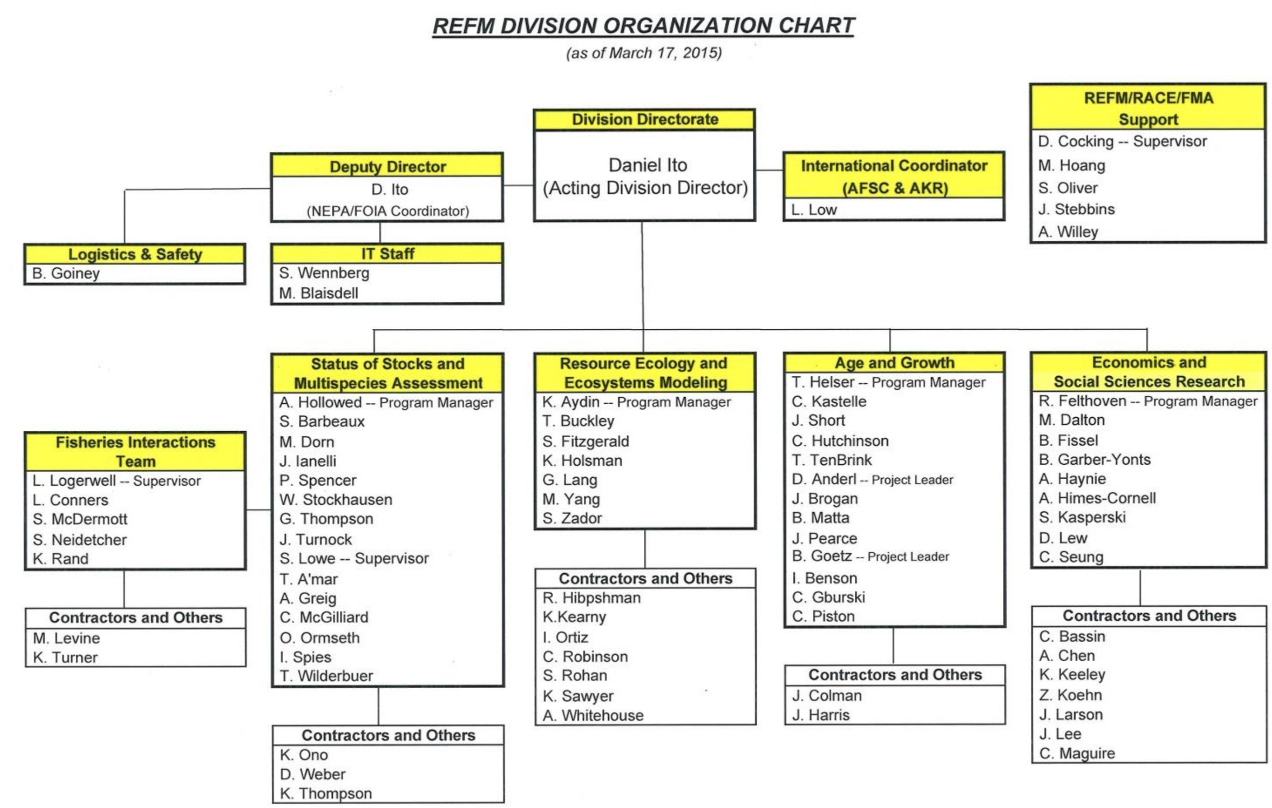
YEUNG, **C.**, and **M.-S. YANG**.
2014. Habitat and infauna prey availability for flatfishes in the northern Bering Sea. Polar Biol. 37:1769-1784.

ZIMMERMANN, **M.**, and **M. M. PRESCOTT**.
2014. Smooth sheet bathymetry of Cook Inlet, Alaska. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-275, 32 p. Online. (.pdf, 3.28 MB).

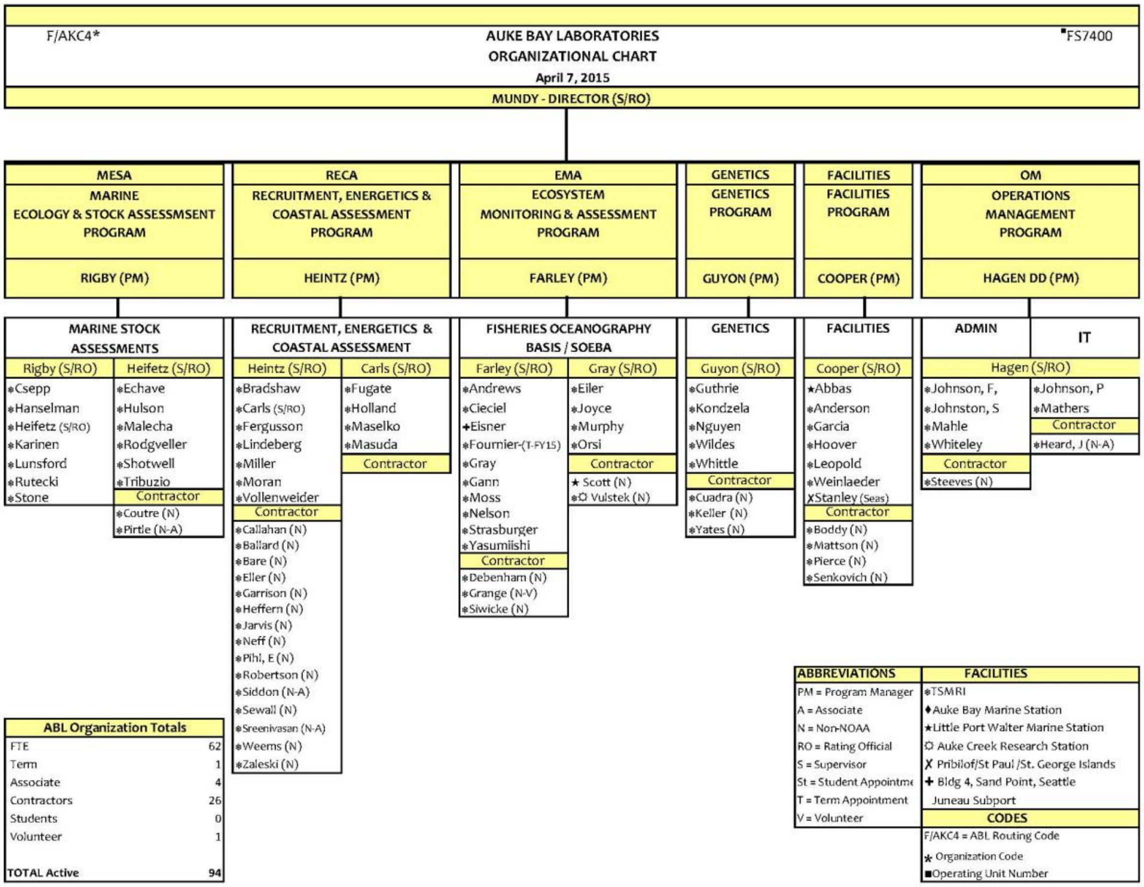
APPENDIX II. RACE ORGANIZATION CHART



APPENDIX III. REFM ORGANIZATION CHART



APPENDIX IV – AUKE BAY LABORATORY ORGANIZATIONAL CHART



APPENDIX V – FMA ORGANIZATIONAL CHART