Ecosystem Monitoring & Assessment (EMA) Program

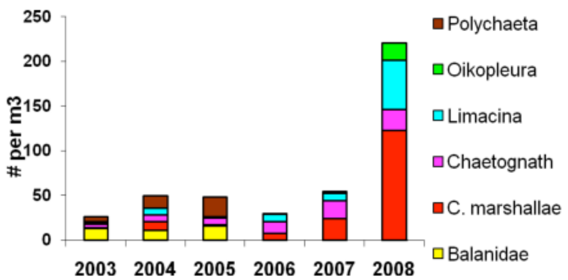

Figure 1. Mean abundance (# per m³) of large zooplankton within the southeastern Bering Sea Shelf. Data from Bongo nets tows with 505–um mesh nets.

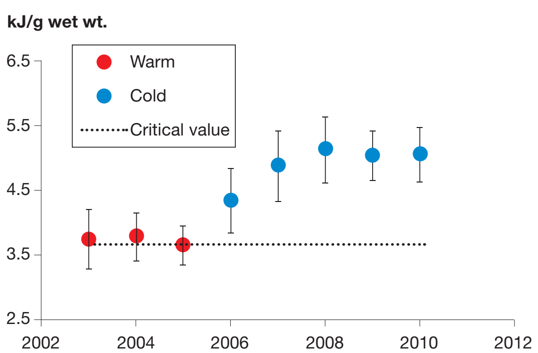

Figure 2. Energetic status of age–0 walleye pollock during years with warm (black) and cold (gray) spring and summer sea temperatures on the eastern Bering Sea shelf. The critical value (line) is the energetic status of age–1 walleye pollock collected during spring (survived winter) in southeast Alaska.

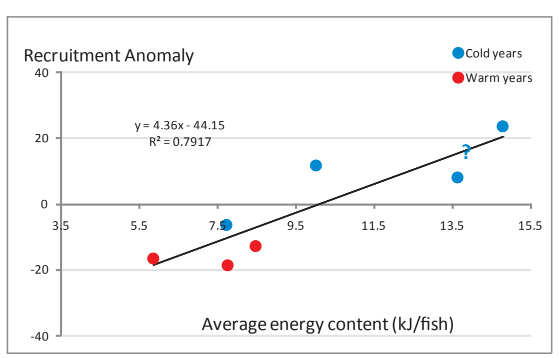

Figure 3. The relationship of survivorship (Recruitment Anomaly) of age–1 walleye pollock to average energy content of age–0 walleye pollock collected 1 year earlier in the eastern Bering Sea.

BASIS: Linking Recent Changes in Ocean Conditions With Pelagic Fish Recruitment

The AFSC conducts regular, comprehensive trawl surveys of marine fish and invertebrate populations in the Bering Sea using chartered commercial fishing vessels. The established survey design is to conduct annual surveys of continental slope groundfish in the Bering Sea. Auke Bay Laboratories (ABL) Ecosystem Monitoring and Assessment (EMA) program conducts these comprehensive trawl surveys and related research in the exclusive economic zone off Alaska as required to monitor and describe trends in abundance and distribution of commercially and ecologically valuable groundfish populations. Scientists within the EMA program conduct these comprehensive surveys as part of the Bering Aleutian Salmon International Survey (BASIS) designed to improve our collective understanding of fisheries and oceanographic ecosystem indices in the North Pacific Ocean and to clarify mechanisms linking recent changes in ocean conditions with pelagic fish recruitment.

Climate models predict a gradual increase in atmospheric temperature, with the greatest increases occurring in sub-arctic and arctic regions. The evidence for current warming trends is the pole-ward retreat of seasonal sea ice cover in the Arctic. Continued warming is predicted to have a profound effect on Bering Sea ecosystems. For instance, there is evidence that climate warming will increase water column stability on the eastern Bering Sea shelf, limiting the flux of nutrients into the photic zone and perhaps negatively impacting primary and secondary productivity. In addition, large-scale climate cycles are affecting regional climate trends. Shifts in the position of the Far Eastern Low and Aleutian Low pressure systems determine whether or not the Bering Sea experiences warming or cooling and also affects the velocity of ocean currents. The position of these atmospheric low pressure systems (NE and W, respectively) during 2002 to 2005 brought warmer air to the Bering Sea during winter and was related to decreased storm activity during summer. The position of these low pressure systems shifted again (SW and E, respectively) during 2006, resulting in colder arctic air covering much of the Bering Sea during winter and summer which increased storm activity.

Identification of linkages between climate and the ecosystem requires a conceptual framework in which to compare observational data and build numerical models. BASIS collects observational data on the biological characteristics of fish and subsequent physical and biological oceanographic data that may affect fish recruitment. The surveys began in 2002, a time of anomalously warm spring and summer sea temperatures. These warm sea temperatures continued through 2005, switching to anomalously cold from 2006 to 2010. The survey is conducted during late summer to early fall to address the Critical Size and Period hypothesis for juvenile (Pacific salmon) and age-0 pelagic fish (walleye pollock and Pacific cod) species. Fish that do not reach a critical size and energetic fitness prior to their first winter at sea may sustain higher overwinter mortality.

BASIS data have been used to support the predictions that, in years with early ice retreat, more primary production remains in the pelagic environment of the eastern Bering Sea, and that high numbers of age-0 pollock survive to summer. However, in these years, production of large crustacean zooplankton is reduced (Fig. 1), depriving age-0 pollock of lipid-rich prey in summer and fall. Consequently, age-0 pollock energy reserves (Fig. 2) are low and predation on them is increased. The result is weak recruitment of age-1 recruits the following year (Fig. 3). A revised oscillating control hypothesis indicates bottom-up constraints on pollock recruitment in very warm periods. Prolonged warm periods with decreased ice cover will likely cause diminished pollock recruitment and catches relative to recent values.

For more information on the effects of climate on marine ecosystems of the eastern Bering Sea, see Coyle et al. (2011) and Hunt et al. (in press).

By Ed Farley

New Regulatory Requirements Prompt New Observer Sampling Protocols and Increase the Number of Observer Days at Sea

In 2010 the National Marine Fisheries Service (NMFS) issued regulations to implement Amendment 91 to the Fishery Management Plan for Groundfish of the Bering Sea and Aleutian Islands Management Area starting in January 2011. These regulations are intended to minimize Chinook salmon bycatch in the Bering Sea (BS) pollock fishery while maintaining potential for full harvest of the catch by establishing a cap on Chinook salmon bycatch in the fishery. The regulations increased observer coverage requirements to ensure that all catches of BS pollock are monitored and required a substantial change in the observer sampling protocol for salmon to support the estimation of Chinook salmon bycatch and the collection of samples for genetic stock of origin analyses.

Amendment 91 applies to owners and operators of catcher vessels, catcher processors, motherships, inshore processing plants, and the six Western Alaska Community Development Quota (CDQ) Programs participating in the pollock fishery in the BS, as managed under the American Fisheries Act. All Pacific salmon, as well as king and tanner crabs and Pacific halibut, are classified as prohibited species in the groundfish fishery off Alaska, and catch of these species must be avoided. Prior to January 2011, regulations required that any prohibited species caught must be returned to the sea as soon as is practicable after an observer had collected any required data from the species. With the implementation of Amendment 91, bycatch of all salmon species in the BS pollock fishery must be retained. Further, the operator of a vessel and the manager of a shoreside processor or stationary floating processor (SFP) must not discard any salmon or transfer or process any salmon under the Prohibited Species Donation Program until the total number of salmon by species has been determined by the observer and the observer's collection of any scientific data or biological samples from the salmon has been completed.

Above: An observer collecting biological data from a salmon Left: Pollock on the sorting line at a shoreside processing plant. Photos by FMA Division.

The Fisheries Monitoring and Analysis (FMA) Division modified the observer sampling protocols for salmon to meet the data collection needs specified in Amendment 91 to ensure that salmon caught in the BS pollock fishery are counted by species and that genetic specimens are collected from systematically selected individual Chinook and chum salmon. Sampling protocols for chum salmon were modified similarly to those for Chinook salmon to provide consistency for observers in the genetic sampling protocols and because chum salmon are also encountered frequently in the BS pollock fishery. Biological data and scale samples continue to be collected from salmon other than Chinook or chum salmon encountered in the observer's species composition sample.

Observers have collected genetic specimens from Chinook and chum salmon in the BS pollock fishery since 1995 to obtain data on the origin of the salmon caught and sampled in this fishery. These data collections were initially small and grew incrementally each year. With the implementation of Amendment 91, the genetic specimen data collections were increased and altered to use a more statistically rigorous method requested by data users.

Previously a fraction of pollock catcher vessels carried observers during all trips, and the vessel observer monitored the offload for all prohibited species with assistance from the plant observer. On observed trips, the vessel observer gave the plant observer information regarding all salmon caught (including any encountered and discarded at sea) to the plant observer, and the plant observer submitted data showing the total number of each species of salmon occurring in each delivery. Plant observers also counted and reported total number of each species of salmon occurring in each delivery from an unobserved vessel.

Monitoring deliveries of pollock at shoreside processing plants and SFPs is now the top priority of plant observers. All BS pollock catcher vessels now carry observers during all trips. To facilitate complete monitoring of every delivery, the onboard vessel observer assists the plant observer in monitoring the offload. All salmon encountered at sea are placed into the catcher vessel's holding tanks. At the plant, all salmon are sorted out and placed into secured bins. At the end of the offload, the observer conducts a count by species of the salmon and collects specimens and biological data.

On catcher processors and motherships, all salmon are sorted from the catch and placed into secured bins. When the sorting for an individual haul is complete, the observer conducts a count by species of the salmon and collects specimens and biological data. Previously, the observer collected data from prohibited species encountered within their species composition samples. At the end of the processing of each haul, the observer counted and reported the total numbers of salmon in that haul. The increased observer coverage required by Amendment 91 for vessels participating in the BS pollock fishery has contributed to a 19% increase in observer days at sea for the first half of 2011 compared to the same period in each year from 2008 to 2010.

Weekly scheduled communication and coordination among FMA staff, industry, the NMFS Alaska Region Office, and the NMFS Office for Law Enforcement has fostered smooth operations as all participants become accustomed to the new protocols and regulations and has allowed for rapid response to any issues as they arise. New monitoring programs often require adjustments after implementation, and we continue to assess the new protocols, adjust them as needed, and communicate any changes to the involved parties. As we move into the second half of the year we are using the lessons learned in the first half to facilitate continued cooperation among all participants and the collection of high quality data for data users.

A catcher processor at sea. Photo by FMA Division.

More information on Amendment 91 may be found at http://www.alaska fisheries.noaa.gov/sustainablefisheries/bycatch/default.htm. The Bering Sea Chinook Salmon Bycatch Management Volume I Final Environmental Impact Statement is available at http://www.alaskafisheries.noaa.gov/sustainablefisheries/bycatch/salmon/chinook/feis/eis_1209.pdf. The Bering Sea Chinook Salmon Bycatch Management Volume II Final Regulatory Impact Review is available at http://www.alaskafisheries.noaa.gov/sustainablefisheries/bycatch/salmon/chinook/rir/rir1209.pdf.

By Allison Barns

Essential Fish Habitat Funding Received

Proposals for FY 2011 essential fish habitat (EFH) recently were funded. Project selection for EFH research is based on research priorities from the *EFH Research Implementation Plan for Alaska*. Approximately $500,000 is spent on about ten *EFH research projects* each year. Research priorities are

1. Coastal areas facing development
2. Characterization of habitat utilization and productivity
3. Sensitivity, impact, and recovery of disturbed benthic habitat
4. Validation and improvement of habitat impacts model
5. Seafloor mapping

The Habitat and Ecological Processes Research (HEPR) team completed a scientific rating of the 2011 proposals in fall 2010. NMFS Alaska Regional Office Acting Deputy Regional Administrator Jon Kurland and HEPR Program Leader Mike Sigler agreed on rankings based on the scientific review and management priorities. Similar to last year, habitat recovery rate proposals were given higher management priority. The management prioritization generally followed the science ranking but a few changes were made to reflect the relevance of the proposals for fishery management decisions.

Principal Investigators	Titles	Funding
Ryer, Spencer, Iseri, Ottmar, Copeman	Determinants of juvenile tanner crab growth from different nursery embayments	$ 83,000
Malecha, Shotwell, Amman	Recruitment and response to damage of an Alaskan gorgonian coral	$ 16,700
Laurel, Stoner	The role of benthic habitat in larval rock sole settlement dynamics	$ 42,740
Yeung, Yang	Quantifying flatfish habitat quality in the eastern Bering Sea by infauna prey density	$ 124,000
Rose, McEntire	Collection of seafloor imagery during AFSC bottom trawl surveys	$ 11,900
Johnson, Thedinga, Lindeberg	Coastal fishes of Alaska: a synthesis of over a decade of nearshore marine surveys	$ 39,000
Wilson, Rooper	Low-cost multibeam mapping to support habitat based groundfish assessment and deepwater coral research in the Gulf of Alaska	$ 67,400
Total		$ 384,740

Ocean Acidification Funding Received

The AFSC received $493,700 for ocean acidification research in FY 2011. These new funds primarily will be used to conduct species-specific physiological research. The species-specific physiological response to ocean acidification is unknown for most marine species. Lacking basic knowledge, research will be directed toward several taxa including king crab, cold-water corals, and walleye pollock. The research will be conducted at the Kodiak, Auke Bay, and Newport Laboratories. The king crab results also will be incorporate into a king crab bioeconomic model; this work will be completed by the AFSC's Socioeconomics Assessment program in Seattle.

Principal Investigators	Abbreviated titles	Funding
Foy	Alaska red king crab growth and survival	180.0
Foy	Alaska king crab genomics	120.0
Carls, Rice	Calcium carbonate measurements, king crab	85.0
Dalton	Alaska red king crab abundance forecasts	44.2
Foy	Travel, planning workshop	2.0
Carls	Travel, planning workshop	2.0
Hurst	Travel, planning workshop	2.0
Dalton	Travel, modeling workshop	2.0
Hurst	Growth and survival of larval pollock	46.0
Stone	Calcium carbonate mineralogy of Alaskan corals	10.5
Total		493.7

Report of the Bering Sea Project (BEST/BSIERP) Principal Investigators' Meeting

Principal investigators of the Bering Sea Project (BEST/BSIERP) met 22–24 March 2011 in Anchorage, Alaska, to discuss and exchange research findings. About one hundred scientists attended the meeting. The goals of the meeting were to present summary results organized around related projects, to organize focal group discussions, and to review progress toward a road map for synthesis of Bering Sea Project results.

Participants presented key research findings on the following topics: physical oceanography, iron and nutrients, benthos, ice algae and primary production, zooplankton, ichthyoplankton, fish surveys, fish and ocean conditions, seabirds and whales, patch dynamics, local and traditional knowledge and subsistence, lower trophic level models, upper trophic level models, competing models, data management, and outreach. Thanks to everyone who contributed to this interesting and productive meeting.

By Mike Sigler

Alaska Ecosystems Program

Life History and Distribution Patterns of Fishes and Cephalopods: A Window into the Foraging Ecology of Pinnipeds

Prey studies are critical to understanding the foraging behavior of threatened and endangered pinnipeds. They are instrumental in our ability to differentiate (and possibly mitigate) the relative impacts of climate vs anthropogenic (commercial fisheries) driven causes of population decline. The Alaska Ecosystems program (AEP) at the National Marine Mammal Laboratory (NMML) researches the ecology of common prey species in conjunction with annual monitoring of pinniped diets. In the eastern Bering Sea and Gulf of Alaska, these include fishes of commercial (i.e., walleye pollock, *Theragra chalcogramma*) and non-commercial (i.e., deepsea smelt, *Leuroglossus schmidti*) importance and squid of the family Gonatidae (Figs. 1 and 2).

Figure 1. Three species of squid from the family Gonatidae: *Gonatopsis borealis*, *Berryteuthis magister*, and *Gonatus* sp. caught in a single haul in the Bering Sea greenbelt. These specimens range from 18 to 60 cm in length and are examples of prey items critical to marine mammal diets throughout the Bering Sea.

Figure 2. This snailfish (probably *Elassodiscus tremenbundus*) collected in the southeastern Bering Sea is common in Steller sea lion (*Eumetopias jubatus*) diets in specific locations along the Aleutian Islands.

An example of NMML participation in cooperative research investigating broad aspects of the North Pacific ecosystem includes a mesopelagic trawl survey conducted in May 1999 and 2000. As a partner with Fisheries-Oceanography Coordinated Investigations (FOCI) and with funding from the Arctic Research Institute, AEP scientists conducted research trawl operations to depths of 1,200 m specifically targeting forage fishes and squid which are not otherwise monitored (Sinclair and Stabeno 2002, *Deep Sea Research II*). A unique trawl net was designed and constructed for these studies. Directed fishing effort in concert with oceanographic measurements provided multi-layered profiles of the distribution, life history, and energetic value of common marine mammal prey species. The contribution of these collections to our understanding of pinniped foraging ecology continues to unfold as new techniques in animal tracking and diet analyses develop (Kurle et al. 2011, *Marine Biology*).

One key benefit of directed forage fish surveys is the collection and proper identification of a size-stratified series of prey bone samples (Fig. 3). For 60 years, pinniped gut and scat samples have been analyzed for the bony remains of their prey without exact identification of many species common in their diet. The directed forage fish surveys expanded the NMML reference collection of forage fish and cephalopod remains, as they appear in juvenile and adult life stages. Size-stratified bony remains, together with collection location of prey, indicate where and at what level of the water column predators are foraging. Identification of prey species through scat and gut analyses is now dramatically improved. A secondary application of prey collections is quantifying the bio-energetic value of a single meal. Ultimately, meal values are applicable to ecosystem-wide modeling efforts, since many of these prey species are also common in the diets of seabirds and groundfish.

Defining the influence of climate on prey dynamics has become increasingly applicable to interpreting trends in diet and population of northern fur seals (*Callorhinus ursinus*) on the Pribilof Islands, home to the largest breeding colonies of fur seals and seabirds in the North Pacific. Recent analyses demonstrate a close link between sea-surface temperatures, the timing of ice retreat, and shifts in predator diets over the past 35 years (Sinclair et al. 2008, *Deep Sea Research II*). Ocean conditions directly influence the movements and year-class success of forage fishes and cephalopods. Shifts in the distribution and abundance of prey are reflected in seal diets and potentially in predator population trends over time.

Our understanding of the mercurial linkages between climate, diet, and population trends of marine predators is rudimentary. However, a research emphasis on the life history and distribution of their prey has furthered our understanding of factors influencing foraging behavior and trends in predator populations that continue to expand through the years.

By Elizabeth Sinclair

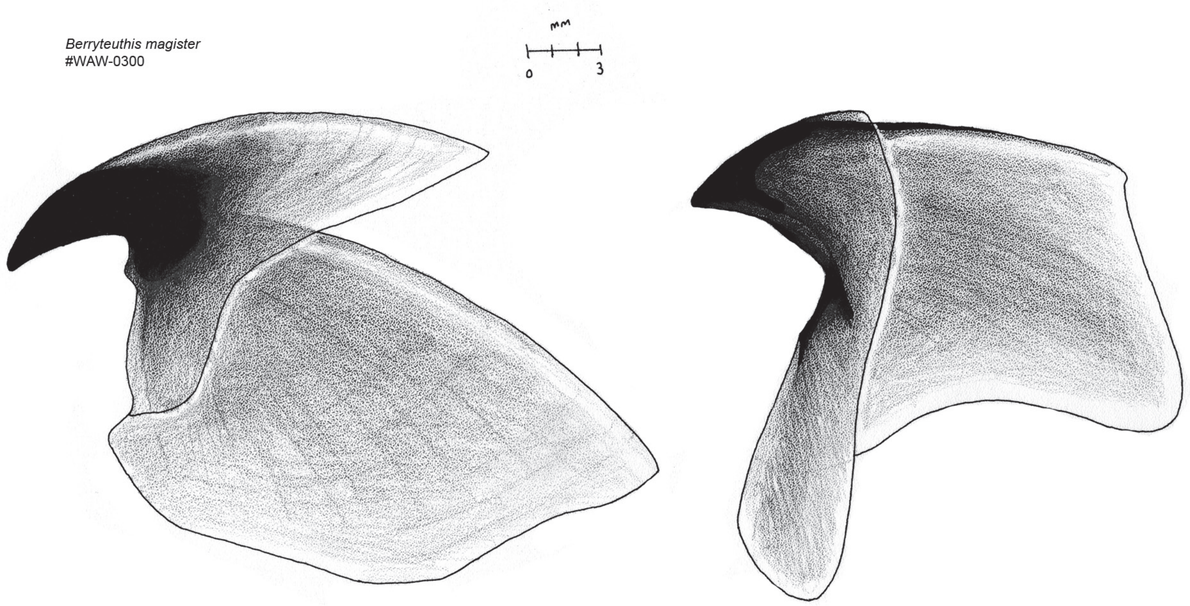

Figure 3. An illustration of beaks from *Berryteuthis magister*, a dominant species in the diet of marine mammals throughout the Gulf of Alaska and Bering Sea. A size-stratified series of this squid species was collected in the eastern Bering Sea and contributed to the NMML reference collection and library of prey energetic values.

Cetacean Assessment & Ecology Program

Pushed to the Edge: Soviet Catches of Right Whales in the Eastern North Pacific

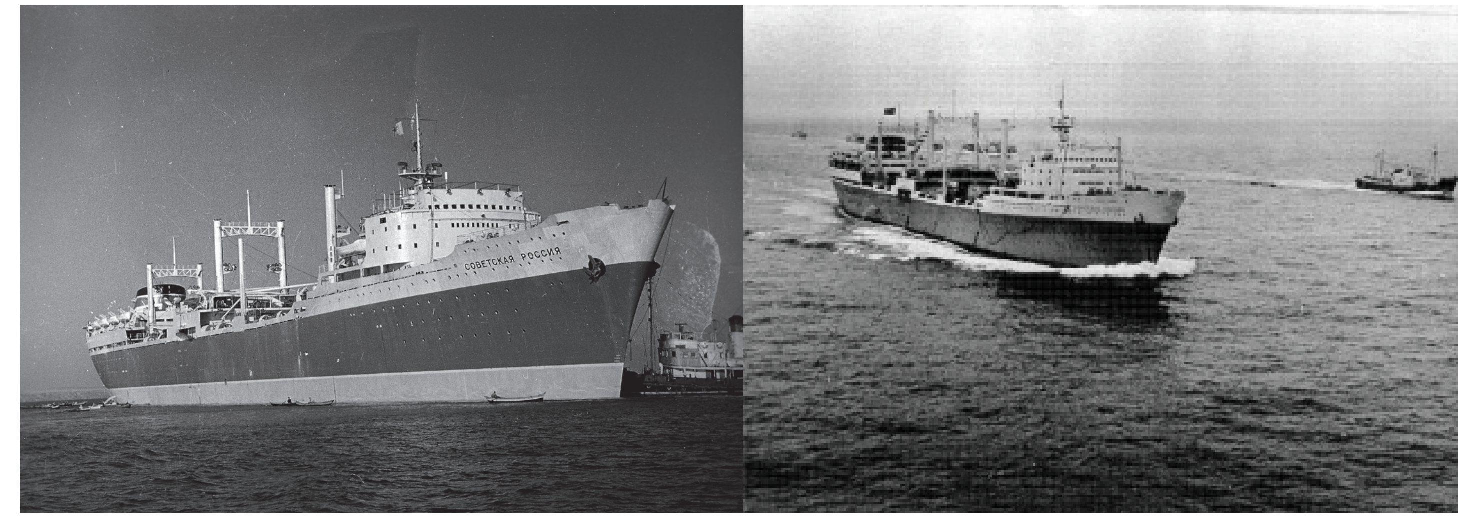

Figure 4. The Soviet whaling factory ship, *Sovetskaya Rossiya*, which killed 142 right whales in the Gulf of Alaska in 1962–63. At 30,000 tons, this was the largest whaling factory ship ever built. Photos courtesy of MOSCOW Project. Photographer unknown.

As reported previously in the AFSC Quarterly Report, July–Sept, 2006, National Marine Mammal Laboratory (NMML) scientists have been centrally involved in documenting the former Soviet Union's extensive campaign of illegal whaling (see Clapham and Ivashchenko 2009, *Marine Fisheries Review*), which took well over 150,000 "unreported" whale catches worldwide. These catches included North Pacific right whales in the southeastern Bering Sea and Gulf of Alaska in the 1960s, as well as in the Sea of Okhotsk. Some information on these catches was published by the former Soviet biologist Nikolai Doroshenko, who documented 372 right whales taken from the eastern North Pacific between 1963 and 1968.

However, a recent search of former Soviet archives has revealed new data on the catches, including discovery of an additional 142 animals taken in the Gulf of Alaska by the *Sovetskaya Rossiya* whaling factory fleet in 1962 and 1963 (Fig. 4). Assuming these catches were indeed all excluded from previous assessments, this would bring the known total from this population to 514 whales, far more than was originally thought. Indeed, it is quite likely that these takes involved the bulk of the remaining right whales at that time, thus seriously jeopardizing any recovery of a population, which had already been severely reduced by historical whaling. Recently, NMML estimated the abundance of the eastern population at about 30 animals, making it the smallest whale population in the world for which an abundance estimate has been calculated (Wade et al. 2011, *Biology Letters*).

A newly discovered scientific report for the *Sovetskaya Rossiya* fleet for 1963 gives previously unknown location data for 112 right whales killed in June of that year in the central and northern Gulf of Alaska, together with the track of the factory ship and summaries of biological data. The sex ratio of the catch was strongly male-biased (73%, or 82 of 112 whales). The great majority of whales (62 of 66 examined) were sexually mature, and the report estimates an average length at attainment of sexual maturity of 15.5 m. Many were large animals, with an overall length range in the catch of 9.7 m to 19.8 m; if the latter figure is correct, it represents a record length for a right whale anywhere in the world (the previous record was 18.2 m, also from the North Pacific). Ten of 18 examined mature females were pregnant. With the exception of data derived from some Japanese scientific catches of right whales, these represent the only available biological data on this species.

None of the *Sovetskaya Rossiya* catches from 1962 and 1963 were in an area south of Kodiak that Nikolai Doroshenko had identified as the location where right whales were taken; this is probably because Doroshenko's data referred to catches made by two other factory fleets (the *Vladivostok* and *Dalnij Vostok* fleets). Further investigations are underway to clarify this question and to assess whether the archives contain additional data on right whales. Meanwhile, the new data will be very useful in designing future surveys, although currently there is no funding at all for North Pacific right whale research despite the critically endangered nature of this population.

This work is part of a Ph.D. study and is an element of an endeavor known as the Memoirs Of Soviet Catches Of Whales (MOSCOW) project, which seeks to preserve memories, photographs, and other materials from the era of Soviet whaling. Photographs and information on this effort are available at http://www.moscowproject.org.

By Yulia V. Ivashchenko and Phillip J. Clapham

Shellfish Assessment Program

Cannibalism in Red King Crab: Effects of Habitat, Predator Density, and Prey Density

Red king crab, *Paralithodes camtschaticus*, an important fishery species in Alaska, exhibits cannibalism both within and among age groups. Cannibalism in crab species can be an important determinant of recruitment success, and this might be especially important in king crab because year-0 and year-1 crabs occupy the same habitat types in the wild. An important aspect of the predator-prey relationship is the predator functional response, which describes how the predation rate of predators varies with prey density. Three common types of functional responses are type I or density independent, type II or inversely density dependent, and type III or density dependent. Type II functional responses are destabilizing and can lead to local extinction of prey species, whereas type III functional responses are stabilizing with a low-density refuge from predation (Fig. 1). The functional response can be changed by differences in habitat, spatial arrangement of prey, predator density, or the presence and density of alternative prey.

The red king crab population in the Gulf of Alaska crashed in the 1980s and has not recovered despite a closure of the commercial fishery. In response, researchers are exploring the possibility of enhancing the population through the release of hatchery-reared crabs into the wild. It is critical to understand the predator-prey relationships between newly released crabs and their predators in order to determine the ideal habitat and density that will maximize survival of the crabs.

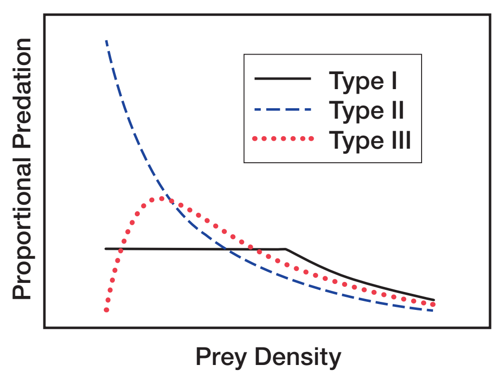

Figure 1: Proportional predation rates as a function of prey density for type I, type II, and type III functional responses. Note that in a type II functional response, as the prey density decreases, the predation rate increases, leading to possible local extinction, whereas in a type III functional response the predation rate decreases as the prey density decreases, leading to a low density refuge from predation.

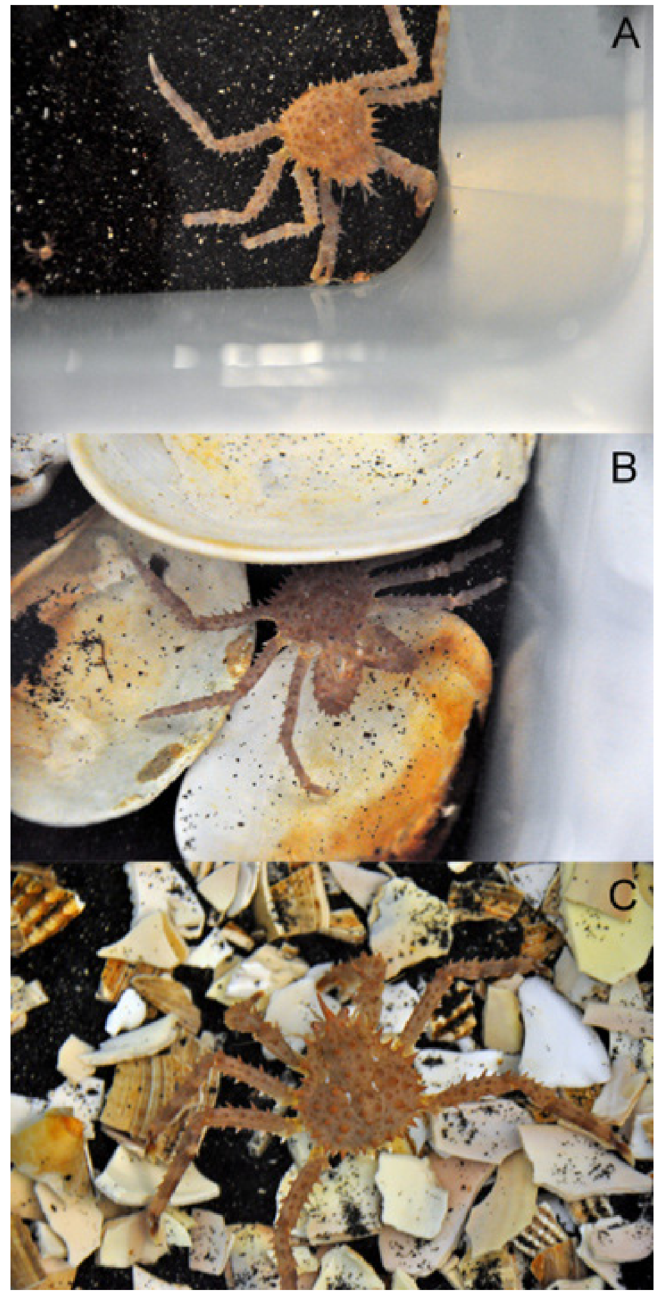

Figure 2: Year-1 red king crabs hunting year-0 red king crabs in A) sand, B) shell, and C) shell hash habitat types during experimental trials. Photos by Chris Long and Jessica Popp.

In this study we used laboratory experiments to determine the predator functional response of year-1 crabs to year-0 crabs in three different habitat types: sand, which was unstructured soft sediment; shell, which was whole clam valves; and shell hash, which were smaller pieces of crushed shell (Fig. 2). Experiments were performed in plastic containers 31 x 20 x 24 cm (L x W x H). Five densities of prey were used in the experiment: 2, 5, 10, 18, and 25 crabs per container. We also examined how predator density (1 or 2 predators) affects the functional response using prey densities of 2, 5, 10, 25, and 50 crabs per container.

The trials were run as follows. At 3 p.m. the day before the trials, the appropriate habitats were established in each container. Then the prey crabs (carapace width 1.4–5.0 mm) were removed from the holding tank, placed at the appropriate density in each of the containers, and acclimatized overnight. At 9 a.m. the day of the trial, predator crabs (carapace length 15–23 mm) were introduced into the containers to initiate the trial. Predators were starved for 24–48 hours prior to use in trials to standardize hunger levels. The predators were allowed to feed for 2 hours and then were removed and the number of surviving prey counted. Proportional predation was calculated for each trial.

The data was fitted to type I, type II, and type III functional response models and the best fit model was chosen. The functional response was a type II in all habitat types; however, the predation rate was lower at all prey densities in the shell habitat than in shell hash and sand (Fig. 3). This indicates that shell habitat provides a good refuge from predation, but that shell hash and sand do not. The functional response was a type II at both predator densities as well. The presence of a second predator decreased both the attack rate and the handling time, resulting in slightly lower predation rates at low prey densities and slightly higher at high prey densities when compared to the single predator treatment (Fig. 4). This indicates that predators may be interfering with each other's foraging.

This work has implications for potential stock enhancement activities, as year-1 crabs could inhibit enhancement success though cannibalism on introduced year-0 crabs, especially given the destabilizing nature of the type II functional response. Given these results, a moderate to high stocking density in complex habitat is the most likely to maximize survival of the crabs. However, more research needs to be done to examine whether the presence of alternative prey changes the functional response to a type III, for this would suggest that a low stocking density would be best. Additionally, as year-1 crabs have the potential to strongly influence the success of the next year class, it may be advisable to stock a given area only once every 2 years. Larger crabs are less effective predators on year-0 crabs, and crabs start to pod and move out of the most complex habitats during the second year.

By W. Christopher Long

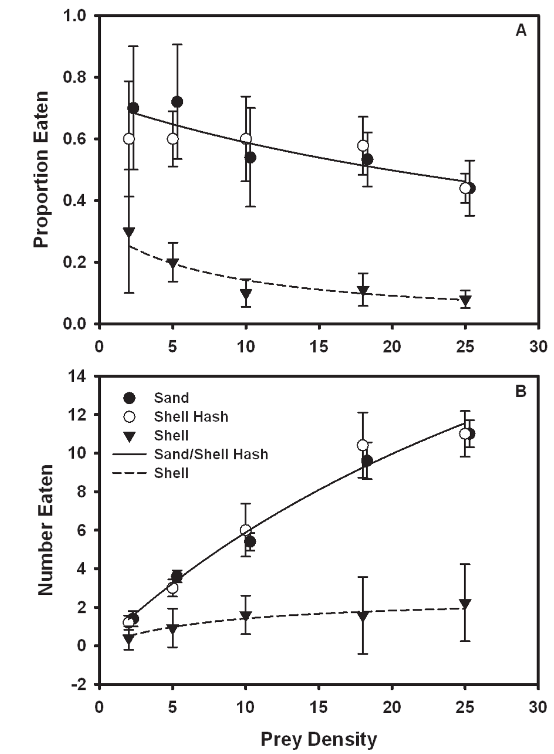

Figure 3: Functional response of year-1 red king crabs to year-0 red king crabs in three different habitats in terms of A) proportional predation and B) number eaten. Symbols represent the mean ± SE. Sand points are offset slightly. Lines represent the type II functional response estimated by maximum likelihood. One line is plotted for sand and shell hash because there was no difference in the functional response between those habitats.

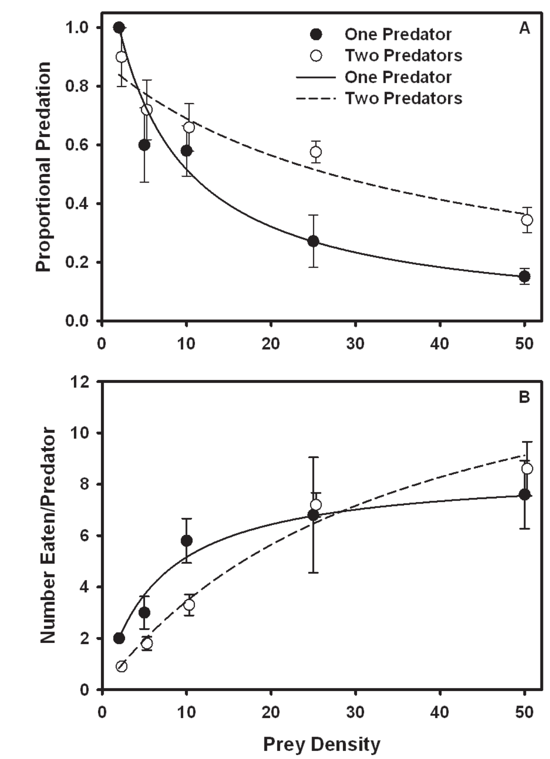

Figure 4: Functional response of year-1 red king crabs to year-0 red king crabs at two predator densities in terms of A) proportional predation and B) number eaten per predator. Symbols represent the mean ± SE, and the two predator points are offset slightly. Lines represent the type II functional response estimated by maximum likelihood.

Red King Crab, *Paralithodes camtschaticus*, Size-Fecundity Relationship and Inter-Annual and Seasonal Variability in Fecundity

Figure 5. Female red king crab brooding eggs.

Embryo production and its effect on population dynamics is poorly understood for crustaceans and is therefore not often included in stock assessment and management; however, such knowledge is necessary to improve management of these species. Stock assessment of Alaskan red king crab, *Paralithodes camtschaticus*, does not incorporate embryo production due to a lack of data. The harvest strategy employed by the Alaska Department of Fish and Game for Bristol Bay red king crab relies on a length-based population model for stock assessment that defines male reproductive potential as mature male abundance (stratified into 5-mm carapace length (CL) size bins) multiplied by the maximum number of females with which a male in a particular size bin can mate. Female spawning abundance, which is used as a proxy for female reproductive potential, is set equal to male reproductive potential or mature female abundance, whichever is less. This method assumes mating always occurs and unfortunately does not include any means to detect reproductive failure.

Timing of Bristol Bay red king crab mating, which occurs between larger hard-shelled males and smaller soft-shelled females, is variable and can occur from the end of January through the end of June. Red king crab females must mate annually to produce a fertilized clutch of eggs. Fertilization is external, fecundity increases with female size, and embryos are brooded approximately 10 to 12 months until hatching (Fig. 5).

Incorporation of fecundity in stock assessment and management of Bristol Bay red king crab requires an understanding of the size-fecundity relationship and its inter-annual variability. Furthermore, since eggs are lost throughout the brooding duration, efforts to relate fecundity to larval output and ultimately recruitment should estimate fecundity close to hatching or estimate rates of egg loss by looking at seasonal changes in fecundity. Our objectives were to determine the size-fecundity relationship and understand interannual and seasonal variability in Bristol Bay red king crab fecundity by modeling data from summers 2007–10 and falls 2007–09. This study will provide critical data to incorporate into stock assessment models to improve management of the stock, and establish a baseline against which future monitoring can be used to test for environmental or fishing-induced effects on stock reproductive potential.

To compare interannual and seasonal variability in red king crab fecundity, egg clutches of females were collected from Bristol Bay, Alaska, in summer and fall. Summer samples were collected June through July 2007, 2008, 2009, and 2010 during the NMFS eastern Bering Sea bottom trawl surveys and fall samples were collected October and November 2007, 2008 and 2009 by shellfish fishery observers during the commercial fisheries. Samples were sent to the Center's Kodiak Laboratory, where they were processed and fecundity estimated (Fig. 6). Data were fit to a series of 23 models and 2 post-hoc models using maximum likelihood fitting techniques. Some of the models included a split point where the slope of the size-fecundity relationship changed above a critical point.

Fecundity increased with female size, but the slope decreased by 40% above 138-mm CL, suggesting senescence which has not been previously reported for this species. Although the size-fecundity relationship of Bristol Bay red king crabs differed among all years examined in this study except for 2007 and 2009 (Fig. 7), the variation observed is minimal (maximum of 5% difference in slope) and likely not biologically

Figure 6. Kodiak Laboratory research technician Lindsey Bidder processing samples for fecundity estimates.

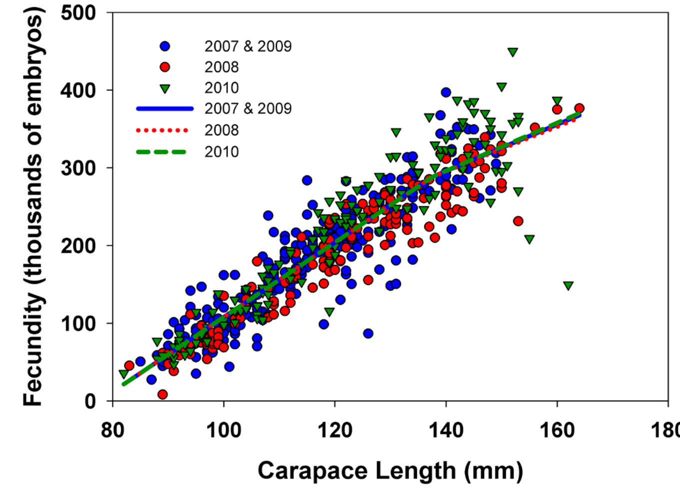

Figure 7. Inter-annual comparison of the size-fecundity relationship of Bristol Bay red king crab. Only the summer data is graphed, the relationships are the same for fall data. Circles and triangles are individual female observations. Lines represent the relationship predicted by the best fit model and are hard to distinguish because they overlap.

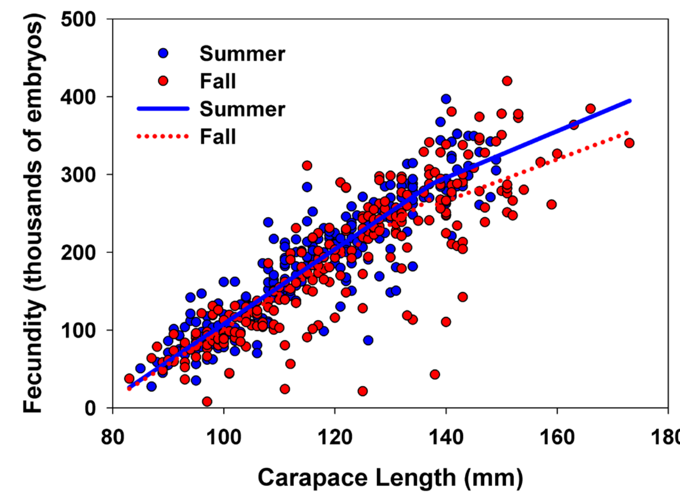

Figure 8. Seasonal comparison of the size-fecundity relationship of Bristol Bay red king crab. Only 2007 and 2009 pooled data are graphed, the relationship is the same for every year. Circles are individual female observations. Lines represent the relationship predicted by the best fit model.

significant as it only equates to a 2% difference in the predicted fecundity of the largest sized female sampled. Fecundity varied seasonally; females smaller than 138-mm CL were 6% less fecund in the fall than summer and females larger than 138-mm CL were 10% less fecund in the fall, suggesting brood loss (Fig. 8).

Our results are a strong starting point for inclusion of embryo production in stock assessment and management, but more information is needed. It is important to note that all samples were taken during cold years in the eastern Bering Sea. It is possible that different environmental conditions affect fecundity; therefore we are cautious to apply our results to other environmental conditions. To more accurately model reproductive potential, data is needed on both temporal and spatial variation in the size-fecundity relationship, and if variation occurs, annual estimates of fecundity are needed.

By Katherine M. Swiney

Behavioral and Growth Correlates of Habitat Use in Three Co-occurring Juvenile Flatfishes

In our study we examined aspects of behavior, intrinsic growth rate, and habitat/depth distribution of the juveniles of three closely related flounder species, English sole, *Pleuronectes vetulus*, Pacific halibut, *Hippoglossus stenolepis,* and northern rock sole, *Lepidopsetta polyxystra*, all right-eyed flounders of the family Pleuronectidae, which co-occur in shallow water nursery embayments around Kodiak. All employ a well-developed detection-minimization strategy involving highly co-evolved morphological and behavioral adaptations. Recent Fisheries Behavioral Ecology Program (FBEP) experiments demonstrate variation in the utilization of behavioral tactics between species. Northern rock sole (hereafter rock sole) are risk-averse; they tend to remain buried and/or prone on the bottom when not feeding, minimize movement, and do not flee unless a predator gets very close. English sole are risk-prone; less inclined to bury, often adopt posture with their head and forward portion of the body elevated off the substrate, and more actively move about, increasing their conspicuousness to potential predators. Pacific halibut (hereafter halibut) are risk sensitive, modifying their behavior to reflect the presence or absence of predators. In the absence of predation risk they behave like English sole. When faced with predation risk they behave more like rock sole. Standardized predation trials have demonstrated that English sole are the most vulnerable to predation, rock sole the least, with halibut intermediate between the other species.

We used these three species to test the premise that intrinsic growth and risk-taking behavior are coevolved and together influence fish distribution along a depth/predation gradient. Why? By understanding a fish's inherent behavior repertoire and scope for growth, we can better understand and characterize its essential fish habitat. First, we conducted a laboratory experiment, comparing the intrinsic growth rates of the three species. We predicted that the intrinsic growth of English sole would be greater than that of either halibut or rock sole. Importantly, we conducted this growth experiment across a range of temperatures encompassing those encountered by fish during their nursery occupancy. As expected, rock sole grew more slowly than halibut and English sole, but this effect was temperature-dependent. Within the overall pattern of increasing growth with temperature, daily length increments (Fig. 9) were similar between species at 5°C and 9°C, but at 13°C and 16°C increments were greater for English sole and halibut than for rock sole. However, contrary to expectations, halibut growth was not lower than English sole growth at these higher temperatures.

In the second portion of this research, we utilized 5 years of field data (tows with a 2-m plumb-staff, 3-mm codend mesh) characterizing the depth distribution of the three species at one of our study sites, Holiday Beach in Kodiak, Alaska. Prior studies demonstrated a strong increase in predation pressure with depth at this site, while invertebrate biomass, and hence forage base for juvenile flatfish, increased with depth. With a risk-prone behavioral strategy, we expected that English sole would be restricted to the shallows, where predation pressure is low. In contrast, we expected rock sole to be found deeper, where their cryptic behavior would allow them to avoid detection by predators, and because prey are more plentiful, minimize time spent foraging. We expected halibut to exhibit a depth distribution intermediate to these two. Of the three species, English sole was most clearly associated with shallow water, being more abundant at 0-5 m than at 15 – 25 m (Fig. 10). In contrast, both halibut and rock sole were more uniformly distributed, with no significant differences in proportional abundance across the depths examined.

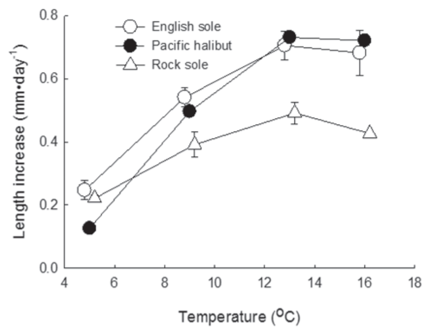

Figure 9. Growth rates of English sole, Pacific halibut, and northern rock sole in terms of mean daily length increase (+SE), at temperatures of 5°, 9°, 13° and 16°C.

Results of this study were partially consistent with our premise that risky behavior and growth are positively correlated.

Results of this study were partially consistent with our premise that risky behavior and growth are positively correlated. Rock sole are risk averse and as expected, their growth rates were the lowest of the three species. Accordingly, rock sole were more uniformly distributed across depth. With a behavioral repertoire that reduces their conspicuousness, rock sole can more successfully coexist with predators. Further, with a lower intrinsic growth rate, rock sole may adopt more of a time-minimization foraging strategy, concentrating their foraging during dusk hours, when they are less vulnerable to piscivores. In contrast, English sole are risk prone and had a higher intrinsic growth rate. Accordingly, they are largely restricted to the shallows where predators are less abundant, and they can maximize their foraging, despite low prey densities, by feeding throughout the day. However, halibut did not match our predictions in either experiment. We believe that a broader understanding of the behavioral plasticity of juvenile halibut may help explain this apparent anomaly. In behavioral experiments, halibut consistently demonstrate an ability to modify their behavior to match the opportunities and risks of their environment. In this study fish were reared with no predation risk. Would halibut exhibit lower growth when subjected to chronic risk? Stated another way, could perceived risk suppress growth? This perhaps is a topic for future research.

On a more applied level, our results expand knowledge of intrinsic growth rates for species of ecological and commercial importance in the north Pacific. Like other ectotherms, temperature strongly influences growth in juvenile flatfish. In the Bering Sea and Gulf of Alaska, bottom water temperature varies by season, depth, and water column structure. This variability has implications for studying the age and size structure of stocks. All three flatfish species have stocks comprised of multiple cohorts originating from broad geographic areas, in which variable temperature regimes can be expected to influence juvenile growth. While each species demonstrated a positive correlation between growth and temperature, the magnitude of the temperature response differed. Halibut were the most temperature dependent, while rock sole were the least. Halibut growth (in terms of length) was 5.8 times greater at the highest observed rate (13°C) than at 5°C. For English sole and rock sole growth was 2.7 and 2.3 times greater, respectively. Being more influenced by temperature, halibut are probably highly dependent upon maximizing growth during the summer, when temperature in the nearshore is high. In contrast, the lower summer growth rates of rock sole may be compensated for by continued modest growth during the rest of the year.

In summary, we attempted to elucidate the relationships between anti-predator behavior, intrinsic growth rate, and depth distribution in three juvenile flatfish species that co-occur in Kodiak nurseries during the summer months. We feel that our approach of more holistically considering coevolved behavior and growth characteristics provides a useful construct for understanding juvenile fish ecology and habitat use.

Clifford H. Ryer

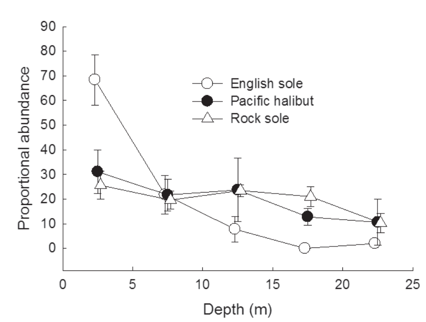

Figure 10. Mean proportional abundance (+SE) for English sole, Pacific halibut, and northern rock sole by depth at Holiday Beach, Kodiak, Alaska during July and August, 2005—09.

Resource Ecology & Ecosystem Modeling Program

Fish Stomach Collection and Lab Analysis

During the second quarter of 2011, Resource Ecology and Ecosystem Modeling (REEM) Program staff began focusing their efforts on analyzing stomach contents from the Gulf of Alaska. The contents of 2,706 stomach samples from 26 species were analyzed from the Gulf of Alaska, and 925 stomach samples from 3 species were analyzed from the Bering Sea. Detailed analysis, with high taxonomic resolution of prey types and enumeration of all prey items, was performed on walleye pollock samples collected during a 2010 hydroacoustic survey for a Bering Sea Integrated Ecosystem Research Program (BSIERP) project. This quarter, 825 euphausiid prey from these stomach samples have been measured and will be used in a future comparison with net-caught euphausiids. Tissue samples of muscle and liver from arrowtooth flounder, Pacific cod, and walleye pollock have been dried, ground, and tinned (160, 276, and 137, respectively) in preparation for stable isotope analysis. Fishery observers returned stomach samples from 133 arrowtooth flounder, 97 walleye pollock, and 15 Pacific cod from Alaskan fishing grounds. In total, 8,272 records were added to the REEM food habits database.

Stomachs are being collected this spring and summer during the AFSC's hydroacoustic survey of the Gulf of Alaska, the bottom trawl survey of the Gulf of Alaska, and the groundfish and crab survey of the eastern Bering Sea. Shipboard analysis of stomach contents is also being conducted on board one of the Gulf of Alaska bottom trawl survey vessels.

By Troy Buckley, Geoff Lang, Mei-Sun Yang, and Richard Hibpshman

Fishery observers returned stomach samples from 133 arrowtooth flounder, 97 walleye pollock, and 15 Pacific cod from Alaskan fishing grounds. In total, 8,272 records were added to the REEM food habits database.

Summer Food Habits of Arctic Cod in the Eastern Bering Sea

The Arctic cod (*Boreogadus saida*) is an ecologically important inhabitant in Arctic waters that extends its distribution southward into the eastern Bering Sea during colder years. The Arctic cod, known to be a predator of a variety of zooplankton and a prominent prey for many birds, marine mammals, and other fishes, is a nodal species in the Arctic marine foodweb. Arctic cod are caught during the AFSC groundfish and crab surveys in the eastern Bering Sea, especially during colder summers. Stomach samples have been collected from them during previous surveys on an *ad hoc* basis over the years but were targeted during the 2010 surveys, yielding 320 samples.

Most of the Arctic cod stomach samples analyzed to date were sampled prior to 2010. These 253 Arctic cod ranged in length from 6 to 26 cm fork length (FL), with the large majority of the stomach samples obtained from fish between 10 and 18 cm FL. The diet of these Arctic cod consisted mostly of small crustaceans in all the size categories examined, but some differences in diet with predator length were seen (Fig. 1). Chaetognaths tended to decrease in importance with increasing size of Arctic cod. Fishes (Teleostei) and slightly larger crustaceans (Decapoda; shrimp and crabs) were consumed primarily by Arctic cod over 15 cm. A consistent, more general trend with increasing size was the gradual decrease in pelagic prey (chaetognaths, copepods, euphausiids, and hyperiid amphipods) and the gradual increase in more benthically oriented prey (gammarid amphipods, mysids, cumaceans, and decapod crustaceans). When analyzed, the stomach samples collected in 2010 may provide some geographically interesting results, as the majority of them were collected in the northern Bering Sea between Saint Matthew Island and the Bering Strait.

By Troy Buckley, Caroline Robinson, and Kimberly Sawyer

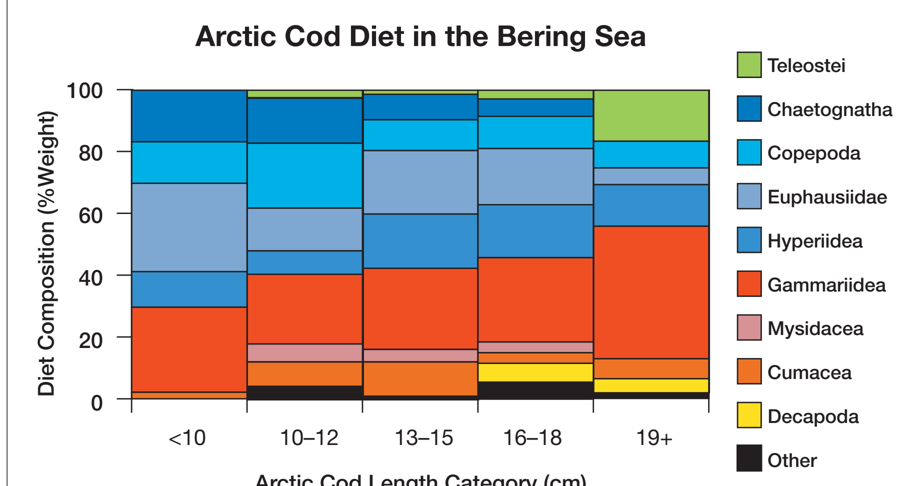

Figure 1. Summer diet composition of 6- to 26-cm FL Arctic cod in the eastern Bering Sea.

Ecosystem Indicators and Modeling: Meetings and Workshops

The modeling and empirical work conducted by workshop attendees have identified possible universal patterns and emergent trends.

In April 2011, Sarah Gaichas and Stephani Zador participated in "Indicators of Status and Change within North Pacific Marine Ecosystems: A FUTURE Workshop," sponsored by PICES (North Pacific Marine Science Organization). Held 26–28 April in Honolulu, Hawaii, the workshop was part of the FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) Science Program. The stated goals of the workshop were to review potential methods for measuring ecosystem resilience, ecosystem-level indicators of status and change, methods to characterize uncertainty in these indicators, and common ecosystem indicators to be used for regional comparisons by the PICES' community. The workshop had approximately 50 international attendees, with 14 presentations and several discussion sections. Stephani Zador presented "A recent indicator-based assessment of the eastern Bering Sea" reviewing the new 2010 Eastern Bering Sea synthesis in the Ecosystem Considerations SAFE report, which was extremely well received by the PICES community. Sarah Gaichas was invited to present "Uncertainty in ecosystem indicators: known knowns, known unknowns, and unknown unknowns," which reviewed methods of estimating and communicating uncertainty across a range of indicator types. The workshop concluded with recommendations for further FUTURE ecosystem indicator development and application.

In May 2011, AFSC researchers Sarah Gaichas, William Stockhausen, and Kristin Holsman joined T. Essington (University of Wasington) and more than 15 other U.S. and international scientists at Woods Hole in Falmouth, Massachusetts, for an intensive Annual Surplus Production Modeling Workshop sponsored by the CAMEO program. Using data from more than 11 temperate marine ecosystems, breakout groups evaluated production trends and fisheries and food-web models for species and guilds from various ecosystems. The modeling and empirical work conducted by workshop attendees have identified possible universal patterns and emergent trends. Results from the workshop are slated for publication in a special issue of *Marine Ecology Progress Series*. The special issue will include papers authored by Gaichas, Stockhausen, and Holsman on the subjects of the effect of environmental and biological covariates on MSY (maximum sustainable yield) and B*msy* estimated from single species and multispecies production models as well as comparisons in harvest metrics resultant from food-web modeling approaches to fisheries management. Results of the workshop will also be presented during a special session at the American Fisheries Society annual meeting in September 2011 in Seattle, Washington.

Sarah Gaichas participated in the Society for Conservation Biology's Second International Marine Conservation Congress (IMCC) held in Victoria, British Columbia, Canada, in May 2011. Along with seven coauthors, she presented "Assembly rules for aggregate-species production models: Simulations in support of management strategy evaluation." This work resulted from the May 2011 CAMEO stock production modeling workshop and is in preparation for submission to *Marine Ecology Progress Series* along with a set of companion papers from the workshop.

Also in May, Sarah Gaichas and Ivonne Ortiz attended the open science meeting of ESSAS (Ecosystem Studies of Sub-Arctic Seas). Sarah Gaichas presented an overview of the May 2011 CAMEO stock production modeling workshop titled "Using production models as tools to examine factors that influence productivity of marine systems: Contrasts across levels of aggregation, ecosystems, and drivers." The production modeling was applied to 11–14 northern hemisphere ecosystems and results compared across systems, levels of species aggregation, and drivers. Preliminary management-relevant metrics and ecosystem attributes were presented and compared across methods and ecosystems. Ivonne Ortiz and Kerim Aydin presented a poster showing modeled seasonal movement of pollock as a function of prey density and temperature (measured as growth). Fish movement is part of the Forage Euphausiid Abundance in Space and Time (FEAST) model, a high resolution model that uses a Regional Oceanography Model System as platform and has two-way feedback with a Nutrient-Phytoplankton-Zooplankton-Benthos module. Both hindcasts and forecasts of FEAST will be run; in the forecast version, FEAST will be used as the real world model for management strategy evaluations.

In June 2011, Kerim Aydin attended the annual meeting of the International Whaling Commission's Scientific Committee in Tromso, Norway, and presented a talk entitled "Developing ecosystem assessment models for the North Pacific Fisheries Management Council." He also summarized recent modeling work performed for FEAST and under the CAMEO program, as described above.

By Sarah Gaichas, Stephani Zador, Kirstin Holsman, Ivonne Ortiz, and Kerim Aydin

Maturity of *Sebastes* spp. in the Aleutian Islands: Filling Critical Life-History Data Gaps for Data-Poor Commercially Important Rockfishes

Estimates of maturity, in particular the proportion of a population mature by age, are an important metric of fish populations and play a critical role in the formulation of fishing reference points and harvest specifications. Age-structured stock assessment models for rockfishes in the Bering Sea-Aleutian Islands (BSAI) management region rely upon maturity data from the Gulf of Alaska (GOA) due to the lack of data in the BSAI. Misspecification of fishing mortality rates would occur if differences existed between the productivity of a species occurring in different regions, and species-specific maturity information will be required for more refined assessment methodologies.

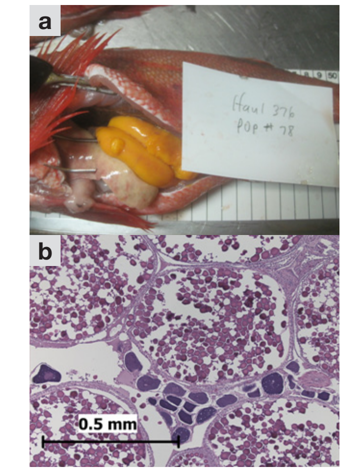

Figure 2. Macroscopic (a) and histological (b) view of an ovary from a mature POP collected in October 2010. Note the yolk globules (advanced vitellogenesis) from the histological view.

The primary focus of this study was to obtain updated maturity information from females for five rockfishes occurring in the Aleutian Islands region: Pacific ocean perch (POP; *Sebastes alutus*); northern rockfish (*S. polyspinis*); blackspotted rockfish (*S. melanostictus*); rougheye rockfish (*S. aleutianus*); and shortraker rockfish (*S. borealis*). Field sampling for ovaries and otoliths occurred during spring, summer, and fall 2010 aboard commercial and AFSC-chartered vessels. After histological examination of ovaries and ageing of specimens, age and length at 50% maturity was estimated for Pacific ocean perch (8.7 yrs at 32.4 cm) and northern rockfish (6.6 yrs at 27.7 cm). The presence of yolk (vitellogenesis) was the determining factor when assigning fish as mature vs. immature. Fall sampling appeared to be ideal for POP and northern rockfish for estimating maturity. Summer POP samples were also included in the maturity analysis. Visual macroscopic inspections of ovaries were also recorded during the fall sampling period for both species (Fig. 2). Macroscopic observations recorded in this study generally matched subsequent histological analysis for both larger specimens and smaller specimens when defining mature vs. immature specimens.

Due to a lack of smaller-sized specimens caught and sampling during periods of reproductive inactivity, maturity estimates for blackspotted, rougheye, and shortraker rockfish could not be obtained. Throughout the sampling periods, blackspotted rockfish within our desired size range exhibited macroscopic and histological characteristics as immature, although many of the larger fish may have been resting or reproductively inactive mature fish (Fig. 3). This was also observed for rougheye and shortraker rockfish. For these species, the seasonal reproductive cycle may be more compressed into the late fall to spring period, and further sampling throughout the year should be conducted to evaluate this hypothesis. Assessment models and harvest recommendations, however, will be improved by obtaining region-specific maturity information from the Bering Sea-Aleutain Islands area for Pacific ocean perch and northern rockfish and periodically updating the maturity information to monitor any temporal trends.

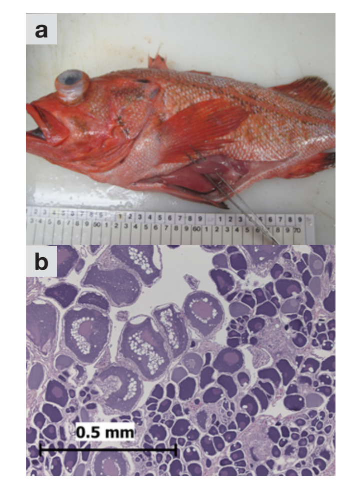

Figure 3. Macroscopic (a) and histological (b) view of an ovary from a large-sized blackspotted rockfish collected in April 2010. There was no evidence of vitellogenesis in the histological view.

By Todd TenBrink

Seabird Bycatch Estimates for Alaskan Federal Groundfish Fisheries.

The AFSC is again producing annual estimates of seabird bycatch from the Alaskan groundfish fisheries monitored through the North Pacific Fishery Observer Program. Provisional estimates for 2007–10 are posted on the AFSC website at http://www.afsc.noaa.gov/refm/reem/Seabirds/Default.php. These estimates are of great interest to many scientists, managers, and stakeholders. This years' estimates represent the third methodology employed since the start of our seabird bycatch monitoring in 1993 (Fig. 1). The first method was carried out by the U.S. Fish and Wildlife Service (USFWS) Migratory Bird Management Division in Anchorage, Alaska, following through on templates for collaboration done in the Dall's Porpoise and High Seas Driftnet Programs of the 1980s and early '90s. The intent was to produce estimates of overall seabird mortality based on these data each year. However, given the complexity and scope of the data and the need of the USFWS to address Endangered Species Act issues at the time, this methodology proved unfeasible for the USFWS.

The AFSC then agreed to dedicate resources, with annual funding support from the Protected Resources Division of the NMFS Alaska Regional Office, to develop procedures to estimate annual seabird bycatch. Marine mammal take estimation was being completed by an analyst from the AFSC National Marine Mammal Laboratory (NMML). Because seabirds had similar estimation challenges (seabird bycatch is a relatively rare event) similar estimation procedures could be used. Estimates were produced for all years (1993 onward) through 2006 (Fig. 4) and made available on the AFSC website and through the Ecosystem Chapter of the annual Stock Assessment and Fisheries Evaluation Reports prepared for the North Pacific Fishery Management Council (available at http://www.fakr.noaa.gov/npfmc/).

These estimates are of great interest to many scientists, managers, and stakeholders.

With retirement of the NMML analyst in 2007 and a new data platform launched in 2008, established procedures could no longer be used. Producing these annual estimates had also used resources that were now needed for other seabird projects. A workshop was held to address rare-event bycatch estimation in 2009 (reported in the April–May–June 2009 AFSC Quarterly Report). This workshop evaluated the stated needs of various end-users for these data. One result of the workshop was that the AFSC worked with the Sustainable Fisheries Division of the Alaska Regional Office, and the Catch Accounting System now produces seabird point-count estimates in a production mode that does not require as much staff resources as previous methods. The AFSC will use the results to again produce annual estimates of seabird bycatch in Alaskan fisheries.

By Shannon Fitzgerald

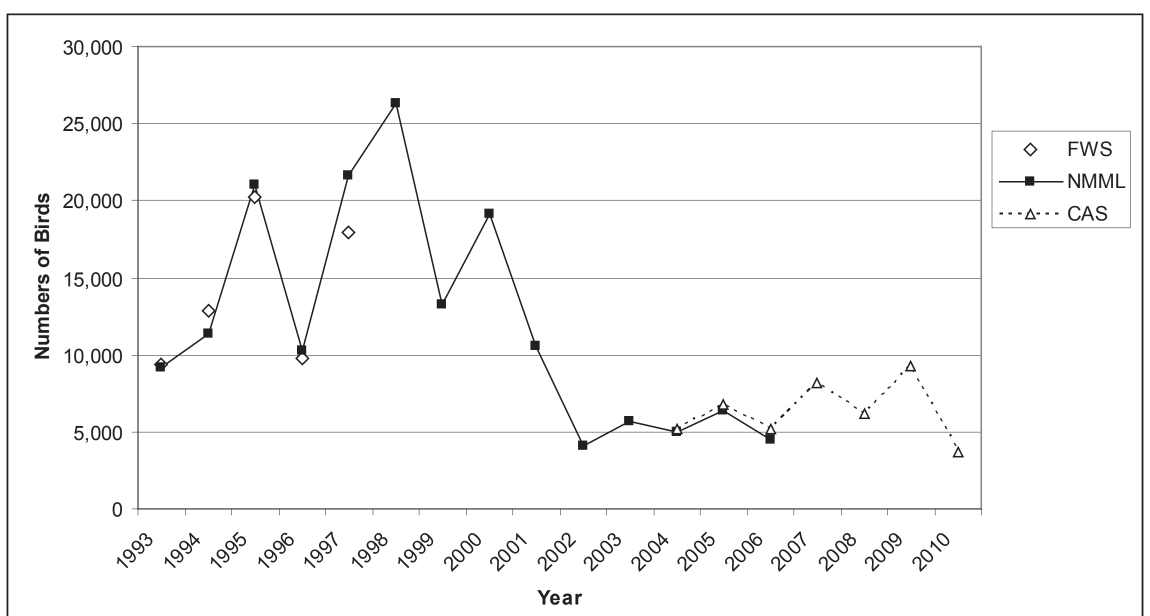

Figure 4. Total seabird bycatch in the Alaskan demersal longline groundfish fishery as estimated by three overlapping methods during the period 1993 through 2010. FWS = U.S. Fish and Wildlife Service; NMML = Alaska Fisheries Science Center National Marine Mammal Lab; CAS = Catch Accounting System.

Optimal Multispecies Harvesting Targets in Biologically, Technologically, and Temporally Interdependent Fisheries

Economic and Social Science Research (ESSR) program researcher Stephen Kasperski is conducting research relating to the multispecies bioeconomic models of groundfish in the Bering Sea. Specifically, his research focuses on the biological interactions among species, technological interactions which result in catching multiple species, and temporal interactions between species as fishermen allocate their effort across multiple fisheries over the course of a year. Results show that the impact of biological and technological interactions can substantially alter the optimal harvest policies compared with a single-species bioeconomic model.

This study uses the arrowtooth flounder, Pacific cod, and walleye pollock fisheries in the BSAI region of Alaska as a case study and finds the net present value of the three species fishery is over $20.7 billion dollars in the multispecies model, over $5.0 billion dollars more than the net present value of the single-species model. This is a function of the interdependence among species and how that affects other species' growth. Given that arrowtooth flounder negatively impact the growth of cod and pollock, substantially increasing the harvest of arrowtooth to decrease its stock size is optimal in the multispecies model, as it leads to increased growth and, therefore, greater potential harvests of cod and pollock. The single species model does not incorporate these feedbacks among species and, therefore, assumes each species is unaffected by the stock rise or collapse of the other species. The vessels in this fishery are also known to exhibit cost anti-complementarities among species, which implies that harvesting multiple species jointly is more costly than catching them independently. As approaches for ecosystem-based fisheries management are developed, the results demonstrate the importance of focusing not only on the economically valuable species, but also on some non-harvested species, as they can affect the productivity and availability of higher value species.

By Stephen Kasperski

Extending Multi-attribute Utility Function (MAUF) Study to Develop Socioeconomic Indicators

Ecosystem-based fisheries management requires a holistic assessment of the status of fisheries by integrating ecosystem indicators for several major management objectives, such as sustainability, biodiversity, habitat quality, and socio-economic status. Scientists have already paid much attention to the first three objectives (i.e., sustainability, biodiversity, and habitat quality) and to the development of associated indicators. Although there have been some efforts to develop socio-economic indicators, most socio-economic indicators in previous studies are not firmly based on economic theory. One exception is a recent study by AFSC researcher Chang Seung (ESSR Program researcher) and collaborating researcher Chang Ik Zhang (Professor, Institute of Fisheries Science Pukyong National University, Republic of Korea). This study uses a multi-attribute utility function (MAUF) approach to calculate several economic indicators for the eastern Bering Sea trawl fishery and uses important economic concepts in utility function theory, such as preferential independence and utility independence, to develop nonlinear utility functions or indicators for stakeholders. This study also aggregates the individual utility functions into a social welfare function or an aggregate index measuring the overall socio-economic status of the fishery. One limitation of the study is that it assumed the opinions of the analyst reflect the preferences of the stakeholders when assessing component utility functions and those of decision makers when aggregating them.

A future study will extend Seung and Zhang's research in two ways. First, the study will elicit stakeholders and policy maker preferences for socio-economic indicators via interviews. Second, to aggregate stakeholder preferences into a social welfare function, the study will use a more formal procedure than employed by Seung and Zhang. Once the aggregate socio-economic index is developed, it will be integrated with non-socioeconomic indicators being developed by other programs within the AFSC.

By Chang Seung

Libby Logerwell Completes Rotational Assignment with National Ocean Service on Oil Spill Impacts in the Arctic

Libby at the Arctic Ocean shore in Barrow, Alaska, in March 2011.

Libby Logerwell, researcher in the Status of Stocks and Multispecies Assessment (SSMA) program, recently completed a 6-month rotational assignment with the Office of Response and Restoration's (OR&R) Assessment and Restoration Division (http://oceanservice.noaa.gov/programs/orr/). Her interest in the assignment grew out of her participation in a workshop on Natural Resource Damage Assessment (NRDA) in the Arctic (http://www.crrc.unh.edu/workshops/nrda_arctic/index.html). Natural Resource Damage Assessment is the process of determining what effects an oil spill has on the environment (including natural resources that humans use) and what restoration projects are needed to restore the system to the way it was before the spill. The workshop findings showed that the same kind of data are needed to assess environmental damage after an oil spill as is needed for monitoring the effects of climate change and fishing.

Libby worked on two projects: 1) the formation of a Joint Assessment Team (JAT) for Arctic Alaska and 2) a conceptual model of oil impacts on Arctic habitats and wildlife. Both projects are described below.

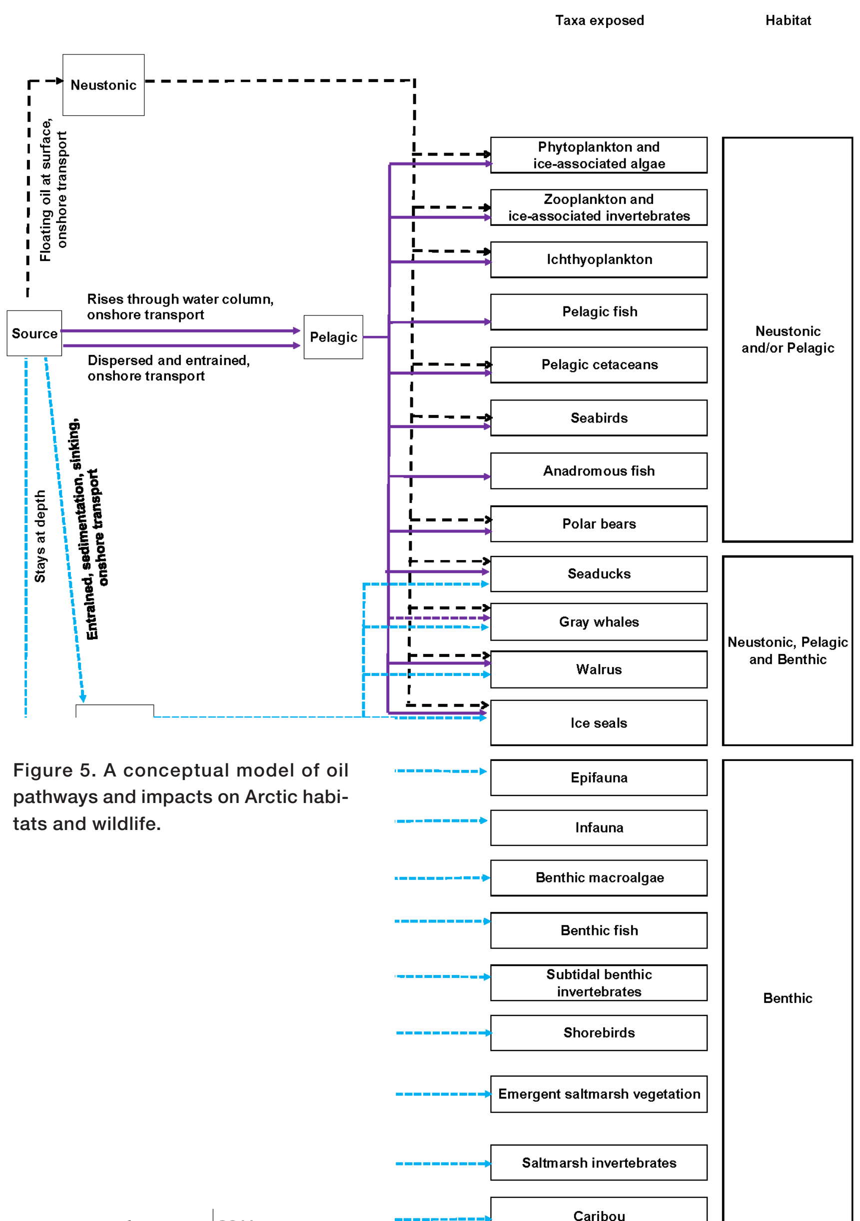

Figure 5. A conceptual model of oil pathways and impacts on Arctic habitats and wildlife.

Joint Assessment Team (JAT)

The JAT is an informal group of state and federal trustees who act on behalf of the public to assess environmental damage and plan restoration projects and oil industry representatives. The goal of the JAT is to build trust and develop good communication so that if an oil spill occurs all interested parties can work together quickly and efficiently. See (http://www.darrp.noaa.gov/partner/cap/relate.html) for more information on JATs in other regions. The JAT met several times in the last few months to discuss the team mission and to determine what activities are priorities for the near future. For example, the JAT plans to refine a conceptual model on oil impacts (see below), develop data collection recommendations based on that model, participate in an upcoming oil spill drill, and reach out to local Arctic communities.

Conceptual Model of Oil Impacts

If there were an oil spill in the Arctic, one of the first tasks would be to determine what wildlife or habitats could be affected. One way to get a handle on this question is to build a conceptual model that lays out all the possible ways oil could move through the marine environment and all the different things that could be exposed to oil. Libby worked with personnel in ORR to build a first draft of such a model. It has been submitted for publication in the proceedings of a seminar to be held in Calgary, British Columbia, this fall (http://www.etc-cte.ec.gc.ca/news/conferences_e.html). The model is a simple flow chart showing how fish, invertebrates, birds, and marine mammals could be exposed to oil at the surface of the ocean, in the water column, and/or on the bottom (Fig. 5). The results of the model-building exercise showed that although there is a lot of information for some wildlife groups in some areas, more information is needed for others. For example, not much is known about fish eggs and larvae from the Beaufort Sea. This is particularly important because the surface waters where fish eggs and larvae are found is likely to be impacted by surface spills related to shipping, one of the higher risks in the Arctic. Also, more data is needed on the toxic effects of oil on Arctic fish, especially Arctic cod, which are food for other fish, marine mammals, and seabirds and so are a key part of Arctic food webs.

By Libby Logerwell

FIT Staff Conduct Successful Atka Mackerel Tag Release Cruise in the Aleutian Islands

Left: A tagged Atka mackerel ready to be released.
Below: Scientists Peter Munro, Joe Collins, and Lynn Lee tag Atka mackerel and record their lengths.

Fisheries Interaction Team (FIT) staff conducted an Atka mackerel tag release cruise from 15 May to 5 June in the Central Aleutian Islands region. The first objective of the cruise, conducted aboard the chartered fishing vessel *Pacific Explorer*, was to assess the local abundance and movement of Atka mackerel by tagging and releasing fish in the Central Aleutians (Tanaga Island and Petrel Bank) and at Seguam Pass. Approximately 8,500 fish were tagged and released at Seguam Pass; 9,000 at Tanaga Island; and 10,000 at Petrel Bank; for a grand total of nearly 28,000 tagged fish (Fig. 6). Secondary objectives included conducting a tag-mortality study and other biological projects such as collecting gonads and otoliths. Another objective was to characterize Atka mackerel habitat by taking oceanographic samples and conducting underwater camera tows at each area where fish were tagged and released. Tagged fish will be recovered by the commercial fishery and during a chartered tag recovery cruise in August 2011.

The goal of FIT's ongoing tag release-recovery studies is to determine the efficacy of trawl exclusion zones as a management tool to maintain prey abundance and availability for Steller sea lions at local scales. Trawl exclusion zones were established around sea lion rookeries as a precautionary measure to protect critical sea lion habitat, including local populations of prey such as Atka mackerel. Localized fishing may affect Atka mackerel abundance and distribution near sea lion rookeries. Tagging experiments are being used to estimate abundance and movement between areas open and closed to the Atka mackerel fishery.

By Libby Logerwell

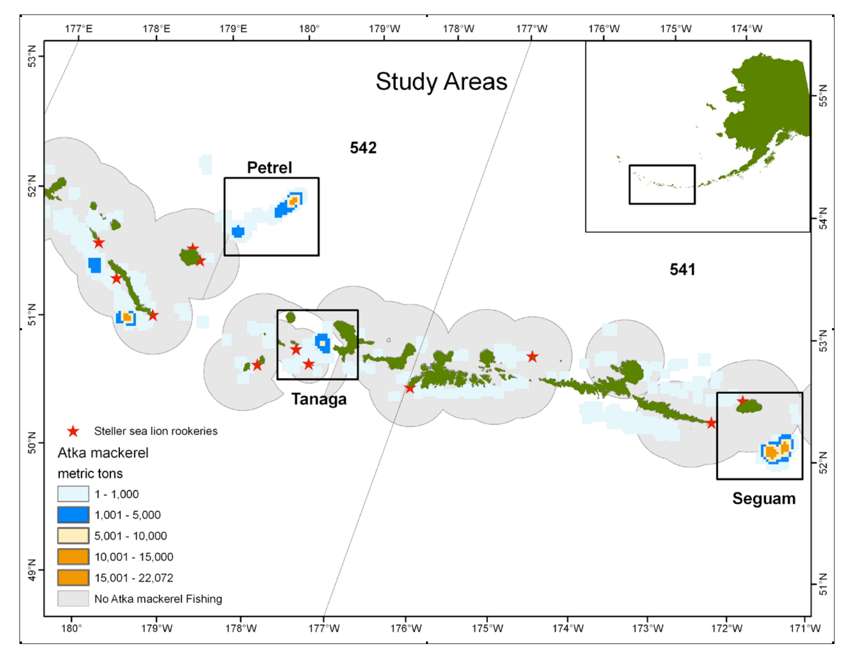

Figure 6. Map showing areas where Atka mackerel were tagged and released: Seguam Pass, Tanaga Island, and Petrel Bank, Alaska.

Report on the Tenth Annual Republic of Korea – United States Fisheries Panel Conference

The Fisheries Panel of a Republic of Korea-NOAA Joint Project Agreement (JPA) holds an annual meeting to review progress in cooperative research on fisheries assessments and management issues. The JPA is an agreement to foster marine science and technology cooperation between the NOAA and two Ministries of the Republic of Korea (the Ministry of Land, Transportation, and Maritime Affairs and the Ministry of Food, Agriculture, Forestry, and Fisheries. The JPA is in its tenth year of implementation under the second 5-year plan. A new 5-year plan is under development to cover the period 2012–17.

This year's Fisheries Panel meeting was held at the AFSC on 22–23 June. The meeting is held as a conference where scientists from both sides report on cooperative research activities and associated research on fisheries assessments and management. The lead of the U.S. side (Patricia Livingston) and the ROK side (Dong Woo Lee) reaffirmed that the past year's cooperative activities have contributed to the scientific research of fisheries resources and their applications to fisheries management strategies for both countries.

By Loh-Lee Low and Julie Pearce

A Report on a Workshop Held at the ESSAS Symposium

Anne Hollowed (SSMA program) and Harald Loeng (Institute of Marine Research, Norway) co-chaired a workshop "Biological consequences of a decrease in sea ice in arctic and sub-arctic seas" as part of the "Comparative Studies of Climate Effects on Polar and Sub-Polar Ecosystems: Progress in Observation and Prediction" symposium sponsored by the Ecosystem Studies of Sub-Arctic Seas (ESSAS) program. Thirty-four scientists from nine nations participated in the meeting. The purpose of the meeting was to assess which species would be likely to establish new breeding populations in regions of the Arctic and its surrounding shelf seas in response to the changes in summer sea ice. Scientists reviewed the life history and habitat associations of fish and shellfish and identified the characteristics of species that would be capable of shifting their range. Analysts then evaluated what biophysical changes would have to occur within Arctic ecosystems to support new species. A list of candidate species was developed. An interesting outcome of the meeting was that it appears that the barriers to colonization of the Arctic by fish and shellfish from the Bering Sea are more substantial than the barriers in the Atlantic. Participants identified gaps in knowledge that are obstacles to predicting where and when new colonies would appear in the Arctic.

A list of key research activities needed to improve our predictive capability was discussed and supported. Four activities were particularly important. 1) Studies of the impact of climate change on the intrusion of Atlantic water into the Arctic and its shelf seas is needed. Most scientists considered this a key mechanism governing the colonization of Arctic regions by sub-Arctic species. 2) Studies of the role of seasonal light and ice on primary production and blooms are needed to evaluate how changes in timing will impact the fish/zooplankton phenology. 3) Research is needed to understand factors governing the timing and spatial extent of zooplankton production in the region including potential interactions between sub-Arctic and Arctic zooplankton. This research would improve our assessment of the prey limitations for pelagic fishes. 4) Periodic fish surveys are needed to monitor shifts in distribution and to improve our understanding of the zoogeography and species interactions in the region.

By Anne Hollowed

A Presentation on a Study to Determine if Acoustic Data can be used to Improve Trawl Survey Biomass Estimates

Paul Spencer gave a presentation titled "Can acoustic data be used to improve trawl survey biomass estimates of Alaska rockfish?" at the University of Washington Quantitative Seminar Series on 3 June. The presentation summarized research conducted with AFSC colleagues Dana Hanselman and Denise McKelvey on the use of hydroacoustics in improving trawl surveys for patchily-distributed rockfish. Survey biomass estimates of Alaska rockfish often show high variability, reflecting their "patchy" spatial distributions. Several survey designs have been proposed for patchily-distributed species, including the Trawl and Acoustic Presence/Absence Survey (TAPAS) design in which hydroacoustic data are monitored in real-time to detect high-density patches that are then sampled at a higher rate than low-density background areas. The research has three main objectives: 1) evaluate the TAPAS design in a rockfish survey; 2) conduct simulation modeling to evaluate how TAPAS might perform under a variety of conditions; and 3) analyze archived echosign data to identify patterns of rockfish spatial characteristics.

A rockfish survey was conducted in 2009 and showed a weak relationship between acoustic energy and trawl catches, resulting in an estimate of precision that was not higher than the precision from simple random sampling; however, a post-cruise analysis that applied an alternative patch definition resulted in some improvement in precision. Simulation modeling indicates that the TAPAS design can perform well when a strong relationship exists between acoustic energy and trawl catches. Because TAPAS is designed to sample each patch encountered, it also performs well when the population consists of many small patches rather than fewer but larger patches. However, when a poor relationship exists between acoustic energy and trawl catches (as observed in the 2009 rockfish survey), TAPAS generally does not result in higher precision estimates than provided by simple random sampling. Analysis of archived acoustic data from AFSC Gulf of Alaska groundfish surveys and the 2009 rockfish survey indicated a wide variety of rockfish aggregation patterns, including 'layer' aggregations that exceeded 800 m horizontally and smaller 'discrete' aggregations, and the rockfish aggregation patterns could not be distinguished from walleye pollock aggregation patterns. The potential gains from the TAPAS design when a strong relationship exists between acoustic energy and trawl catches provides motivation to refine the relationship between these variables, particularly focusing upon isolating the portion of acoustic energy attributable to rockfish and quantifying the relative catchability of the trawl and acoustic gear.

By Paul Spencer

A FRESH Look at Fish Reproductive Biology and its Effect on Fisheries Assessment and Management

Paul Spencer gave a presentation titled "Incorporating reproductive biology into stock assessments: experiences from Alaska and the U.S. West Coast" at the Fish Reproduction and Fisheries Conference (FRESH) in Vigo, Spain, on 20 May. The FRESH project was funded from 2007 to 2011 and consists of a network of scientists interested in the biological processes of fish reproduction and the incorporation of reproductive biology into fisheries assessment and management. The FRESH project has produced several workshops and peer-reviewed publications, with the Vigo conference being the final official activity. The conference consisted of over 50 presentations organized into the following six sessions: 1) Evaluate inputs used to estimate reproductive potential; 2) Standardized methods to estimate total egg production; 3) Causes of variation in reproductive parameters; 4) Methods of examining the causes of variation; 5) The impact of changes in stock reproductive potential on scientific advice; and 6) Methods to include stock reproductive potential in stock assessments.

Spencer delivered the keynote presentation for Session 6, which reviewed current research on reproductive biology being conducted in Alaska and the U.S. West Coast. The Bering Sea/Aleutian Islands Pacific ocean perch and the Gulf of Alaska walleye pollock assessments were used to evaluate how reproductive processes such as maternal effects in egg and larval survival and weight-specific fecundity may affect the estimation of relative stock size, stock-recruitment parameters, and fishing rate reference points. A particularly interesting finding is that the fishing mortality associated with maximum sustainable yield (F_{msy}) increases as the egg production per spawner weight increases. This could affect the estimation of F_{msy} for stocks in which egg production is erroneously assumed to be linear to spawning stock biomass (a common assumption in stock assessments). The proceedings of the FRESH conference will be published in the journal *Fisheries Research*.

By Paul Spencer

Chum Salmon Bycatch Analysis

Scientists from the AFSC continued to contribute to the analysis of groundfish fisheries in order to reduce chum salmon bycatch. The purpose of these analyses are to evaluate the trade-offs of the different alternative management approaches (and numerous sub-options) being considered by the North Pacific Fishery Management Council. The proposed management measures include hard caps (fixed bycatch limits); bycatch limits that trigger time and area closures; and a fleet-managed program for 4–7 day real-time bycatch area closures on (so-called rolling hotspot (RHS) program).

Part of the AFSC's contribution involved integrating information collected by fisheries observers on the numbers and lengths of chum salmon taken incidentally during groundfish fishing operations with the genetic analyses on the stock composition compiled by the Auke Bay Laboratories (ABL). Of particular note was the development which corrects stock composition estimates relative to the size (and hence age) of chum salmon taken incidentally in the pollock fishery. For example, if 100 fish projected from last year's bycatch would have returned to a river (or hatchery) this year, then last year's genetic estimates of the bycatch would apply (not this year's). This allows improved estimates on the impacts the bycatch totals have on specific regions where chum salmon return (e.g., providing answers to questions such as "How many more chum salmon would have returned to western Alaska had *no* bycatch occurred?"). Results confirmed early studies that indicated that during the early part of the summer fishery (June–July) a higher fraction of the chum salmon bycatch originates from western Alaska (about 24%) compared to later in the year (August–October) when the proportion decreases to about 14%. These results also indicate that more than half of the chum salmon bycatch originates from rivers and hatcheries in Japan and Russia. The estimated ratio of western Alaska bycatch relative to the number of regional returning chum salmon averaged less than 1% (with the highest year estimated to have had a 1.5% reduction in returning salmon due to bycatch in the pollock fishery).

Other types of analyses that were included in the draft Environmental Assessment submitted to the Council included two novel approaches to evaluating status quo management measures. In particular, aspects of the RHS program were evaluated by examining detailed vessel-specific patterns in bycatch in recent years. A second approach was to impose a pseudo RHS program on the historical data (prior to the existence of such programs) and estimating the numbers of salmon that would have been avoided in the bycatch had such a program been in place.

At its June meeting held in Nome, Alaska, the Council revised and restructured the suite of alternatives and options and requested new information. The Council will thus review the analysis two more times prior to making a final decision in mid-2012.

By Jim Ianelli and Alan Haynie

Age & Growth Program

Age and Growth Program Production Numbers

Estimated production figures for 1 January – 30 June 2011. Total production figures were 10,103 with 2,139 test ages and 166 examined and determined to be unageable.

Species	Specimens Aged
Blackspotted rockfish	23
Flathead sole	538
Great sculpin	149
Greenland turbot	1.413
Kamchatka flounder	24
Northern rock sole	508
Northern rockfish	331
Pacific cod	892
Pacific ocean perch	1,001
Rex sole	483
Rougheye rockfish	226
Shortraker rockfish	19
Southern rock sole	3,118
Walleye pollock	2,532
Yellow Irish lord	212
Yellowfin sole	303

By Jon Short