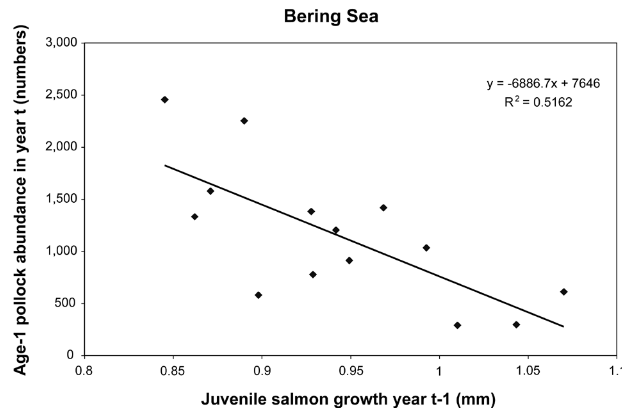
Auke Bay Laboratories (ABL)

ECOSYSTEM MONITORING & ASSESSMENT

Juvenile Salmon Growth as Proxies for Prerecruitment Ocean Productivity and Subsequent Recruitment of Groundfish in the Gulf of Alaska and Bering Sea

The Ecosystem Monitoring and Assessment (EMA) Program recently determined the value of using salmon growth time series as an ecosystem indicator and forecast tool for groundfish recruitment. The concept is that juvenile Pacific salmon growth on the continental shelf is a proxy for the overall productivity of waters above the continental shelf—an important rearing area for age-0 and age-1 groundfish. We used juvenile Pacific salmon growth during their first year in salt water (SW1) in year t to predict the recruitment at age-1 (eastern Bering Sea (EBS) Pacific cod and walleye pollock and Gulf of Alaska (GOA) pollock) and at age-2 (GOA sablefish) in year t+1. Recruitment indices were taken from groundfish stock assessment reports. The measurement of growth during the juvenile life stage was made along the radial axis of the scales collected from adult Pacific salmon. Juvenile marine growth (SW1) of sockeye salmon from Naknek River in western Alaska was used to predict the recruitment of age-1 pollock and cod in the EBS. Juvenile marine growth of sockeye salmon from the Karluk River on Kodiak Island in southcentral Alaska was used to predict the recruitment of age-1 walleye pollock in the GOA. Juvenile marine growth of chum salmon from Fish Creek in southern Southeast Alaska was used to predict recruitment of age-2 sablefish in the GOA. Estimating SW1 from scales of adult salmon rather than from scales of ocean-caught juvenile salmon may be biased due to size selective mortality of smaller fish during the marine life stage. To verify our findings, SW1 was estimated as the average body length of pink salmon captured in the surveys in the southern EBS from EMA Program's BASIS/BSIERP surveys. We also developed a temperature change (TC) index calculated as the difference between the late summer temperature (energy density hypothesis) and subsequent spring sea temperatures (oscillating control hypothesis) in the EBS. We hypothesized that the combined effects of cold summers (energy density hypothesis) followed by warm spring (oscillating control hypothesis) favor the recruitment of groundfish in the EBS.

For the EBS and GOA groundfish stocks, a change in the SW1 and recruitment relationship occurred near the 1988-89 shift in the Arctic Oscillation (AO). The AO is an index of the speed of the counterclockwise atmospheric circulation over the Arctic to lat. 55°N. During the 1977-89 negative AO phase, the tighter and faster circulation of counterclockwise winds in the Arctic stratosphere acted to retain stable cold air in the Arctic. During this phase, the SW1-recruitment relationship was positive, and TC was not significant in the model. During the 1990-present positive AO phase, a looser, slower, and weaker stratospheric circulation pattern results in less stable Arctic air, fewer winter storms, and moves cold air farther south into the Subarctic and GOA. During this AO phase, the SW1-recruitment relationship was negative, and TC was significant in the model, suggesting that temperature may change quality or quantity of prey and increase competition for food among juvenile pelagic fish in the EBS. The importance of the TC index in determining year-class strength of groundfish indicates that temperature-related processes were more important in driving recruitment during the positive phase AO regimes. Positive AO phases impacted fish stocks differentially in the GOA and EBS. The prediction of a more positive and variable AO indicates that the recruitment of groundfish will increase in the GOA and decrease in the EBS.



Fiure 1. Linear regression model output describing age-1 pollock recruitment (millions) in the eastern Bering Sea as a function of juvenile growth measured on scales of age 2.2 sockeye salmon from Naknek River, Alaska.

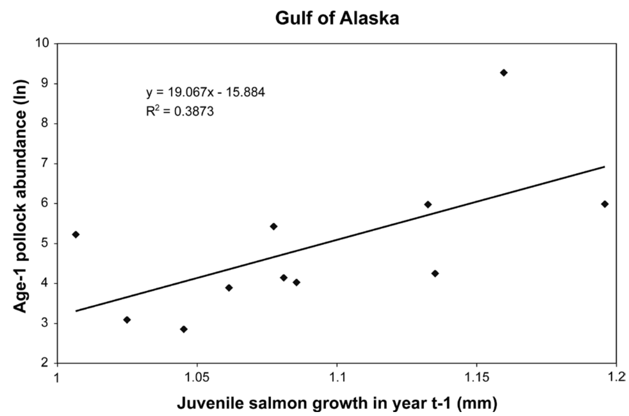


Figure 2. Linear regression model output describing log transformed recruitment (millions) of age-1 pollock recruitment in the Gulf of Alaska as a function of juvenile growth measured on scales of age 2.2 sockeye salmon from Karluk River, Alaska.

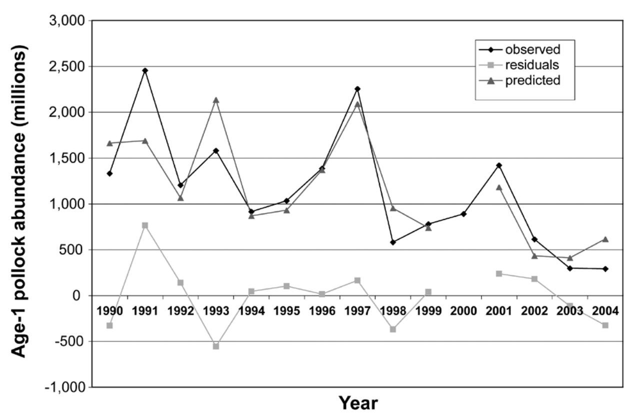


Figure 3. Multiple regression model output describing the recruitment of age-1 pollock (t) in the eastern Bering Sea as a function of the temperature change index and the juvenile growth (t-1) measured on scales of age 2.2 sockeye salmon from Naknek River, Alaska.

During the 1989-2004 period, SW1 was a negative predictor for EBS groundfish and a positive predictor for GOA groundfish. For the EBS, SW1 explained 52% of the annual variability of age-1

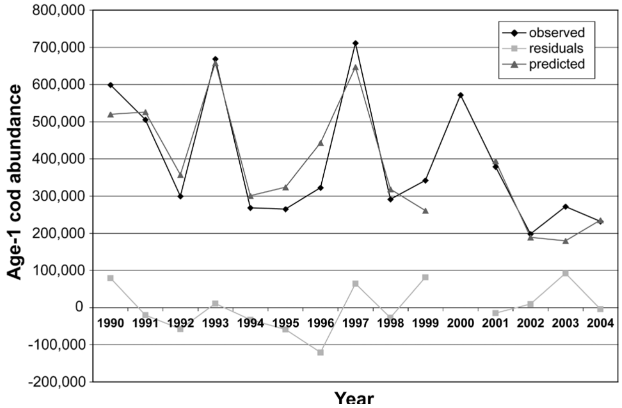


Figure 4. Multiple regression model output describing the recruitment of age-1 Pacific cod (t) in the eastern Bering Sea as a function of the temperature change index and the juvenile growth (t-1) measured on scales of age 2.2 sockeye salmon from Naknek River, Alaska.

pollock recruitment (Fig. 1). For GOA stocks, SW1 explained 32% of the annual variability in the log transformed age-1 pollock recruitment (Fig. 2) and 59% of the annual variability in age-2 sablefish abundance. For the EBS, the TC index and SW1 explained 75% of the annual variability in age-1 walleye pollock abundance the subsequent year (Fig. 3) and 87% of the annual variability in age-1 Pacific cod in the subsequent year (Fig. 4).

To verify our findings we used a short time series of the mean body length of ocean-caught juvenile pink salmon from the BASIS survey in the southern EBS, an area south of lat. 60°N and between long. 161°W and 168°W. For years 2003-07, the model with the average annual length of pink salmon and the TC index explained 80% of the annual variability in the estimated recruitment of age-1 Pacific cod and 95% of the annual variability in the estimated recruitment of age-1 pollock.

Juvenile Pacific salmon body length and marine growth (SW1) were important ecosystem indicators and predictors of subsequent recruitment of groundfish in the EBS and the GOA. Juvenile marine growth helped explain additional variation in recruitment not accounted for by climate indices. Colder summer sea temperatures and shorter juvenile salmon during age-0 life stage and warmer spring sea temperatures during age-1 corresponded with higher subsequent recruitment of age-1 pollock and cod in the EBS. The long-term monitoring of the biology of adult Pacific salmon provides a historical perspective of how the dynamics of marine species respond to low-frequency changes in climate. Monitoring juvenile salmon and age-0 groundfish at sea provides a real-time and more precise tool for predicting the recruitment of commercially important species prior to the age of determination of year-class strength.

By Ellen Martinson

FISHERY ECOLOGY DIET & ZOOPLANKTON

Exploring Conspecific Predation of Pacific Salmon at Sea in Alaska

Conspecific predation on juvenile Pacific salmon has been considered a potential factor in regulating marine recruitment of salmon. In his 1962 treatise on the regulation of abundance of pink salmon populations, the Canadian fisheries biologist W.E. Ricker developed a series of hypotheses around potential factors that could affect populations of this species. One hypothesis involved marine depensatory mortality, in which inbound migrant adult pink salmon of one brood line could become predators on outbound seaward migrant juveniles of the opposite brood line. However, surprisingly little has been published on the topic of marine predation on juvenile salmon by salmon or other species in the decades since Ricker formed his hypotheses.

Researchers from ABL's Southeast Coastal Monitoring (SECM) project have monitored potential predators of juvenile salmon during monthly surveys in Southeast Alaska since 1997. During these May-September surveys, predator complexes have been sampled in addition to other biophysical features associated with juvenile salmon habitat use and stock distribution. In the 14 years of sampling epipelagic habitat with a Nordic surface trawl, more than 1,000 guts of immature and adult salmon have been examined, including approximately 400 pink, 90 chum, 20 sockeye, 118 coho, and 386 Chinook salmon. Until 2010, predation on juvenile salmon was only observed in adult coho (13%) and immature Chinook salmon (0.2%). Two incidents of predation by adult pink salmon on pink salmon juveniles were observed in June 2010. In other years, coho and Chinook ate juvenile pink and chum salmon ranging from approximately 80 to 200 mm fork length from June to September, with up to four juvenile salmon prey per gut. These predation events occurred in Icy and Chatham Straits, Cross Sound, and in coastal waters off Icy Point. In addition to conspecific salmon predation, other juvenile salmon predators were identified from another 14 non-salmonid species representing 1,100 potential predators. The principal salmon predators identified were spiny dogfish, Pacific sandfish, pomfret, walleye pollock, salmon shark and, in one year (1999), age 1+ sablefish. Overall, predation rates were low in Southeast Alaska, but occasional episodes of high predation by non-salmonids on juvenile salmon could have impacted harvest of returning adult salmon.

To explore conspecific predation of salmon in another Alaska region, SECM scientists collaborated with biologists from the Cordova office of the Alaska Department of Fish and Game (ADF&G) to examine Ricker's hypothesis of predation by the odd-year broodline of pink salmon in Prince William Sound (PWS) as a potential cause of depressed returns of even-year pink salmon in 2009. During seine test fisheries, returning adult pink (214) and chum (42) salmon were examined in southwest PWS in summer. Of all the adult salmon sampled, four predation events were recorded in June and July, by both species. However, the five salmon prey encountered included only juvenile chum salmon and two unidentified salmon. Since the latter were observed in adult pink salmon, we could not rule out that cannibalism by alternate broodlines occurred, but evidence from Southeast Alaska suggests that such predation is uncommon. Results from 2010 studies in PWS are not yet available.

By M. Sturdevant, R. Brenner, J. Orsi, E. Fergusson, J. Moss, and B. Heard

GENETICS

Stock Composition of Salmon Bycatch Samples Completed

The Genetics Program at ABL recently completed its stock composition analysis of Chinook and chum salmon bycatch samples from the 2009 Bering Sea trawl fishery. Results were presented to the North Pacific Fishery Management Council (NPFMC) in Sitka, Alaska, in June 2010. We're now working with the North Pacific Groundfish Observer Program (FMA Division) to develop revised sampling protocols for collecting representative genetic samples from the salmon bycatch with our final recommendations due to the NPFMC later this summer. Research is also ongoing at the Little Port Walter Marine Station to uncover how hatchery releases can impact local fish populations where coho salmon are being used as the model species. The Auke Creek weir, a facility operated by NMFS in collaboration with the ADF&G and the University of Alaska, recently shifted from counting outmigrant sockeye, pink, and coho salmon smolts to enumerating returning adult sockeye salmon. Through collaborations with the University of Alaska, genetic samples are collected from the returning sockeye salmon to investigate genetic structure important for planned supplementation experiments.

By Jeff Guyon

MARINE ECOLOGY & STOCK ASSESSMENT

Recruitment and Response to Damage of an Alaskan Gorgonian Coral

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. This information is critical to understanding long-term effects of anthropogenic disturbances, such as commercial fishing, on the population dynamics of benthic habitat.

In 2009, ABL scientists initiated a multi-year study to examine recruitment and recovery of the gorgonian coral *Calcigorgia spiculifera*. This species is broadly distributed in the Gulf of Alaska and along the Aleutian Islands and was chosen because it is found within diver depth. *C. spiculifera* as well as many other gorgonian corals is found in areas and depths that coincide with trawl and longline fisheries and can be damaged by these fisheries. The body plan of *C. spiculifera* is similar to many other gorgonian corals commonly found throughout the North Pacific Ocean. Therefore, sensitivity to disturbance, rate of recovery, and recruitment of *C. spiculifera* is likely to be similar to other coral species; thus, results from this research could be applied broadly. Recovery rate and recruitment data are necessary for modeling habitat impacts and forecasting recovery and will ultimately guide fisheries managers in making decisions regarding benthic habitat conservation measures. In this study, recruitment is being investigated by observing settlement of coral planulae onto rings equipped with natural stone tiles; coral recovery is being examined by observing the response of colonies to damage treatments.

The study site Kelp Bay in Southeast Alaska has hundreds of *C. spiculifera* colonies concentrated at depths easily accessible to scuba divers. Field operations in Kelp Bay began in August 2009 when a team of four divers located and tagged 48 *C. spiculifera* colonies. Of that total, nine colonies were fitted with settlement rings equipped with removable tiles (Fig. 5). The remaining 39 tagged colonies were ascribed to three damage treatment groups and a control group. The damage treatments were designed to mimic actual damage that can occur from a passing trawl. These treatments were performed *in situ* and included deflection, gorgonin excision, and branch severance. Video of each colony was recorded before and after the treatments were performed to establish baseline coral characteristics and to identify immediate treatment effects. In June 2010, the dive team returned to the study site and collected a subsample of the stone tiles. The tiles were preserved in solution and will be inspected in the laboratory for adhesion of coral recruits. Damaged and control colonies were videoed once again so that comparisons can be made to pretreatment images. Subsequent site visits in September 2010 and beyond will allow additional tile collections and will detail the long-term effects of disturbance.

By Pat Malecha

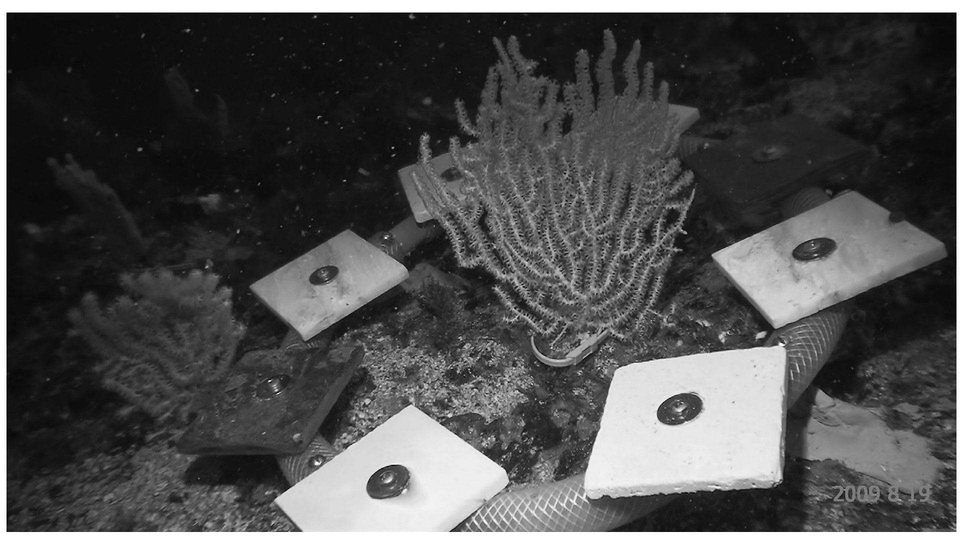


Figure 5. A *Calcigorgia spiculifera* colony inside a settlement ring. Photo by Erika Ammann.

Fisheries Monitoring & Analysis (FMA) Division

The FMA Division's Continuing Role in the Central Gulf of Alaska Rockfish Pilot Program

The Central Gulf of Alaska (GOA) Rockfish Pilot Program (RPP) is an example of a fishery which transitioned as a pilot program from open access to a Limited Access Privilege Program (LAPP). Launched in 2007, the RPP has been a highly successful program due to collaboration between NMFS and industry participants. A description of the project at inception is available in the April-June 2007 issue of the AFSC Quarterly Report) Outcomes of the RPP include reduced halibut bycatch rates, reduced discard rates, and increase in production of high-value products (Catch Share Spotlight No. 11 (http://www.nmfs.noaa.gov/sfa/domes_fish/catchshare/docs/goa_rockfish.pdf). The Fisheries Monitoring and Analysis (FMA) Division plays an active role in ensuring the fine-scale quota monitoring needs of this limited access program are met.

Observers Nicole Hageman and Ariane Frappier collect specimens for an AFSC rockfish maturity project. Photo by Rob Swanson.

Prior to the RPP, the GOA rockfish fishery was a derby style race for fish and typically only lasted for about 3 weeks. Participating catcher vessels were required to carry an observer during 30% of their fishing days within the target fishery. The RPP is a share-based management program permitting harvesters to form voluntary cooperative associations and receive exclusive harvest privilege. Through cooperative management of the fishery, participants may adopt conservation-minded practices without forfeiting overall opportunity in the fishery as would occur in a derby style fishery. As a result, the fishing season has extended from mid-May to November. Participating vessels are required to carry observers during 100% of their fishing days due to the need for high resolution data to track quotas within a LAPP. Additionally, shoreside processors have been required to have an observer to cover each 12 hour period during which it receives or processes fish, and the observer may not be concurrently assigned to another processor.

A close working relationship between the FMA Division and observer providers is essential to ensuring that observers and equipment are in place when needed. FMA staff also work closely with industry representatives to address any data issues that may affect a cooperative's ability to manage their fleet's quota. Data collected for the RPP are transmitted to FMA's main office via custom software. The approximately 35 participating catcher vessels share 16 laptop computers equipped with custom at-sea data entry software. Observers on catcher vessels enter their data while at sea; the data are transmitted from the processing plant because the laptop computers are not equipped with the necessary data transmission software. Eight catcher processor vessels typically participate in this fishery and are required to be equipped with the at-sea data entry and transmission software at all times. FMA staff ensure that the hardware and software are functioning correctly and are able to transmit data in a timely manner.

The RPP also has created new opportunities for scientific studies on rockfish. FMA field staff work closely with other AFSC staff and observers to collect specimens for a study of development and spawning maturity in several rockfish species. The longer fishing season enables the collection of specimens at varying stages of maturity, thereby permitting scientists to better understand the reproductive biology and seasonality of spawning for each species. The data from these collections are used for stock assessments and for managing the fishery.

The RPP was created as a pilot program and will expire after the 2011 fishing season. However, during its June 2010 meeting, the North Pacific Fishery Management Council took final action to define a rockfish catch share program to replace the RPP to allow continuation of this valuable fishery. The details of the Council's recent action can be found on the Council's website at http://www.fakr.noaa.gov/npfmc/current_issues/groundfish/RockfishMotion610.pdf. As NMFS works to implement the Council's action, FMA staff will work to ensure that the information needs from this fishery are met now and into the future.

By Allison Barns and Rob Swanson

National Marine Mammal Laboratory (NMML)

ALASKA ECOSYSTEMS

Real-Time Polymerase Chain Reaction Analysis of Northern Fur Seal Telomeres

Bobette Dickerson with the Alaska Ecosystems Program traveled to Juneau, Alaska, to use the quantitative PCR (polymerase chain reaction) machine in the genetics facilities at Auke Bay Laboratories to examine an alternative approach to ageing northern fur seals.

Currently, the only reliable way to age northern fur seals is to examine the "rings" in their teeth, which, of course, requires the removal of a tooth. For obvious reasons, this is a less than desirable method for ageing. Recent studies (primarily focused on birds) have examined the relationship between the length of an animal's telomeres and the age of the animal, which has led to the ability to estimate age in some species based on a small genetics sample. Every chromosome has a telomere attached to the end of it (tandem repeat sequence) which, in general, shortens as the organism ages. However, the telomeres of a given individual can and will shorten faster or slower than the telomeres of others based on factors besides age, such as environmental perturbations and other stressors, and the effects of these factors and ageing on the shortening of telomeres vary by species. Thus, the feasibility of using telomere length as an indicator of age must be validated for each species, and possibly each population, in which it is attempted.

Because telomeres exist on each chromosome in a given organism and do not shorten at exactly the same rate on each chromosome, it is difficult to determine the average length of the telomeres in a given animal using traditional molecular techniques. The quantitative PCR machine allows for an analysis of real-time PCR (RT PCR). By comparing the results of the RT PCR conducted on telomeres with results for a single copy gene in the same animal, Bobette was able to estimate the relative average length of the telomeres in 200 northern fur seals (collected from the Pribilof Islands) for whom age will be known based on examination of their teeth. It is hoped this will result in a reliable age-to-telomere-length curve, which would enable us to age animals with just a small tissue or blood sample.

Although the results are pending, thus far, we know that the RT PCRs worked very successfully, and we will know by this fall if this method is sufficient for ageing northern fur seals. Without the support and collaboration of the ABL research team, this work would not have been possible.

By Bobette Dickerson

CETACEAN ASSESSMENT & ECOLOGY

Guadeloupe Humpback Whale Satellite Tagging Project

Humpback whales migrate to the West Indies to breed each winter from a broad range of feeding grounds across the temperate and high latitudes of the North Atlantic Ocean. The largest concentrations of North Atlantic humpbacks today occur on Silver, Navidad, and Mouchoir Banks to the north of Hispaniola, as well as in Samaná Bay in the northeastern Dominican Republic. Since scientific research on humpbacks in the Caribbean began in the early 1970s, researchers have worked in this area to establish abundance estimates and describe the spatial and temporal distribution, habitat preference, migration, mating behavior, acoustics, stock identity, and genetics for the entire North Atlantic population. Although humpback whales have historically used the entire Caribbean Sea as a winter breeding ground, a comparison of modern sighting data to whaling records indicates a shift in distribution from the Lesser (southern) to the Greater (northern) Antilles.

While humpback whales over-wintering in the Dominican Republic are one of the most intensely studied large whale populations in the world, very little survey effort has taken place in Guadeloupe or elsewhere along the Antillean chain. On 24 April 2010, I met with researchers from the Dominican Republic, University of Guadeloupe, and University of Paris South in Guadeloupe to conduct a humpback whale tagging project. This survey was meant as the first step in an attempt to answer some of the following questions: What feeding ground stock do these whales come from? What sex and maturity classes are represented at this time of year? How long are whales staying in Guadeloupe waters?

Eighteen individual whales, including four calves, were observed during 9 days of survey effort (Fig. 1). Seventeen of those individuals were biopsied, and five adults were satellite-tagged (using an air rocket transmit deployment system and tags designed and manufactured by Wildlife Computers in Redmond, Washington). To date, locations have been received from three tags (Fig. 2). One tag was still transmitting positions as of this writing, as the whale continued her northward migration with her calf. High quality song recordings were obtained from three individuals. The College of the Atlantic and the Provincetown Center for Coastal Studies curate local and international North Atlantic Humpback whale catalogues (NAHWC) that include photographs and sighting history data for humpbacks seen during the feeding and breeding seasons. To date, none of the individuals photographed during the Guadeloupe survey (Figs. 3a, b) have been matched to the smaller Gulf of Maine humpback whale catalog, but comparisons with the NAHWC are under way. The biopsy samples are being processed

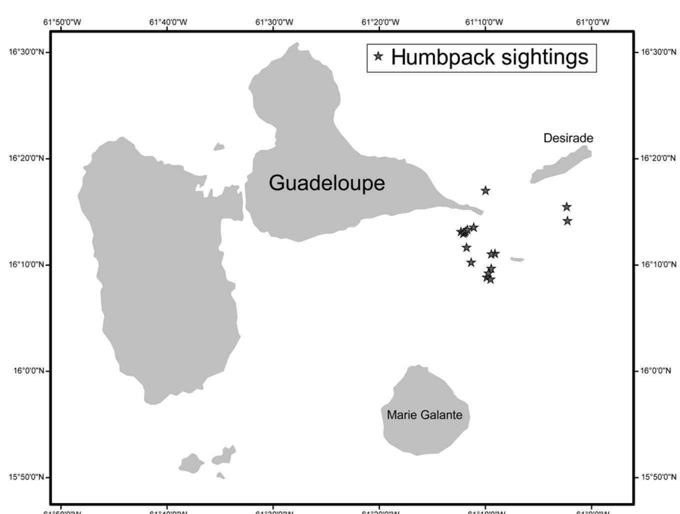


Figure 1. Individual humpback whale sightings, 24 April-10 May 2010.

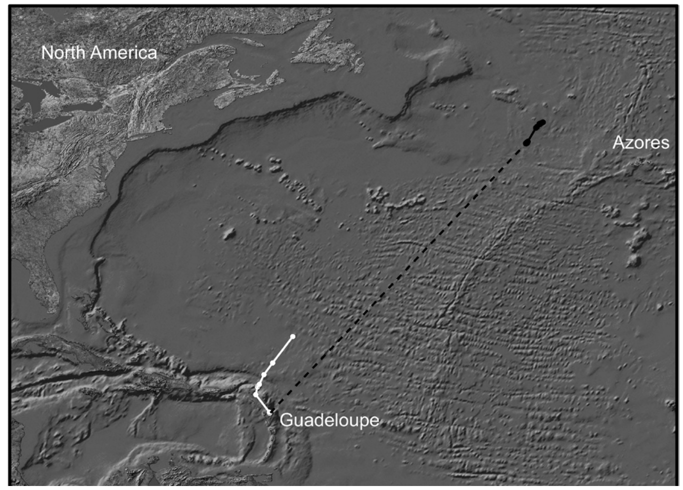


Figure 2. Satellite telemetry from two of the tagged humpback whales. The tag shown in white stopped transmitting on 8 May 2010, but the tag shown in black was still giving reliable positions as of this writing.

Figure 3 a, b. Humpback whales photographed off St. Francois, Guadeloupe.

at the University of Guadeloupe, and we hope they will shed some light on the stock structure and feeding ground origin of the animals seen in this area. Further acoustic, satellite-telemetry, genetic, and photo-identification studies are needed to help determine the spatio-temporal distribution of the humpbacks that use the Leeward Islands during the winter months.

By Amy Kennedy

POLAR ECOSYSTEMS

Research Cruise Aboard the *McArthur II* in the Central Bering Sea, April-May 2010

The Polar Ecosystems Program (PEP) participated in an ice-seal research cruise in the central Bering Sea this spring, 26 April-25 May 2010, aboard the NOAA ship *McArthur II*. Primary objectives for the cruise were to deploy satellite-linked tags on ribbon and spotted seals and to collect biological samples including blood, blubber biopsies, hair, whiskers, skin, and scats. Satellite-linked tags provide critical information on haul-out and dive behavior and seasonal movements; data collected this year will be combined with information collected during similar cruises conducted since 2005 to provide additional information on haul-out and dive behavior and seasonal movements. The biological samples will be used to establish baseline data for research projects (including diet, physiology, disease, and contaminant studies) being conducted with ribbon and spotted seals; current data about much of the biology of these seals are scarce.

Both ribbon and spotted seals have been petitioned to be listed under the U.S. Endangered Species Act, primarily out of concerns about global warming and the loss of sea-ice habitat. Information on the timing of haul out is critical for estimating abundance from previous and future aerial surveys, and data on movements and dive behavior will help to identify important habitat.

The *McArthur II* departed Kodiak, Alaska, on the morning of 26 April and arrived at the ice edge and began research operations the morning of 30 April. A typical day consisted of survey observations from 9 am to 8 pm Hawaii-Aleutian Standard Time; observation times were centered close to local solar noon. The survey observations were interrupted by small-boat excursions to capture and tag seals when we encountered sufficient concentrations of seals and suitable ice. Seals were captured on ice floes with large, hand-held landing nets. The field crew consisted of seven biologists from NMML's PEP and California Current Ecosystems Program, one biologist from the Alaska Department of Fish and Game, and one veterinary technician from the Wildlife Health Center, School of Veterinary Medicine at University of California, Davis (Fig. 4). We conducted surveys and tagging operations daily until the evening of 22 May, and the *McArthur II* returned to Dutch Harbor, Alaska, on the morning of 25 May.

Figure 4. The 2010 *McArthur II* ice seal cruise crew included biologists from the Polar Ecosystems Program, California Current Ecosystems Program, Alaska Department of Fish and Game, and a veterinarian from the School of Veterinary Medicine, University of California, Davis. Back row, left to right: Dave Withrow, Erin Moreland, Josh London, Gavin Brady. Front row, left to right: Jay VerHoef, Jeff Harris, Tracey Goldstein, Lorrie Rea, Heather Ziel.

We captured 42 seals in all, comprising 23 ribbon and 19 spotted seals. We attached satellite transmitters to 17 ribbon and 8 spotted seals (Figs. 5, 6). We deployed 14 SPOT tags (Wildlife Computers, Redmond, WA), attached to the seals' hind-flippers, which will provide long-term movement data and haul-out timelines but only when the seals are hauled out with their flippers exposed. We also deployed 11 SPLASH and 6 MK10 tags (Wildlife Computers); these tags provide more detailed information about the seals' locations at sea and diving behavior. These tags must be glued to the hair on the seal's back or head and, thus, could only be attached to seals that had sufficiently completed their annual molt. In addition to the satellite-linked tags, we attached a numbered flipper tag to the hind-flipper of each seal that identified it as being previously captured.

This year we expanded our sampling protocol compared to what we have done in the past. Sampling typically included length and girth measurements, mass, blood, a small piece of skin for genetics analysis, any fecal material present on the ice for diet analysis, and any urine on the ice for domoic acid analysis. This year, we also collected hair for mercury analysis, blubber for contaminants or fatty acid analysis, whiskers for stable isotope analysis, nasal swabs for disease analysis, and an ultrasound for blubber depth. We also took many photos to document sampling for each animal; photos generally included teeth, claws, any tags attached, overall condition, the release of the seal, and anything else that was distinct or important. We obtained blood samples from 37 seals, from which we collected whole blood, serum, plasma, and red blood cells, and measured hematocrits and hemoglobin levels. We also collected 42 skin samples and nasal viral swabs, 33 whiskers, 18 blubber biopsies, 29 fecal samples, 29 hair samples, 14 urine samples, and 26 ultrasounds from captured seals. All of the samples, including those collected in the past and those added to the sampling protocol this year, will be helpful in establishing baseline data for a variety of analyses about the biological condition of these seals.

By Josh London and Heather Ziel

Figure 5. A ribbon seal pup in the Bering Sea with satellite-linked transmitter attached to the back and orange flipper tags attached to the rear flippers. Photo by Dave Withrow.

Figure 6. A spotted seal pup in the Bering Sea with satellite-linked transmitter attached to the back. Photo by Dave Withrow.

Resource Assessment & Conservation Engineering (RACE) Division

GROUNDFISH ASSESSMENT

Research Vessels Begin Biennial Bottom Trawl Survey of Aleutian Islands

Two vessels chartered by Resource Assessment and Conservation Engineering (RACE) Division's Groundfish Assessment Program are conducting more than 2 months of scientific bottom trawl surveys in the Aleutian Islands, continuing a time series of biennial or triennial surveys that stretches back to 1980. The results of these surveys are used to derive fishery-independent estimates of abundance, distribution, and biological condition for groundfish resources in the Aleutian waters of Alaska.

Scientists on the *Sea Storm* and the *Ocean Explorer* are expected to complete 420 survey trawl hauls over a 70-day period along the continental shelf and upper continental slope of the southeastern Bering Sea and Aleutian Islands archipelago. They started 6 June in Dutch Harbor and are scheduled to end their charters in Dutch Harbor on 14 August. The boats started the survey near Unimak Pass, surveying stations on the Bering Sea side of the nearer islands of the Aleutian archipelago; west of the Islands of Four Mountains (long. 170°W) they began sampling stations both north and south of the chain. The vessels will continue to work their way westward past Attu Island to Stalemate Bank (long. 171°E). The survey period will be broken into three legs, with breaks in Dutch Harbor on 29 June and in Adak on 22 July.

As of the end of June, when crews completed the first survey leg, about one-third of the stations had been sampled, and the project is on schedule to be completed successfully. Each boat holds six scientists plus the skipper and crew. In addition to core staff from the AFSC, scientists from Humboldt State University, the University of Washington, and the University of Alaska Fairbanks are participating on various legs of the survey.

The biennial survey monitors trends in the distribution and abundance of commercially and ecologically important groundfish species such as walleye pollock, Pacific cod, Atka mackerel, flatfish, and rockfish. It also helps us measure various biological and environmental parameters such as sea surface and bottom temperatures and the size, age, and food habits of important groundfish species. The survey has been carried out every other year since 2000. Before then, it was conducted approximately every 3 years beginning in 1980.

The vessels make 15-minute trawl hauls at randomly preselected stations. The trawl catches are sorted, weighed, and enumerated by species (Fig. 1). Samples are collected from selected species to determine fish sex, size, age, sexual maturity, and food habits. Data on the location and depth of the survey tows, the fishing dimensions and performance of the trawl, and environmental observations are recorded using a variety of monitoring instruments on the vessel or that are attached to the trawl headrope. Sample depths will range from depths greater than 15 m near shore to 500 m on the upper continental slope.

Following completion of the survey in early August, scientists will edit and finalize the data they collected on fishing effort and catch rates. For each species, they will use the data to estimate abundance and describe their geographic and depth distribution. They will also generate estimates of population size and age distributions of the groundfish species that are annually assessed and managed by the North Pacific Fishery Management Council. Results of the survey will be provided to stock assessment modelers and analysts by the end of September. Assessment teams will then combine that information with data from

Figure 1. Frank Shaw prepares for sorting a catch of walleye pollock and flatfish aboard the chartered fishing vessel *Sea Storm* during the 2010 bottom trawl groundfish assessment survey of the Aleutain Islands.

Figure 2. Scientists, engineers, and technicians observe deployment of the Klein 7180 long-range sidescan sonar system during training exercises conducted in Puget Sound, Washington. Photo by Bob McConnaughey.

the fishery and results of previous surveys to update the stock assessments.

By Mark Wilkins

Habitat Researchers Participate in Long-range Sidescan Sonar Training and Testing

Members of the Groundfish Assessment Program's Habitat Research Group received formal operator training for the newly delivered Klein 7180 long-range sidescan sonar system (LRSSS). The LRSSS is a towed underwater platform (towfish) with multiple acoustic, environmental, and navigational sensors which, combined with topside processing electronics, efficiently collects, processes, and archives seafloor and water-column data. In particular, the LRSSS is capable of very broad coverage at high speeds, as compared to conventional towed systems. This capability increases the area of seabed that can be mapped per survey day thereby improving vessel productivity. The technology is innovative and applicable to multiple strategic goals. For example, the Habitat Research Group is collecting quantitative backscatter data for use in basin-scale continuous-valued fish habitat models, while NOAA hydrographers are interested in the LRSSS as an efficient tool for their emerging survey work in the Arctic.

Representatives of L-3 Communications Ocean Systems (Sylmar, California) conducted the LRSSS training at the Naval Undersea Warfare Center in Keyport, Washington. In addition to members of the Habitat Research Group, the training group included scientists, engineers, and technicians representing the NOAA Office of Coast Survey (Hydrographic Systems & Technology Program), the NOAA Office of Marine and Aircraft Operations (Electronics Engineering Branch), the Naval Undersea Warfare Center, and the University of New Hampshire (Center for Coastal and Ocean Mapping). The training program consisted of a day of classroom lectures on 13 April followed by 3 days of hands-on activities aboard the Navy vessel *Discovery Bay* (YTT-11). The classroom session covered setup and logging procedures, deployment and recovery operations, and software applications. The underway operations were conducted in Port Madison, an embayment located off the north end of Bainbridge Island in Puget Sound (Fig. 2). The shipboard training included system start-up, towfish deployment, operator controls, system software, and towfish recovery.

During the following week (19-22 April), systematic performance testing was conducted while underway in Port Madison. These exercises, involving the Habitat Research Group and a subset of the training class, were intended to better characterize the LRSSS and to guide future engineering work that will enhance performance and ease of use. Both the training and the testing exercises are part of ongoing preparations for a cooperative, large-scale field experiment in the Bering Sea. This project will compare the cost-benefits of the LRSSS with more conventional acoustic systems, including two hull-mounted hydrographic-quality multibeam echosounders and another high-resolution sidescan sonar system. The FISHPAC project will also provide hydrographic-quality bathymetric data to the NOAA Pacific Hydrographic Branch for updating nautical charts in areas with outdated or non-existent information.

By Bob McConnaughey

NEWPORT LABORATORY: FISHERIES BEHAVIORAL ECOLOGY

Experimental Examinations of Temperature Interactions in the 'Match-Mismatch' Hypotheses Using Pacific Cod Larvae

The temporal synchrony of marine fish larvae and zooplankton is being severely altered as the result of changing climatic conditions. Pacific cod have an extremely narrow spawning window in the spring (single-batch spawners) and may, therefore, be particularly susceptible in the timing of prey production and changing temperature field. At the AFSC's Fisheries Behavioral Ecology Program (FBEP) laboratory at the Hatfield Marine Science Center in Newport, Oregon, experiments have been under way to examine the response of Pacific cod larvae to 'matches' and 'mismatches' in prey availability in cold and warm years.

To collect eggs, we have repeatedly chartered cod-jigging vessels out of Kodiak, Alaska, to catch Pacific cod off their spawning grounds in early spring (Fig. 3). Female and male gametes were stripped and eggs were fertilized at sea. Fertilized egg batches (Fig. 4) were then shipped back to the FBEP laboratory to begin experimental feeding trials.

In the laboratory, we manipulated timing and magnitude of prey introduction under cold (3°C) and warm (8°C) conditions over a 6-week period. Larvae were reared in 100-L tanks on enriched rotifers, but at week 3, half of the feeding treatments were switched from either a low-food (LF) to a high-food (HF) prey density or from a HF to a LF prey density. Remaining treatments were maintained on a LF or HF ration throughout the 6-week period.

Early into the experiment (week 3), it was evident that temperature, not timing or prey abundance, explained the majority of growth variation in this species (Figs. 5 and 6). However, at high temperatures, significant effects of prey abundance were detectable at the end of the experiment (6 weeks; Fig. 5). Prey timing (match-mismatch) was demonstrated to be important only if 1) it occurred at high temperatures and 2) mismatches in prey occurred after the 3-week prey switch, largely due to the buffering effects of the yolk-sac period and compensatory growth mechanisms of the larvae.

The effects on survival were also interesting. Despite some variance explained by prey level and prey timing, most of the survival variance was due to temperature (i.e., warm temperatures resulted in a 2-4× survival increase (Fig. 7)). Therefore, even in the absence of predation, there appears to be a strong effect of temperature on stage-duration mortality.

These experiments support the idea that strong year classes of Pacific cod will be positively linked with temperature in the North Pacific. However, there are no guarantees. While Pacific cod can increase their growth rates following early prey mismatches, larval mortality in the wake of a complete absence of prey would be magnified under warm conditions. For example, based on yolk-reserves alone, earlier work in our lab indicated Pacific cod larvae would not be able to take advantage of the late blooms in the

Figure 3. Adult Pacific cod caught on jigging gear aboard the fishing vessel *Miss O* in April 2007. Photo by Benjamin Laurel.

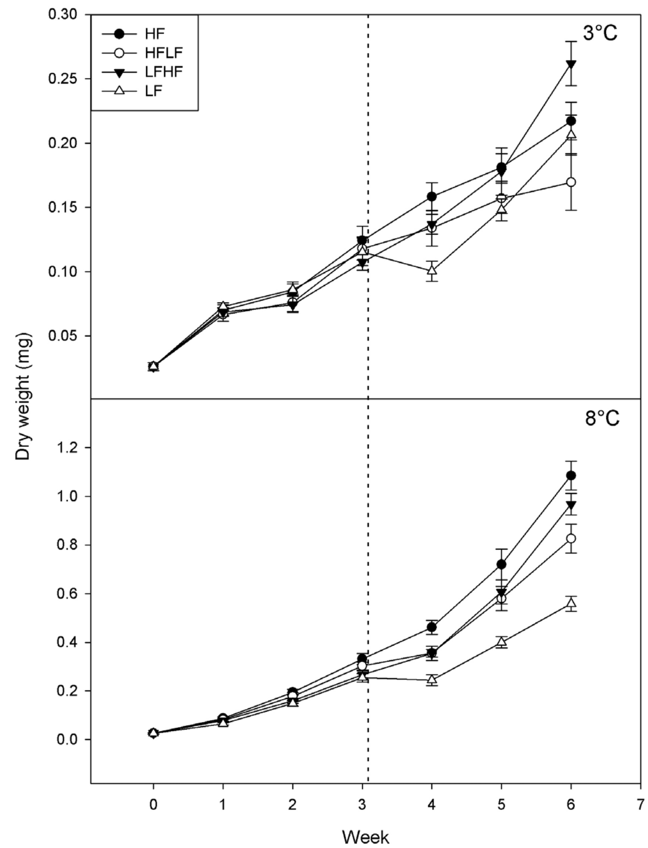


Figure 5. Changes in larval mass at two temperatures under varying 'match' conditions (i.e., high food (HF)) and varying mismatch conditions (i.e., low food (LF), (3) HF then LF (HF-LF), and (4) LF then HF (LF-HF)). The dotted line indicates the timing of prey switch in the HFLF and LFHF treatments. Most growth variance is explained by temperature (note the differences in scale along the y-axis between top and bottom panel.

Figure 4. Fertilized batches of Pacific cod being prepared for shipment back to the FBEP lab in Newport, Oregon. Photo by Benjamin Laurel.

Figure 6. Pacific cod larvae (3 weeks post-hatch) reared under high food conditions at 8°C. Photo by Benjamin Laurel.

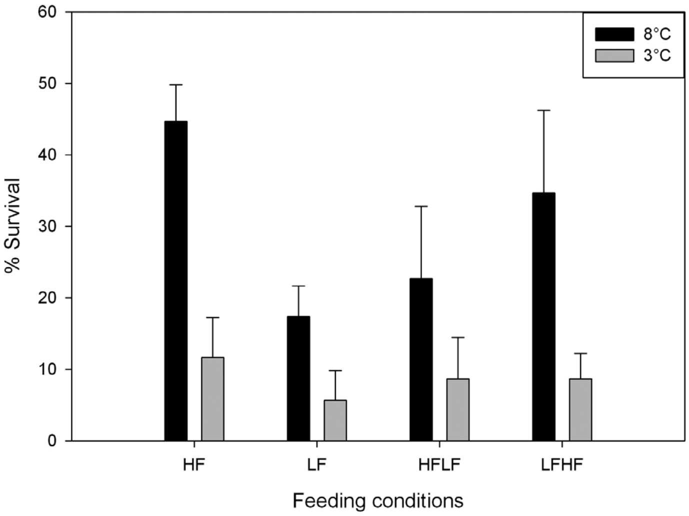


Figure 7. Differences in survival at 6-weeks post-hatch. Note that most differences in survival are due to temperature rather than feeding conditions.

Bering Sea if peak larval supply precedes the bloom by more than 2 weeks, whereas at colder temperatures (e.g., 0°C), this window of opportunity is nearly doubled. Collectively, our results demonstrate a clear need to consider the physical environment, both as a driver of lower level productivity and as a major factor influencing the physiology and food requirements of larvae interacting with their prey.

By Benjamin Laurel

KODIAK LABORATORY

Does Maternal Size Affect Red King Crab Recruitment Potential Due To Embryo or Larval Production?

A priority for fishery managers is to develop biological reference points based on monitored characteristics of a population, such as reproductive potential, which reflect population status. Stock assessment and management of Alaskan red king crab, *Paralithodes camtschaticus*, (Fig. 8) does not currently incorporate recruitment potential based on embryo or larval production. To improve upon this, data on fecundity, embryo quality, and larval quality variability due to maternal size is needed.

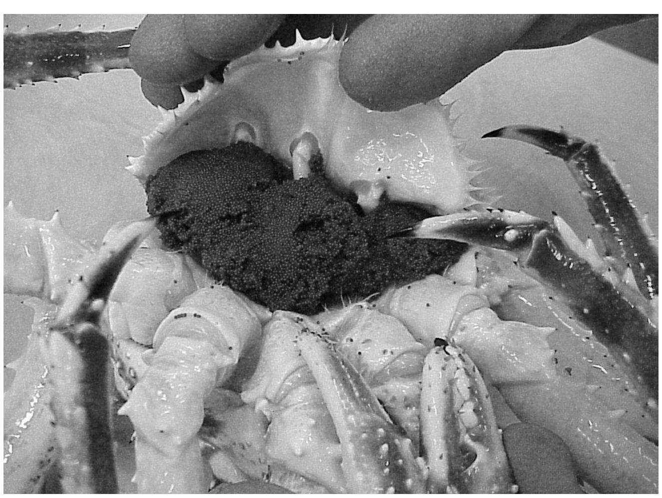


Figure 8. Female red king crab brooding eggs. Photo by Katherine Swiney.

Red king crab fecundity increases with maternal size (Fig. 9). Egg loss may occur over the 10- to 12-month brooding period, so fecundity data should ideally be collected close to hatching. In Bristol Bay, however, red king crab fecundity is typically estimated shortly after extrusion; therefore, an understanding of egg loss during brooding is necessary. Between 2007 and 2009, fecundity from small (<105 mm carapace length (CL)) and large females (≥ 105 mm CL) early in the brooding period (summer) was compared to later (fall) fecundity. There was no clear pattern for small females, with results among years ranging from 16.7% lower fall fecundity, to no seasonal difference, to 11.8% higher fall fecundity. Large females were 4.8%-8.2% less fecund in the fall than summer (Fig. 10), suggesting embryo loss during brooding which should be accounted for in stock assessment and management.

Maternal size influences embryo quality, larval quality, and recruitment potential in some, but not all, crustacean species. For example, American lobster, *Homarus americanus*, fecundity and embryo quality both increase with increasing maternal size resulting in larger females having a higher recruitment potential. In 2008, larval quality based on dry mass, carbon (C) and nitrogen (N) content, and time to 50% mortality (LT_{50}) under starvation conditions was assessed as a function of maternal size from crab

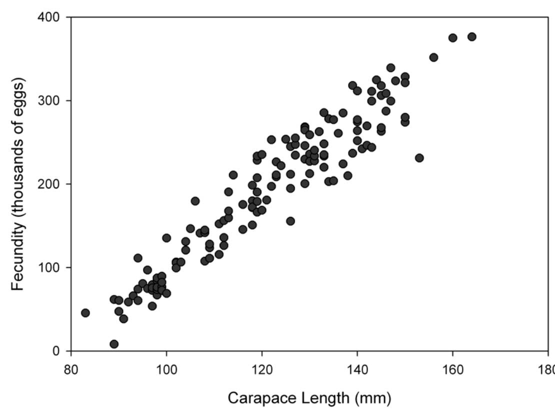


Figure 9. Scatterplot of Bristol Bay red king fecundity by maternal size summer 2008.

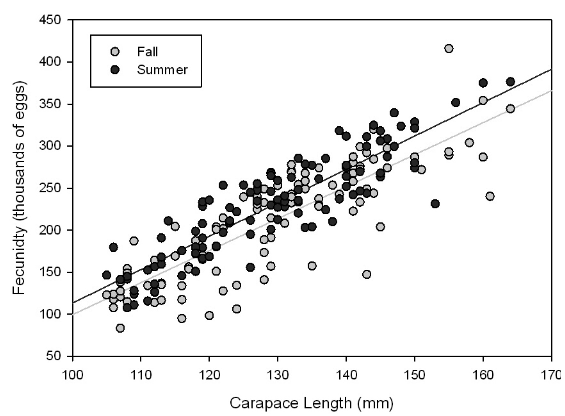


Figure 10. Seasonal comparison of large (≥ 105 mm carapace length) Bristol Bay red king crab fecundity by maternal size summer and fall 2008.

93-135 mm CL. Maternal size did not affect any of the measured parameters. In 2009, embryo quality based on dry mass, and C and N content was assessed from red king crab females 86-145 mm CL. Among these measures of quality only N content significantly increased with maternal size although maternal size explained very little of the variance ($r^2 = 0.16$). To determine if maternal size effects on embryo N levels persist inter-annually, samples are being collected in 2010.

Larger females likely have a higher recruitment potential due to higher fecundity even if larval quality does not vary with maternal size. Maternal size effects on fecundity and embryo loss must be considered in order to incorporate recruitment potential into stock assessment and management of red king crab.

By Katherine Swiney

Resource Ecology & Fisheries Management (REFM) Division

RESOURCE ECOLOGY & ECOSYSTEM MODELING

Fish Stomach Collection and Lab Analysis

During the second quarter of 2010, most of the fish stomach analysis conducted by Resource Ecology and Ecosystem Modeling (REEM) Program staff continued to focus on very detailed identification and enumeration of prey taxa. This information is being used to satisfy requirements of an essential fish habitat (EFH) project and a project dealing with flatfish prey selectivity in the eastern Bering Sea. This information is also a critical component of a Bering Sea Integrated Ecosystem Research Program (BSIERP) project to examine the functional feeding responses to predator, prey, and environmental conditions. Stomach samples were analyzed from eight predator species from the eastern Bering Sea (n = 2,374). Laboratory personnel also dried 797 tissue samples in preparation for stable isotope analysis. Fisheries observers returned 80 stomach samples from the eastern Bering Sea and 19 stomach samples from the Gulf of Alaska. In total, 17,265 records were added to the REEM food habits database.

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

Ecosystem Modeling

As a follow-up to previous workshops with field biologists to develop the FEAST (Forage/Euphausiid Abundance in Space and Time) model (part of the BSIERP project funded by the North Pacific Research Board), meetings with individual field biologists have been carried out to better incorporate their feedback into the model. The FEAST model code has now been substantially modified by REEM researcher Kerim Aydin to have an age-length structure (as opposed to length-based only) and to include all 12 fish species and catch removals; trial runs are being carried out for 1999. REEM researcher Ivonne Ortiz gave a presentation of FEAST on behalf of Kerim Aydin at the PICES (North Pacific Marine Science Organization) Symposium on Climate Change Effects on Fish and Fisheries: Forecasting Impacts, Assessing Ecosystem Responses, and Evaluating Management Strategies. The symposium was held in Sendai, Japan. Aydin and Ortiz also have been collaborating with Henry Huntington (BSIERP/PEW Arctic Program) on “calorie-sheds” mapping based on subsistence harvest of marine species by native Alaskan communities. Ortiz, with coauthor AFSC scientist Elizabeth Logerwell, also submitted a paper to *Marine and Coastal Fisheries* as part of the special issue on Atka mackerel.

By Ivonne Ortiz and Kerim Aydin

Cameo Workshop on End-to-End Ecosystem Modeling

In April, Kerim Aydin cochaired the Comparative Analysis of Marine Ecosystems (CAMEO) End-to-End Ecosystem Modeling Workshop in Woods Hole, Massachusetts. This workshop brought together over 40 researchers from NOAA, the National Aeronautics and Space Administration, and multiple academic institutions to discuss and compare methodology for developing end-to-end ecosystem models. End-to-end marine ecosystem models are those that include ocean physics and plankton dynamics and explicitly model food web connections to fish, marine mammals, and humans. The workshop focused on model evaluation methods, such as data assimilation and model forecast skill assessment.

By Kerim Aydin

International Stock Production Modeling Workshop

In May, REEM ecosystem modelers participated in the international Stock Production Modeling Workshop funded through the CAMEO program. The workshop, led by Bern Megrey (AFSC) and Jason Link (Northeast Fisheries Science Center), was held in Woods Hole, Massachusetts, from 10 to 14 May 2010. Fifteen U.S. scientists from the NMFS Alaska and Northeast Fisheries Science Centers, the Universities of Washington, Maryland, Rhode Island, and Alaska worked together with seven Canadian and three Norwegian colleagues to assemble data on eight ecosystems for comparisons using production modeling methods. The ultimate goal of the comparisons is to elucidate how three types of drivers—fishing, feeding, and physical environment—interact to affect ecosystem production. In advance of the workshop, REEM researchers Sarah Gaichas and Kerim Aydin provided time series data for all major groundfish species in the Gulf of Alaska and eastern Bering Sea, as well as diet matrices from the food web models for those ecosystems. They also contributed background presentations on the Gulf of Alaska ecosystem and methods for fitting ecosystem models to time series data. Buck Stockhausen and Teresa A’mar (Status of Stocks and Multispeces Assessment Program) contributed background presentations on the Bering Sea ecosystem and environmental time series for the Gulf of Alaska. Each participant is also contributing to one or more of the ongoing projects described below.

During the workshop, data from Gulf of Alaska and eastern Bering Sea ecosystems was compared with data from the Straight of Georgia ecosystem in the northeast Pacific, the Gulf of Maine/Georges Bank, Scotian Shelf/Bay of Fundy, Labrador/Newfoundland, and Gulf of St. Lawrence ecosystems in the northwest Atlantic, and the Norwegian/Barents Sea ecosystem in the northeast Atlantic. Four projects were initiated at the workshop. First, the data from all of the ecosystems were categorized into a common aggregation framework encompassing habitat, feeding, taxonomic, and life history type guilds, and a database with information from all eight ecosystems was assembled. Second, a multispecies surplus production model was used to determine the potential consequences of applying several different aggregate biological reference points to a simulated fish community with known productive capacity and species interaction terms. Third, single species surplus production models were fit to data for the same or similar species across the ecosystems to compare estimated surplus production and examine the effects of physical covariates and species interactions for those species across the ecosystems. Finally, aggregate surplus production models were fit to summed data for all species within several ecosystems to examine differences in ecosystem-level surplus production.

The workshop was extremely productive and significant progress was made on all four projects in just a week. Workshop participants have submitted abstracts to present results at four international conferences in 2010, with many more expected in future years. Multiple peer-reviewed publications were outlined at the end of the workshop with contributions from all participants to be submitted in the next year.

By Sarah Gaichas

Observer Seabird Training and the Collection of Seabird Data

AFSC scientist Shannon Fitzgerald and Coastal Observation and Seabird Survey Team (COASST) representative Jane Dolliver traveled to Anchorage, Alaska, in June to meet with Kathy Kuletz and Tamara Zeller of the Migratory Birds Management Group, U.S. Fish and Wildlife Service (USFWS), to discuss observer training and the collection of seabird data. COASST was chosen by the AFSC's Coordinated Seabird Studies Group to provide the observer seabird training sessions in Seattle, Washington, during 2010

The AFSC is exploring this training option over in-house training in order to more effectively provide services to clients on a broad range of topics. By bringing in a team of experts in training of seabird identification (especially those seabirds recovered as bycatch) AFSC staff can focus resources on other products. An important step, however, is to ensure that the training provided to observers at each location, Seattle and Anchorage, are consistent. In Anchorage, Zeller has provided training for several years (with Kuletz handling those duties previously). The June meeting was valuable in comparing presentation materials and approaches and coordinating those efforts.

This was also an excellent opportunity for Fitzgerald and Kuletz to meet and discuss the Seabird Observer Notes aspect of the program. Responding to requests from the USFWS in 1992, while improved seabird monitoring and observer training was being developed, the Fisheries Monitoring and Analysis (FMA) Division's Observer Program has had observers record notes and observations outside of the normal bycatch information captured in their species composition and other standard forms. This has led to much interesting information and has formed the basis for additional work, such as the ongoing efforts to further quantify seabird mortality on trawl vessels. Through an excellent effort by the FMA Division, those notes have now been moved into a format where they are captured electronically and managed in the Observer Program's relational database.

By Shannon Fitzgerald

ECONOMICS & SOCIAL SCIENCES RESEARCH

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

Economic and Social Sciences Research (ESSR) Program researcher Stephen Kasperski is developing multispecies bioeconomic models of groundfish in the Bering Sea. These models are designed to account for 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. Ecosystem-based approaches to fisheries management should address both the interactions that occur in the biological ecosystem as well as the larger economic system in which the harvesters operate. Single-species management of multispecies fisheries ignores these interactions and can lead to the detriment of the health of the ecosystem, fish stocks, and fishery profits.

The model developed in this study solves a dynamic optimization problem of maximizing the value from a three-species fishery and determines the optimal harvest quota of each species given the biological, technological, and temporal interactions. The model is currently being applied to the pollock, Pacific cod, and arrowtooth flounder fisheries in the Bering Sea to estimate optimal harvesting quota for each species over time. The population of each species will be simulated into the future with and without each set of interactions to isolate the impact of each type of species interactions on the sustainability and profitability of the fishery. The current theoretical results highlight the importance of including biological, technological, and temporal interactions when determining quota in a multispecies fishery.

By Stephen Kasperski

Eliminating Double Counting When Estimating Regional Economic Impacts of Harvest Changes

Demand-driven input-output (IO) models are useful in calculating the economic impact from changes in final demand, enabling analysts to examine interindustry transactions. Some previous studies, however, argue that it is more appropriate to use supply-driven models in situations where the output level (e.g., harvest level or total allowable catch (TAC)) is altered, because the change in demand is not known. In addition, for complex international sectors such as North Pacific fisheries, it is not necessarily easy to derive changes in final demand that would correspond to the initial change in output in the supply side. However, supply-driven models that calculate the forward linkage effects have been criticized due to technical theoretical issues, and economists have criticized the models in applications where they are used to explain changes in physical output arising from changes in physical factor inputs (common in fisheries applications).

To address these weaknesses and correctly estimate the economy-wide impacts of an exogenous change in productive capacity (e.g., change in harvest level or TAC), we can run the demand-driven IO model with changes in output specified as final demand changes and with regional purchase coefficients (RPCs) for all the directly impacted industries (e.g., fish harvesting and processing industries) set equal to zero. By setting the RPCs to zeroes, the model can effectively prevent other regional industries from purchasing the output from these seafood industries, and therefore, avoid the double counting problem typically encountered when demand-driven approaches are used to calculate the impacts of exogenous change in output. ESSR researcher Chang Seung is developing this type of model to improve estimates of regional economic impacts of various fishery management actions involving changes in catch of certain species or landings of certain vessel types.

By Chang Seung

Developing an Alaskan Community Data Collection Project

The North Pacific Fishery Management Council (NPFMC), the AFSC, and community stakeholder organizations have identified as a priority ongoing collection of community-level economic and socioeconomic information in Alaska, specifically related to commercial fisheries. The AFSC's ESSR Program is developing a voluntary data collection program intended to provide systematic annual data for economic impact assessment of communities involved in North Pacific fisheries (initially focused on Alaska communities for feasibility reasons) and will ensure that both commercial fisheries data and community-level socioeconomic and demographic data are collected at comparable levels of spatial and thematic resolution. Such data will facilitate analysis of the impact of commercial fisheries and proposed changes in commercial fisheries management, both within and across North Pacific communities involved in commercial fishing.

Data collected from communities in this survey will include information on community revenues based in the fisheries economy, fisheries support program costs, vessel expenditures in ports, fisheries infrastructure available in the community, support sector business operations in the community, and demographic information on commercial fisheries participants from the community. Information to be collected in this program is intended to capture the most relevant and pressing types of data needed for economic analyses of plants, vessels, and communities. Additional data categories may be added once the survey instrument is pretested.

The ESSR Program is developing a draft survey instrument for this data collection. Pending Office of Management and Budget clearance, the ESSR Program anticipates mailing the questionnaire to 136 fishing communities in Alaska in spring 2011.

By Amber Himes

Alaskan Community Meetings Being Held to Revise Profile Template

Community Profiles for North Pacific Fisheries—Alaska, NOAA Technical Memorandum NMFS-AFSC-160 published in 2005, developed community profiles for 136 communities engaged in or dependent upon the fisheries in and off Alaska. ESSR Program researchers will revise and update that report following the availability of new community data from the 2010 U.S. Census. To assist with planning the community profile updates, ESSR staff will contact end-users of the profiles document (such as researchers employed by NPFMC and NOAA to conduct social impact assessments) to gather their input on how the document can be improved and what parts of the current document are most useful to them. In addition, ESSR Program staff will conduct five public meetings with community members from the 136 communities in the 2005 profiles. The community meetings will be held in late August and early September in Anchorage, Dutch Harbor, Bethel, Nome, Petersburg, and Kodiak. The meetings will be used to create a revised template for the community profiles, increase input of communities and the fishing industry into the profiles, facilitate a greater understanding of the relationship between communities and fisheries in the fisheries management process, increase the utility of the profiles, and build ongoing relationships between the AFSC and local communities.

By Amber Himes

Data Collection Survey to Produce Processor Profiles for Inclusion in Alaska Community Profiles

Workers come from many places inside and outside Alaska to work seasonally in its fish processing facilities. As a result, the population of an Alaska community with a fish processing plant can increase significantly during peak processing seasons. However, very limited information is available in a consolidated location or format about these fish processing facilities. Our study proposes to obtain basic information such as an estimate of the number of individuals employed at each processing facility during the months of operation, the peak number of workers for processing various species by season, the ethnicity of processing workers, types of lodging and other accommodations and activities available for processing workers, whether or not the company provides meals for the processing workforce in a company galley, the interactions between seasonal processing workers and permanent residents of the community, and the history of the fish processing facility in the community. Such information is important when attempting to forecast possible social impacts of fishing regulations on communities which have an onshore fish processing facility. This information will be gathered through a voluntary phone survey as well as through site visits to a few selected communities (Cordova, Petersburg, and Kenai, Alaska) pending Office of Management and Budget approval.

The NOAA Technical Memorandum *Community Profiles for North Pacific Fisheries—Alaska* provides short descriptions of 136 communities in Alaska involved in commercial, recreational, and subsistence fishing. These community profiles have been used in various Social Impact Assessments to inform fisheries management. The profiles currently include limited information on the fish processors present in each community due to lack of availability of this type of data.

A small number of the community profiles include information on the number of processing employees at a certain processing plant only if this information was readily available on the Internet; however, for the most part, the community profiles only include the total number of processing plants in each community and the species they typically process. This limited information doesn't allow for a detailed picture of the social role of fish processors in the profiled communities. The community profiles will be updated when the new 2010 U.S. Census data is released in 2011. Our survey project will produce "processor profiles," short narrative descriptions of all the onshore fish processing plants in the state of Alaska that will augment and update existing community profiles.

All onshore fish processing plants in Alaska will be recruited to take part in this phone survey. Plant managers will be the primary point of contact. The phone survey will take approximately 10-20 minutes to complete. Onshore fish processing plants in the communities of Cordova, Petersburg, and Kenai, Alaska, will be recruited to take part in the site-visit survey portion of the study. These communities were selected because they have not previously received a site visit and have the largest number of fish processing facilities in their subregions. The in-person survey will take approximately 40-60 minutes to complete. Participation is voluntary for both the phone and site-visit surveys. However, each plant's participation is highly valued, and the resulting processor profiles will help provide more detailed information on the important social role of processors in communities. Participating plant managers will have the opportunity to review the processor profile and suggest changes.

By Christina Package

The Impacts of Climate Change on Fleet Behavior in the Bering Sea Pollock Catcher/Processor Fishery

This project, one element of the Bering Sea Project component of the BEST-BSIERP Ecosystem Partnership, examines how changes in climate conditions affect the fishing activities of the eastern Bering Sea (EBS) pollock catcher/processor fleet. Decreasing ice cover and increasing ocean temperatures are predicted to occur over the next 40 years and are expected to have an impact on the entire marine ecosystem of which commercial fishing is an integral part. These changes may have significant effects on the range and distribution of the pollock population, as well as where the fleet is able to fish. Biological literature has found evidence of northward shifts of the distribution of subarctic species in the Bering Sea, including walleye pollock, but the fishery and fish populations may not necessarily move together. Fishing vessels are driven by the search for dense aggregations of fish of the type and quality that can generate the highest valued product, are restricted by environmental conditions and the cost of travel, and are affected by world markets and economic conditions.

Our project examines the observable characteristics of the Bering Sea pollock catcher/processor fleet over the last 11 years to predict how the fleet may respond to climate change. We use a spatial discrete choice modeling approach to quantify the importance of price differences, expected catch per unit effort, travel costs, environmental conditions, and vessel diversity in the decision of where to fish. We compare the spatial distribution of fishing in particularly warm and cold years.

Ice cover and ocean temperatures affect where the fleet is able to fish, and in the winter season we observe small-scale shifts in the distribution of fishing toward the north in warm years. In the summer season, we observe a redistribution of effort from northern to southern areas of the fishing region in warm years. If prices and fish distribution and populations are related to climate regimes, we would predict these patterns to continue as warm years in the EBS become more frequent. Historically, spatial price variation in the fishery is highly correlated with climate regimes, but there is no clear mechanism to explain this linkage. Thus, we forecast changes in the location of the fishery both with prices linked to climate regimes and independent of them, which would assume that the observed correlation was by chance.

By Alan Haynie and Lisa Pfeiffer

BSAI Crab Annual Catch Limits and Rebuilding Analyses

ESSR Program staff have collaborated extensively with members of the NPFMC's Bering Sea/Aleutian Islands (BSAI) crab plan team (CPT) to develop and analyze alternatives for implementing the annual catch limits (ACLs) required under the Magnuson-Stevens Act Reauthorization and to develop rebuilding plans for eastern Bering Sea snow and Tanner crab stocks and Pribilof Island blue king crab stocks. Extending earlier work performed for the NPFMC and incorporating input from the CPT and the Scientific and Statistical Committee, ESSR economist Mike Dalton developed time series vector autoregression price forecasting models for Alaskan red and golden king crab and snow crab. CPT member and ESSR economist Brian Garber-Yonts worked with stock assessment analysts to integrate simulation of crab population and directed catch forecasting with price forecasting to simulate economic outcomes and illustrate the trade-offs between reducing the risk of overfishing and the attendant cost in foregone revenue under ACL and snow crab rebuilding alternatives. Economic analyses of revenue implications of ACL alternatives have been produced for each of nine BSAI crab stocks regulated under the Council's crab fishery management plan, as well as alternative rebuilding scenarios for Bering Sea snow crab, and incorporated into the initial review draft environmental assessment (EA). The draft EA was presented to the Council and SSC at the June meeting in Sitka. The final EA is scheduled to be issued for the October Council meeting.

By Brian Garber-Yonts and Michael Dalton

Crab Economic SAFE

The 2010 draft crab economic stock assessment and fishing evaluation (SAFE) document was presented to the crab plan team at the May CPT workshop in Girdwood, Alaska. The economic SAFE represents a statistical abstract of the BSAI crab fisheries, and includes data summaries from the BSAI crab economic data reports (EDR) as well as eLandings catch and landings data, commercial operators annual report data on crab production and wholesale trade, NMFS Alaska Restricted Access Management Division data on quota share initial allocations and annual individual fishing quota (IFQ) and individual processor quota (IPQ) issuance and use, and marine fuel price statistics for Seattle and BSAI region ports from Pacific States Marine Fishery Commission's monthly fuel price survey. Of particular interest are results from crab EDR data on crew compensation and employment effects of consolidation in the crab fisheries following rationalization, which are subject to further analysis in a paper by Abbott, Garber-Yonts and Wilen, to be included as an appendix to the final 2010 crab economic SAFE report, scheduled for release in September 2010.

By Brian Garber-Yonts and Jean Lee

Economic Data Collection for Amendment 91/Chinook Bycatch Incentive Monitoring

ESSR Program staff collaborated extensively with Council staff and members of industry to refine data collection instruments to monitor the effectiveness of management measures and incentive mechanisms adopted under Amendment 91 to promote reduction of Chinook salmon bycatch in the American Fisheries Act (AFA) pollock fisheries. Associated draft regulatory language and Paperwork Reduction Act documentation were developed in collaboration with NMFS Alaska Regional office staff in preparation for Council review in October. Survey instruments have been developed for collecting data according to Council directives to support the monitoring of market activity and prices for transfers of the Chinook prohibited species catch (PSC) allocation within the Incentive Plan Agreement structure approved under Amendment 91, as well as surveys of pollock vessel captains regarding Chinook salmon avoidance and fuel consumption and costs for participating vessels. Draft survey instruments were reviewed in an industry workshop held at the AFSC in June, and feedback provided therein provided a significant basis for clarifying monitoring objectives and improving the survey instruments, which are currently under revision for presentation to the Council in October. If approved by the Council, data collection is expected to be implemented in 2012.

By Brian Garber-Yonts, Ron Felthoven, and Alan Haynie

Implementation of Annual Crab and Amendment 80 Economic Data Reports

Annual economic data reporting requirements for the BSAI crab and Amendment 80 groundfish fisheries include June submission deadlines for the previous calendar year fisheries. Economic data report programs were administered for the second and sixth year of data reporting in the Amendment 80 and BSAI crab fisheries, respectively.

By Brian Garber-Yonts

Advances in Bioeconomic Models of North Pacific Crab Stocks

Bioeconomic models usually assume population dynamics that do not represent explicitly the biological fundamentals of individual growth because including these processes makes the mathematics of a model too difficult to analyze. However, the AFSC's ocean acidification research plan calls for an analysis of the economic effects of ocean acidification on North Pacific crab fisheries, and biological fundamentals should not be ignored. Therefore, we are developing a more realistic bioeconomic model that can be applied to North Pacific crab stocks, one in which growth and survival processes are explicit and depend on an animal's size.

While biological models with these properties are readily available, the challenge is in coupling the biological and economic models such that the resulting bioeconomic model is actually useful for analysis. The objective here is to solve for a set of dynamic decision rules that solve an inter-temporal optimization problem under uncertainty (e.g., maximizing expected present value of fishery profits), subject to the constraints of a size-structured biological growth model. In this case, the mathematics are too daunting unless a careful path is followed that preserves the linearity of the optimal decision rules. An advantage of this approach is that it provides regression equations that can be used with maximum likelihood estimation and testing.

We consider first the treatment of fishing effort as a scalar variable in a bioeconomic model in which size-structured stock dynamics are explicit. In this case, scalar effort is multiplied by a selectivity vector to produce a multivariate catch variable that applies to size classes in the model. The optimal decision rules are found by solving the roots of a characteristic polynomial for the bioeconomic model. We conducted an analysis that ascertained the following: 1) Solving the dynamic optimization in the most basic form of the bioeconomic model (i.e., linear constraint, quadratic objective, scalar control and scalar stock) reduces to finding the roots of a cubic polynomial; and 2) If the catch is drawn from multiple size classes, then the degree of the characteristic polynomial grows. For example, if the catch is drawn from two size classes then the characteristic polynomial is quintic. After that, adding a size class to the selectivity vector for the catch increases the degree of the polynomial by 1, for example, with three size classes in the catch the degree is 6, and with four size classes in the catch the degree is 7.

Consequently, we are not necessarily constrained in how many size classes that we include in the dynamic optimization, but we will be constrained in the number of size classes in the model that appear in the catch for the directed fishery. To keep the bioeconomic model tractable, we are currently working on a male-only model for eastern Bering Sea snow crab with five size-classes to capture the basic dynamics.

By Mike Dalton, Brian Garber-Yonts, and André Punt

STATUS OF STOCKS & MULTISPECIES ASSESSMENT

11th National Stock Assessment Workshop

The National Marine Fisheries Service held the 11th National Stock Assessment Workshop (NSAW), 17-20 May, in St. Petersburg, Florida. The NSAW was held in conjunction with the first National Habitat Assessment Workshop (NHAW), 18-20 May at the same location. A joint session of the NSAW and NHAW workshops was held 18-19 May with the theme of "Incorporating Habitat Information in Stock Assessments." Sandra Lowe of the Status of Stocks and Multispecies Assessments (SSMA) Program represented the AFSC on the NSAW Steering Committee. The theme of the 11th NSAW was "Improving Characterization of Scientific Uncertainty in Assessments to Improve Determination of Acceptable Biological Catches (ABCs)." The objective of this year's NSAW was the advancement of stock assessment methods to improve determination of the level of acceptable biological catch (ABC). The National Standard 1 Guidelines highlight the need for improved assessment and forecasting methods so that ABC can be set with a known and acceptable probability of overfishing. Where feasible, these methods should take into account the effect of ecosystem and environmental factors on fish stocks. Where data-rich methods cannot be applied, suitable approaches need to be developed to provide guidance for ABC specifications.

Several SSMA staff attended the workshop and gave presentations. Anne Hollowed, Susanne McDermott, Grant Thompson, Paul Spencer, and Jack Turnock gave oral presentations. Sandra Lowe presented a poster and moderated a session on developing a comprehensive approach for characterizing uncertainty. Their respective abstracts follow.

A Framework for Incorporating Climate Impacts on Pelagic Ocean Habitats Into Stock Assessments
Anne B. Hollowed, Angie Greig, Libby Logerwell, and Chris Wilson; AFSC, Seattle, WA

The volume of suitable pelagic ocean habitat can influence the dynamics of recruitment and growth of marine fish. In the case of recruitment, habitat volume influences survival through its role in governing the overlap of predators and prey and through its role in governing competition for limited resources. In the case of juvenile and adult growth, habitat volume influences the probability of spatial overlap between predators and prey. We present a framework for quantifying climate-induced shifts in pelagic ocean habitats and incorporating these shifts into the walleye pollock stock assessment as explanatory variables governing growth and recruitment. In this study acoustic backscatter and oceanographic data collected on the eastside of Kodiak Island from 2001 to 2006 are used to demonstrate the analytical approach. In most years, dominant pelagic fish species are walleye pollock and capelin. These species exhibit niche partitioning in most years and patterns of habitat association are used to identify proxies for essential foraging habitats for capelin and pollock. The volume of suitable habitat for the western central Gulf of Alaska is estimated by applying these habitat definitions using GIS software. The role of habitat volume is compared to time trends in size at age and reproductive success to establish functional relationships between habitat volume and key life-history parameters. These estimates are incorporated into stock assessments to assess the influence of these factors on the resource.

An Independent Estimate of Natural Mortality for Atka Mackerel Using Tagging Data

Susanne McDermott, James N. Ianelli, Sandra A. Lowe; AFSC, Seattle, WA

The importance of reliable natural mortality (*M*) estimates has long been recognized for stock assessments as applied for fisheries advice. *M* is often confounded with other parameters (e.g., selectivity and catchability), and tagging studies hold promise to avoid these problems. For Atka mackerel, *Pleurogrammus monopterygius*, assessments in Alaska, *M* estimates have been derived from life-history parameter correlates. Information outside the assessment is needed to configure appropriate prior distributions of *M*. Tagging data provide a means to estimate natural mortality independent of fishery or life history data. In this study a model of 3 years of tagging data from two distinct aggregations in the Aleutian Islands is proposed to estimate natural mortality. Preliminary results indicate that tagging data can provide supplemental information to stock assessments. However, more data are needed to validate assumptions from the tagging model (e.g., that the estimates reflect a long-term average for the population or apply only for the time period and areas considered in the study).

Specification of Observation Error Variances

Grant G. Thompson; AFSC, Seattle, WA

Except for pure process error models, all stock assessment models require specification of observation error variances. However, there appears to be no consensus among practitioners as to how this should be done. One school of thought holds that the specified variances should be equal to the values implied by the respective sampling designs. A problem with this approach is that the distributional assumptions included in 'off the shelf' stock assessment packages may not correspond to the actual sampling designs. For example, most stock assessment packages assume that age/size composition data are drawn from a multinomial distribution, but actual sampling may violate the multinomial assumption. In such cases, it is necessary to compute a multinomial sample size that produces a variance equal to that from the actual sampling distribution. An example is provided. A second school of thought holds that the specified variances should be larger than those implied by the respective sampling designs, so as to compensate for any process error not included explicitly in the model. These larger values are typically determined within the stock assessment model itself by iterative reweighting. However, this practice is at best an approximation, as it can be shown that adjusting observation error variances cannot compensate completely for unmodeled process error. Moreover, this practice has the effect of adding parameters to the model, thus tending to increase the variances of estimates in general. It can be shown that better performance is obtained by modeling the process error explicitly.

Trawl Survey Designs for Reducing Uncertainty in Biomass Estimates for Patchily-Distributed Species

Paul Spencer[1], Dana Hanselman[2,] and Denise McKelvey[1]; [1]AFSC, Seattle, WA; [2]AFSC, Juneau, AK

"Patchiness" in the spatial distributions of marine populations such as Alaska rockfish can arise from heterogeneous habitat characteristics and can result in errors in survey biomass estimates when high-density patches are either over-represented or under-represented in survey trawls. In this study, we developed a spatial survey simulation model to evaluate the influence of spatial aggregation on biomass estimation and considered alternative trawl survey designs intended to reduce the variability of biomass estimates. Variants of double sampling procedures were simulated in which high-density areas identified from acoustic data in the first sampling phase were then assigned increased trawl sampling densities in the second sampling phase. Geostatistical analyses of hydroacoustic data collected in Alaskan trawl surveys were used to simulate spatial distributions of fish populations. Simulated survey biomass estimates and sampling variability were evaluated as functions of several factors, including the spatial aggregation of the population and sampling density. When the relationship between the hydroacoustic data and fish density was strong, the double sampling procedure resulted in reduced variance in estimated biomass relative to simple random sampling with equivalent sample size. However, the variance in estimated biomass from the double sampling design was not substantially reduced when the relationship between hydroacoustic data and fish density was weak. The potential improvement in variance when a strong relationship exists between hydroacoustic data and rockfish density offers motivation to continue to refine analyses of hydroacoustic data and rockfish spatial patterns.

Estimating Scientific Uncertainty in Allowable Biological Catch (ABC) Control Rules for Bering Sea and Aleutian Islands (BSAI) Crab Stocks

Jack Turnock[1], Robert Foy[2], Anne Hollowed[1], André E. Punt[3], Lou Rugolo[1,] and Diana L. Stram[4]; [1]AFSC, Seattle, WA; [2]AFSC, Kodiak, AK; [3]University of Washington, School of Aquatic and Fishery Sciences, Seattle, WA; [4]North Pacific Fishery Management Council, Anchorage, AK

A shared management scheme exists for the BSAI crab stocks, between the Federal government and the State of Alaska. Annual catch limit (ACL) provisions of the Magnuson-Stevens Fishery Conservation and Management Act require that ACL control rules be devised that establish a buffer between the overfishing limit (OFL) and an ABC to account for scientific uncertainty in the OFL. Scientific uncertainty arises from several sources but can be divided into two main categories for computing the ABC: 1) uncertainty within a stock assessment that can be quantified using standard methods of variance estimation, and 2) sources of uncertainty which cannot be captured in this way. Examples of the latter include: a) errors in proxy definitions for F_{MSY} and $B_{MSY;}$ b) errors associated with the values for prespecified parameters of population models (e.g., natural mortality, *M*, and catchability, *q*); c) methodology (e.g., how survey area swept estimates are computed); and d) the choice of which data sources are included in assessments. For stocks with functional assessment models, within-assessment uncertainty is a standard output while additional uncertainty can be estimated using other methods (retrospective analyses, between-year variability in assessment outcomes). In these cases, the relationship between *P** (the probability that the ABC exceeds the true OFL) and the buffer between the OFL and ACL, can be estimated by stock. For stocks without assessment models, the scientific uncertainty associated with OFL can be computed using Monte Carlo simulation. For stocks with insufficient biomass data, the OFL is based on historical catch data, and a default buffer must be assumed based on informed judgement.

Deciphering Environmental Patterns and Effects From Messy Data
Sandra A. Lowe; AFSC, Seattle, WA

Alaska Atka mackerel (*P. monopterygius*) is an important component of the Aleutian Islands (AI) ecosystem and supports a large commercial fishery. Sustainability of this population has been dependent on highly variable recruitment and the consistent appearance of strong year classes. Interestingly, strong year classes of AI Atka mackerel have occurred in years of hypothesized climate regime shifts 1977, 1988, and 1999, as indicated by indices such as the Pacific Decadal Oscillation. El Niño Southern Oscillation (ENSO) events are another source of climate forcing that influences the North Pacific. Preliminary analyses have not indicated a relationship between strong year classes of Aleutian Atka mackerel and ENSO events. We reexamine this relationship in light of significant recent recruitment events. Quantitative observations about the ENSO effects on fishes can be difficult, and as such we also examine anomalies of weight-at-age tracked by cohort to decipher potential patterns that may reflect environmental influences. We suggest ways that environmental indicators of growth patterns may be incorporated into the stock assessment.

By Sandra Lowe

ICES, PICES, and FAO International Symposium: Climate Change Effects on Fish and Fisheries: Forceasting Impacts, Assessment Ecosystem Responses, and Evaluating Management Strategies

Climate change has many impacts on marine ecosystems and on human uses of ecosystem services. Improved scientific support for policy and management decision-making in the face of these potential impacts is essential. To facilitate the advancement of this critical research, the International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), and the Food and Agricultural Organization (FAO) held an international symposium in Sendai, Japan, on April 25-29. Anne Hollowed, Senior Scientist and Program Manager of the Status of Stocks and Multispecies Assessments (SSMA) Program, served as a symposium convener. The symposium was convened to provide a forum for scientists and policymakers to discuss the potential impacts of climate change on marine ecosystems and uses of these ecosystems, and to consider the strategies that society can take to be prepared for anticipated impacts. The 2010 symposium builds on the 2008 ICES, PICES, and Intergovernmental Oceanographic Commission International Symposium on the Effects of Climate Change on the World's Oceans, which was held in Gijon, Spain, in May 2008. The 2010 symposium:

- provided a forum to discuss techniques for investigating the impacts of climate change on population parameters, distribution, migration, production, and abundance of fish and shellfish in capture and cultured fisheries and on food web processes supporting fish and shellfish;
- provided an opportunity for scientists to discuss their observational, analytical, and modeling approaches with other research teams in order to stimulate methodological improvements;
- allowed experts to identify analytical techniques needed to reliably forecast climate change impacts on marine fish and shellfish populations including methods for quantifying the uncertainty in projections and ways to address the uncertainty in policy and management; and
- allowed experts from diverse disciplines to discuss policies and strategies for society and users of marine resources in the face of a changing climate and altered marine ecosystems.

SSMA staff Anne Hollowed, Jim Ianelli, and Teresa A'mar gave presentations. Their respective abstracts follow.

Scenario-based Models for Predicting Stakeholder Responses to a Changing Climate: A Case Study for the Eastern Bering Sea
Anne B. Hollowed[1], Nicholas A. Bond[2], Alan Haynie[1], James N. Ianelli[1] and Franz J. Mueter[3]; [1] AFSC, Seattle, WA; [2] University of Washington, Joint Institute for the Study of Atmosphere and Ocean, Seattle, WA; [3] University of Alaska, School of Fisheries and Ocean Sciences, Juneau, AK

The North Pacific Research Board and the National Science Foundation are funding a large interdisciplinary research program to provide forecasts of the impacts of climate change on the eastern Bering Sea ecosystem. These forecasts require scenarios of future stakeholder engagement and decision rules to simulate how stakeholders will respond to a changing environment. A retrospective analysis is conducted to explore how fishers and policy makers shifted their strategies in response to past changes in climate and societal pressures. Three factors emerged as the key drivers influencing stakeholders and managers: changes in socioeconomic conditions, changes in fisheries management, and changes in scientific understanding. Stakeholder decision rules are developed to predict responses to legal or economic constraints governing commercial fishing in the region. Ecosystem scenarios are derived by statistical downscaling climate/ocean forcing for the region from Intergovernmental Panel on Climate Change (IPCC) model output. The scenarios of stakeholder responses are developed for the following stressors: a) changes in the demand for seafood, b) increasing fuel prices, and c) resource partitioning due to species interactions, fisheries interactions, or Marine Spatial Planning. Scenarios of shifting ecosystem conditions will include: a) shifting zoogeographic boundaries due to climate change, and b) shifting reproductive potential due to changing climate. The trade-offs and risks associated with each stakeholder scenario are discussed. The decision rule approach provides a foundation for communicating with stakeholders and attempts to initiate discussions of more complex adaptive and holistic management and modeling approaches.

The Challenges of Developing Fisheries Stock Assessment Approaches, Harvest Control Rules, and Management Strategies to Satisfy and Adapt to Increasingly Complex Management Objectives in a Changing Environment

James N. Ianelli; AFSC, Seattle, WA

The task of applying the best available information for fisheries management advice is growing rapidly as the number of stocks or stock components considered increases. Stock assessments are highly uncertain; adding links through consumption observations and environmental parameters generally inflates the uncertainty on stock dynamics. From the fisheries harvest side, transparency of activities is generally better, but there remain serious information gaps for managers (e.g., lack of observer data, information on costs, fishery responses to different types of regulations, etc.). Adding nonstationary dynamics to both of these sets of processes (at the ecosystem and fisheries management levels) further complicates predictions beyond near-term trends. Forecast methods exist that distill complex adaptations and interactions and perform well in predictive tests. However, these methods generally ignore processes typical in annual fisheries decision making including how broad-reaching management systems respond to new information. In this paper, we propose a fisheries management scenario where routine assessments are tested periodically for productivity changes that may affect estimated stock "target" levels. This provides a way for managers to evaluate the consequences of applying periodic adjustments to such reference points. We contrast this with typical stock assessment models (which use up-to-date "best available" data) linked to management control rules (for setting quotas) that are revised periodically based on extensive management strategy evaluations that typically ignore productivity changes.

Incorporating Climate Variability Into the Assessment of Gulf of Alaska Pacific Cod

Z. Teresa A'mar[1], André E. Punt[2] and Grant G. Thompson[1]; [1]AFSC, Seattle, WA, [2]University of Washington, School of Aquatic and Fishery Sciences, Seattle, WA

The exploration of the relationships between environmental forcing and recruitment and representing them within an operating model is a key component in the development of a management strategy evaluation framework which incorporates climate variability. The management strategy for the fishery for Pacific cod, *Gadus macrocephalus,* in the Gulf of Alaska (GOA) consists of an age-structured stock assessment model and a harvest control rule. The relationships between age-0 abundance and climate indices and the uncertainty associated with these relationships were characterized within a statistical catch-at-age population dynamics operating model similar in structure to the stock assessment model for GOA Pacific cod. The operating model incorporated region-specific historical climate indices and was fitted to the data used for the stock assessment for GOA Pacific cod. The results from the operating model were compared with those from the 2009 stock assessment with respect to recruitment, stock status, and management measures. This comparison allowed for quantifying how the inclusion of climate data affected estimation precision, error, and bias.

By Anne Hollowed

Field Trials of Octopus Tagging: Pot Gear a Success

Research conducted by the AFSC and the University of Alaska, Fairbanks (UAF), with funding from the North Pacific Research Board (NPRB), is meeting with success in developing field methods for studying the giant Pacific octopus, *Enteroctopus dofleini,* in Alaskan waters (Fig. 1). The three-pronged study, begun in 2009, is aimed at collecting basic life history information on this enigmatic species and developing field methods for further scientific study and management. Tagging efforts near Dutch Harbor in fall 2009 and spring 2010 resulted in over 400 tagged octopus, with 42 recaptures. A spring 2010 gear trial of longlined habitat pot gear (Fig. 2) off of Kodiak Island captured 91 live octopus, ranging in size from 2.5 kg (5.5 lbs) to 22 kg (48.5 lbs).

Changes to the fisheries management plan for the Bering Sea that will be enacted in 2011 call for separation of the "other species" category into separate management groups such as sculpins, sharks, squids,

Figure 1. A small giant Pacific octopus captured in habitat pot gear is prepared for measurement. Photo by Elizabeth Conners.

Figure 2. Crewman Don Dumm prepares to launch an octopus habitat pot. Photo by Elizabeth Conners.

and octopuses. This means that the AFSC and the NPFMC will have to monitor and regulate catch for each of these groups separately in federal fisheries. Similar changes are expected for the Gulf of Alaska fisheries management plan within a few years. In preparation for this regulatory change, AFSC scientists have been compiling preliminary stock assessments for these "non-target" groups. For most of these groups, information on such characteristics as life history, population biomass, growth patterns, and natural mortality is lacking.

Octopus has turned out to be a particularly difficult case. While some groups, like sculpins, can be assessed based on data from the groundfish bottom trawl surveys, a bottom trawl does not effectively sample octopus populations. Studies or surveys of octopus requires a specialized gear directed at octopus. This winter, AFSC and the Alaska Department of Fish and Game collaborated in designing and building "habitat pot" gear specifically for octopus. Small unbaited pots act as temporary lairs for the octopus, which stay inside when the pots are pulled to the surface. Four longline strings consisting of 40-45 pots of varying designs captured 91 octopus in May and June 2010; further testing of this gear is planned for fall 2010.

Tagging studies conducted by UAF scientist Reid Brewer near Dutch Harbor, Alaska, have confirmed the feasibility of a type of tag called a visible implant elastomer (VIE) tag for octopus. Dots of brightly-colored plastic are injected just under the octopus's skin on the back of the mantle, in an area with relatively little natural pigment. By using several different colors, many unique codes of three or four spots are possible. Octopus recaptured after several months still had readily visible tags. Based on results of the preliminary study, NPRB has funded follow-up octopus tagging work for 2010-12. Researchers hope that tagging studies will document seasonal movement patterns in *E. dofleini*, which may be important in managing octopus as a state and federal resource. Tagging data may also be fitted to quantitative models that yield estimates of such parameters as natural mortality, growth, and local biomass. These parameters could prove very important for future stock assessment of this group.

In order to find out more about octopus life history, AFSC biologist Christina Conrath is examining gonad development in octopus specimens donated by commercial fishermen and caught during gear trials and trawl surveys. Community involvement from local scuba divers in Kodiak and Dutch Harbor is also being sought to locate octopus dens and incubating egg clusters. Research diving in both locations is planned to document the seasonality of egg laying and incubation in Alaskan waters. The project will continue through winter and spring 2011.

By Elizabeth Conners

Quantifying Area Disturbed by Trawl Fishing Gear in the Eastern Bering Sea, 1990-2009

Fishing gear can affect habitat used by a fish species for the processes of spawning, breeding, feeding, or growth to maturity. An estimate of the area of seafloor disturbed by trawl gear may provide an index of habitat disturbance. The area disturbed in the eastern Bering Sea was calculated from observer trawl data each year from 1990 to 2009. The duration of each trawl haul was multiplied by a fishing effort adjustment as outlined in Appendix B of the January 2005 EFH EIS (www.fakr.noaa.gov/habitat/seis/efheis.htm). The adjustment converted trawl haul duration to area disturbed based on the type of trawl gear used (pelagic or bottom) and the vessel length. The adjustment also expanded smaller vessel fishing effort, which has 30% observer coverage, to simulate 100% coverage. Records of missing trawl haul duration data and short wire hauls (hauls pulled in but not immediately brought on board) were assigned the average trawl haul duration over all years of 228 minutes (no more than 5% of hauls in any given year needed this adjustment).

An upper limit of the total area potentially disturbed by trawl hauls was estimated by assuming that no trawl hauls overlapped spatially. To estimate the percent disturbed, it was necessary to determine the total area of the eastern Bering Sea being considered. The NMFS reporting areas for the Bering

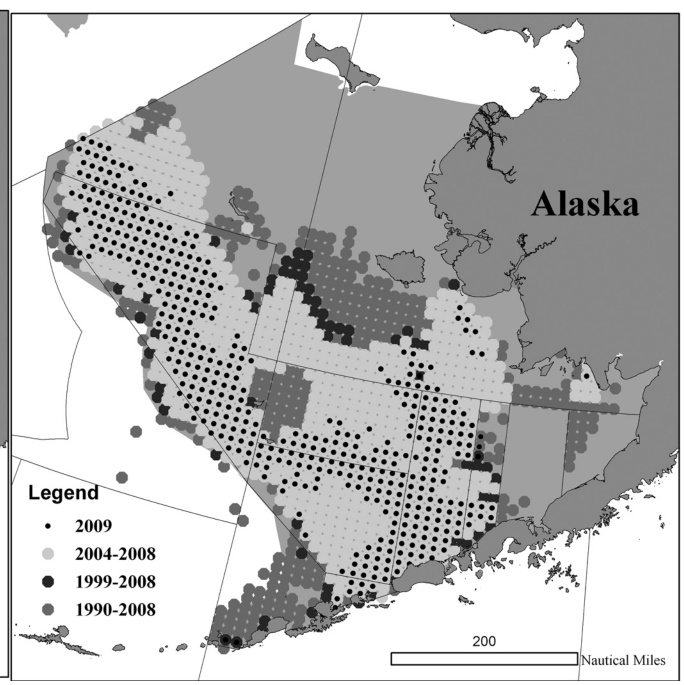


Figure 3 (left). Map of eastern Bering Sea area considered when estimating percent of area potentially disturbed by trawl fishing gear. Figure 4 (right). Map of 400 square kilometer cells with some trawling in cumulative time periods. Cells with fewer than three vessels are not shown.

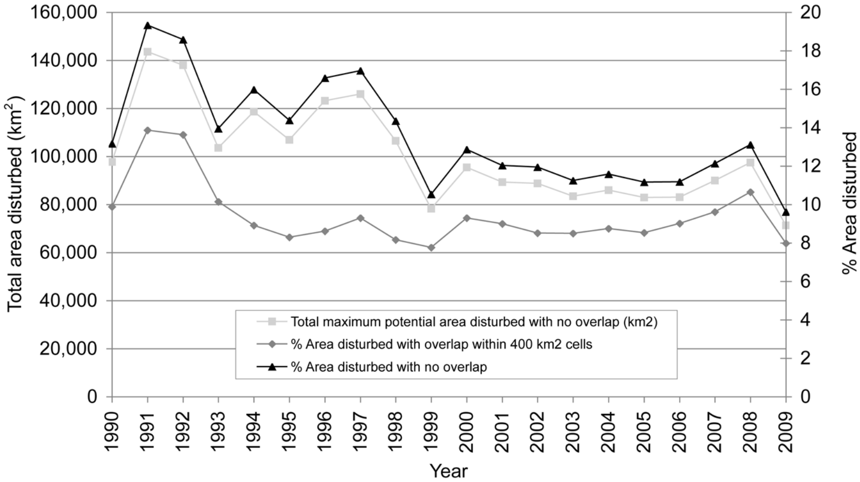


Figure 5. Total maximum potential area disturbed (assuming no spatial overlap of trawls), and the percent area disturbed. The black line, representing percent area disturbed, sums the area disturbed assuming no spatial overlap of trawl hauls in a year, thus providing an upper limit to the estimate of area disturbed. The dark gray line represents the percent area disturbed with spatial overlap of trawl hauls within 400 km^2 cells, thereby, limiting the disturbance of trawls recorded in a cell to 400 km^2.

Sea were used as a baseline; however, Norton Sound was excluded because it is beyond the range of many commercially fished groundfish species. The Bering Sea Habitat Conservation boundary was used to exclude areas beyond the shelf break. The resulting total area considered was 742,647 km^2 (Fig. 3). The percentage of area disturbed was estimated in two ways: 1) with no spatial overlap of trawl hauls in a given year, providing an estimate of the maximum potential percent of area disturbed and 2) with spatial overlap of trawl hauls within 400 km^2 cells to limit the disturbance of trawls recorded in a cell to 400 km^2, providing an estimate of the potential percentage of area disturbed. The average distance of a haul based on recorded start and end locations is 14 km with a standard deviation of 10 km. The cell size was chosen to reflect this spatial resolution of the hauls. Though this cell size allows some overlap of hauls, it still may overestimate the percent area disturbed in a year. Figure 4 shows the locations of the 400 km^2 cells where trawling disturbances accumulated over various time intervals .

Status and Trends: The maximum total area of seafloor in the eastern Bering Sea potentially disturbed by trawl gear varied around 120,000 km^2 in the 1990s and decreased in the late 1990s to approximately 90,000 km^2. The area disturbed remained relatively stable in the 2000s with a slight increase during 2007-08. The percentage of total area disturbed varied between 10% and 15% in the 1990s and between 9% and 11% in the 2000s. However, due to trawls overlapping the same area, a more realistic estimate of area disturbed was likely less than 10% from the mid-1990s on. Reduction in hours fished in the 2000s indicates greater fishing efficiency.

Factors Causing Trends: Trends in the extent of seafloor area disturbed can be affected by numerous variables such as individual fishery movements, fish abundance and distribution, management actions (e.g., closed areas), changes in the structure of the fisheries due to rationalization, increased fishing skills (e.g., increased ability to find fish), and changes in vessel horsepower and fishing gear.

During 1993-99, fishing effort was more concentrated in the southern area compared to 1990-92 and 2000-08, where effort was spread out spatially, particularly towards the northwest. This may, in part, explain the larger difference between the upper and lower estimates of percent area disturbed (with no overlap and with overlap within 400 km^2 cells, respectively) during 1993-98 relative to other years (Fig. 5).

As of 1999 only pelagic trawls can be used in the Bering Sea pollock fisheries. To check to see if this affected the trends, the graph was recalculated making no distinction between gears. The result showed no change in the trend. Short hauling which are hauls which a net is pulled in but not immediately brought on board was only identified in the database from 1995 onward, however short hauling accounts for only 2% of the total hauls and does not explain the early 1990 trends.

Implications: Habitat damage varies with the physical and biological characteristics of the areas fished, recovery rates of HAPC biota in the areas fished, and management changes that result in spatial changes in fishing effort.

By Angie Greig

AGE & GROWTH

Age and Growth Program Production Numbers

Estimated production figures for 1 January–30 June 2010. Total production figures were 15,766 with 3,252 test ages and 163 examined and determined to be unageable.

Production figures for 1 January through 30 June 2010.

Species	Specimens Aged
Arrowtooth flounder	792
Atka mackerel	105
Dover sole	468
Dusky rockfish	606
Flathead sole	299
Giant grenadier	784
Greenland turbot	502
Northern rock sole	1,893
Northern rockfish	498
Pacific cod	1,961
Pacific ocean perch	581
Rougheye rockfish	150
Southern rock sole	509
Walleye pollock	5,860
Yellowfin sole	758

By Jon Short