Alaska FISHERIES SCIENCE CENTER

Quarterly Report

July August September 2012

Measuring Effects of Ocean Acidification on Our Living Marine Resources

U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Alaska FISHERIES SCIENCE CENTER

www.afsc.noaa.gov

The Alaska Fisheries Science Center (AFSC) *Quarterly Report* is produced by the Center's Communications Program.

NOAA FISHERIES

Cover image. Megalops crab larva
Photo by Jay Clark/Matt Wilson

Crab life history..

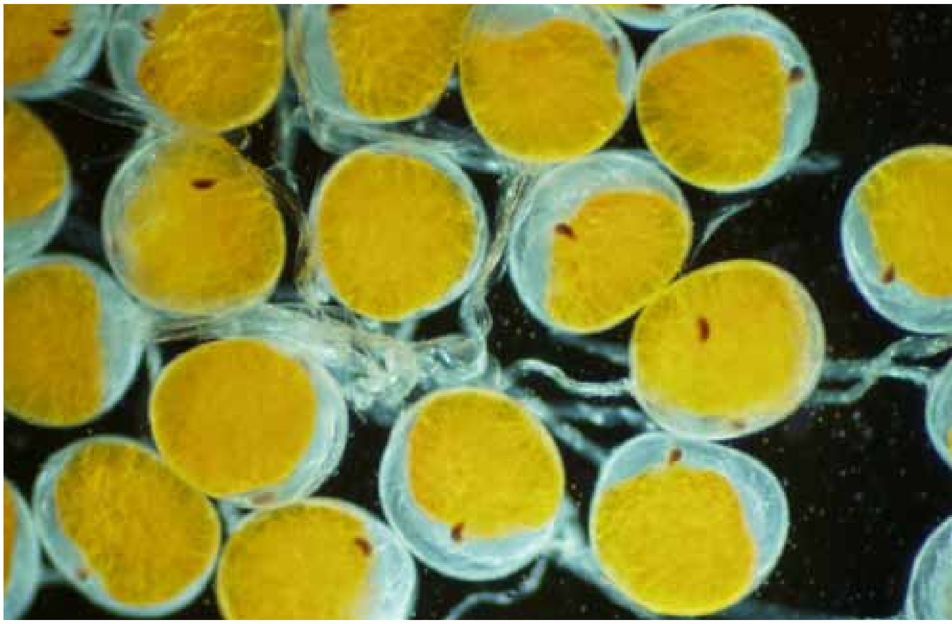
Ocean Acidification: Monitoring and Measuring the Physiological and Population Response of Living Marine Resources in Alaska

Robert J. Foy, Mark Carls, Michael Dalton, Tom Hurst, W. Christopher Long, Michael F. Sigler, Robert P. Stone, Katherine M. Swiney

In the United States and other coastal nations, ocean acidification has quickly become a common topic of scientific research. Ocean acidification also has become a public concern as news headlines warn of this potentially threatening byproduct of global climate change. In March 2009, the U.S. Congress passed the Federal Ocean Acidification Research Monitoring Act, a bill to establish an interagency committee to develop an ocean acidification research and monitoring plan and to establish an ocean acidification program within NOAA. NOAA accordingly developed the NOAA Ocean and Great Lakes Acidification Research Plan in 2010, a plan to improve monitoring capacity, assess organismal response, forecast biogeochemical and ecological responses, provide data synthesis, develop management tools, and provide public outreach and education about ocean acidification in the open and coastal oceans and the Great Lakes.

What Is Ocean Acidification?

Global climate change studies have revealed that the rate of increase in atmospheric carbon dioxide (CO_2) concentration has increased substantially since the industrial revolution (mid-1700s). The world's oceans have absorbed between 30% and 50% of that new CO_2. The increase in oceanic CO_2, when incorporated into the carbonate system, has resulted in an average decrease of surface ocean pH by 0.1 units, the equivalent of a 30% increase in acidity. The increased acidity reduces the saturation of calcium carbonate, making it more difficult for some calcifying organisms to sequester calcium and carbonate to build shells. In the North Pacific Ocean, the saturation depth of calcium carbonate is already shallow (<200 m) relative to the North Atlantic (~2,000 m). Therefore, the marine organisms in Alaska are particularly at risk to effects associated with ocean acidification. In addition, some species such as golden king crab (*Lithodes aequispinus*) in Alaska already inhabit undersaturated environments; understanding how they cope with this environment will help us evaluate the effects of ocean acidification on Alaska species.



Crab embryos.

The Alaska Fisheries Science Center Plan

Scientists at the Alaska Fisheries Science Center (AFSC) have worked locally, nationally, and internationally since 2007 to address the potential impacts of ocean acidification on scales from individual organisms to ecosystems. In 2008, AFSC scientists developed a research plan to test the hypotheses that reduced ocean pH and the resultant reduction in availability of calcium carbonate would have wide-ranging effects, including reduced growth, survival, and reproduction of commercially important fish and shellfish,

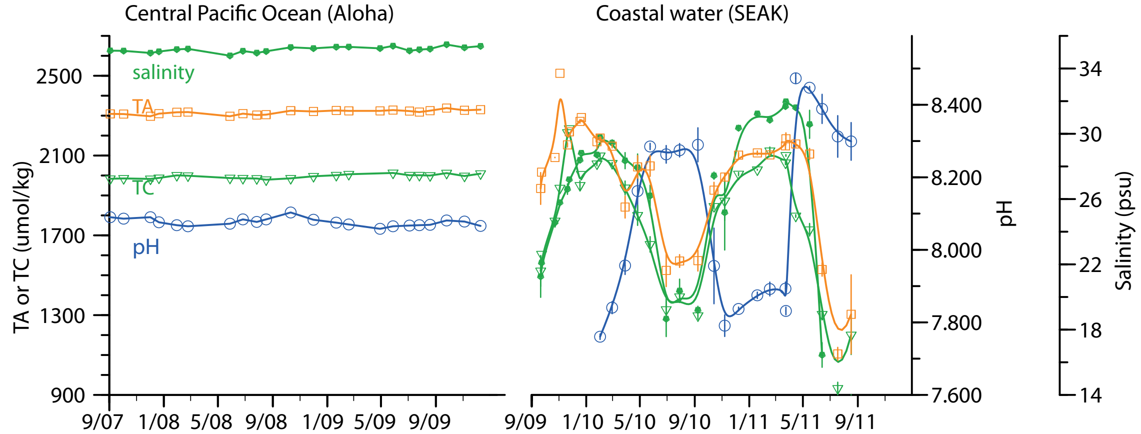


Figure 1. Annual carbon and salinity cycling in surface coastal waters (0 to 0.5 m) of Southeast Alaska and surface open ocean conditions (0 to 10 m) in the central Pacific Ocean at station Aloha. Data are salinity (practical salinity units, psu), total alkalinity (TA), total dissolved inorganic carbon (TC), and pH. Open ocean data were limited to the most recent 2 years of available data.

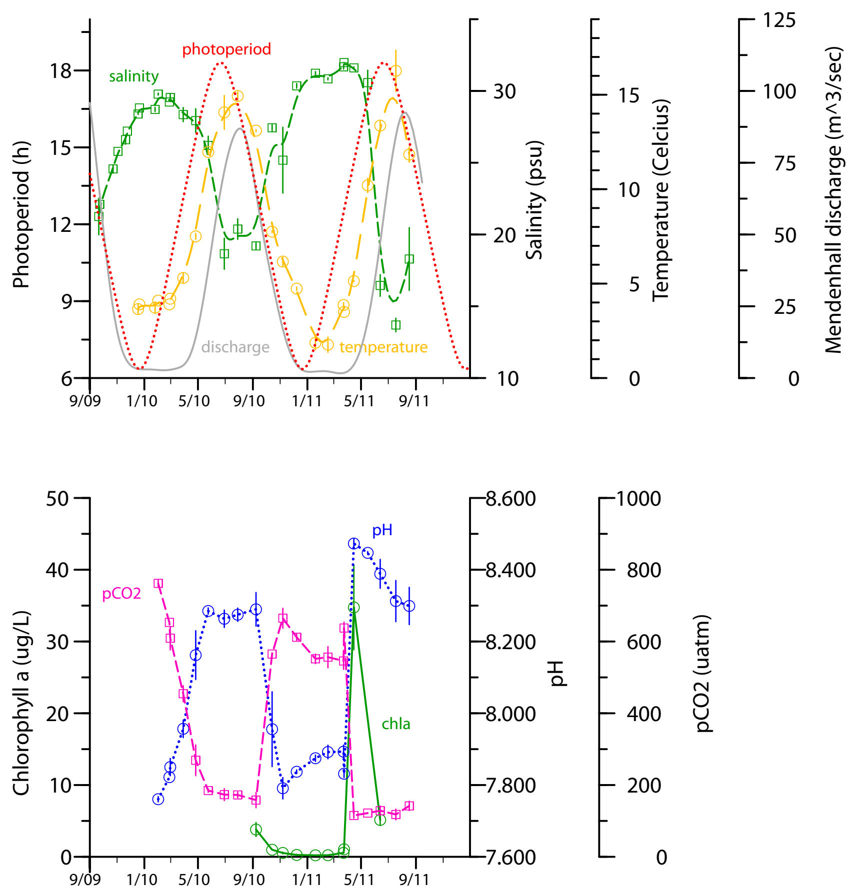


Figure 2. Relationship among photoperiod, water temperature, salinity, and terrestrial discharge in surface water (top panel) and pH, pCO_2, and chlorophyll a in surface water (bottom panel). Data were averaged among three inside water sites (Auke Bay, Favorite Channel, and Lena Cove).

ecologically important prey of those species, and cold water corals. Species-specific physiological responses to ocean acidification were not well understood, so a broad research effort was considered for several taxa including shellfish, calcareous plankton, coldwater corals, and fish. Prioritization was given to the larval and juvenile stages of commercially and ecologically important taxa more likely to be directly affected by ocean acidification in Alaska. Calcareous invertebrates such as shellfish are likely to suffer direct effects of reduced calcium carbonate availability and have a commercial importance in Alaska. Calcareous invertebrates such as pteropods and euphausiids are likely to be directly affected and are important prey items of commercially important fish species and of marine mammals. Coldwater corals are sensitive to ocean carbonate chemistry and are important habitat for commercially important species such as rockfish. The early life stages of commercially important fish species may be affected by direct and indirect effects of ocean acidification.

While still a relatively new research direction for AFSC scientists, significant progress has been made identifying appropriate research foci, developing accurate and repeatable methodologies, measuring baseline parameters important for understanding ocean carbonate chemistry, testing the physiological response of key marine organisms, and finally, estimating the impacts at population scales. Infrastructure was developed at the AFSC's Juneau, Kodiak, and Newport seawater laboratories including CO_2 delivery systems, pH monitoring systems, CO_2 monitoring systems, and carbonate chemistry analytical instruments.

Monitoring in Alaska

Although monitoring coastal and oceanic carbon chemistry is one goal of the AFSC research plan, funding restrictions have resulted in a limited effort in Alaska. Collaborative efforts to support the Ocean Acidification Research Center at the University of Alaska Fairbanks have led to increased capacity to measure the carbonate chemistry of the Gulf of Alaska and Bering Sea. Local coastal monitoring of carbonate has occurred only in Southeast Alaska.

Carbonate seasonal patterns in eastern Gulf of Alaska coastal water have been monitored by Mark Carls and Lawra Vanderhoof at the AFSC's Auke Bay Laboratories in Juneau. Initial results from their studies conducted in 2009-11 were compared to 2007-09 data from the open ocean in the North Central Pacific near Hawaii (Fig. 1). Although the data sets were not collected during the exact same time period, seasonal trends and annual averages were compared. Those comparisons showed that mean pH was similar in the open ocean and coastal waters, while mean total alkalinity (TA) was substantially greater in the open ocean (2,320 µmol/kg) than in the coastal water (1,725 µmol/kg) due to salinity differences. The mean total dissolved inorganic carbon (TC) was somewhat greater in the open ocean (1,978 µmol/kg between 2008 and 2010) than in the coastal waters (1,576 µmol/kg). Annual changes in pH, TA, and TC were about ten times greater in the Southeast Alaska waters than in the North

Figure 3. Experimental CO_2 dosing systems at the Kodiak and Newport Laboratories.

Central Pacific waters. Seawater pH was highest in spring-summer and lowest in winter, while TA, TC, and salinity have the opposite seasonal trend.

Salinity seasonal patterns (resultant from solar and hydrological cycles) may be the primary driver of seasonal carbon variability in Southeast Alaska coastal water. Annual trends in TC and TA are similar to salinity trends (Fig. 1), suggesting that salinity is either driving carbonate parameters or may be responding to the same underlying driver. Annual pH patterns are about six months out of phase with salinity. Depth profiles of salinity, pH, TC, and TA provide further information to support salinity as a likely factor driving pH variability as each declined with depth.

A seasonal increase in pH coincident with increases in chlorophyll a concentrations in the water suggests that plankton blooms increase pH in coastal or inside water (Fig. 2). In theory, this relationship is expected as removal of dissolved carbon from the water should increase pH. Several more seasonal observations will be necessary to more rigorously substantiate (or refute) the hypothesis that phytoplankton blooms influence the pH in Southeast Alaska waters.

Shoaling of corrosive deep Pacific water is not likely the explanation for seasonal variation in Southeast Alaska coastal waters because pH cycles are about six months out of phase from when corrosive water is likely to be shoaling in Alaska. The Central Gulf of Alaska is predominantly a downwelling region in the winter with weak upwelling in the summer. Higher pH values in Southeast Alaska during the winter suggest that upwelling is not a major factor in acidifying waters in this region.

Crab Research

King and Tanner crab experimental studies have been conducted by Chris Long, Katherine Swiney, and Robert Foy at the AFSC's Kodiak Laboratory. The effects of increased CO_2 on the survival, condition, and growth of king and Tanner crab species were investigated from 2009 to 2011. At the same time, infrastructure was developed to support a multi-year program capable of assessing both direct and indirect effects of ocean acidification on shell building in commercial crab species in Alaska (Fig. 3). The results of this research program will not only provide empirical data specific to the physiological response of crabs, but will also support modeling efforts on the indirect impacts of ocean acidification associated with food webs and fisheries interactions.

Red King Crab Experimental Studies

Initial experiments tested the effects of ocean acidification on late-stage embryos and larvae of red king crab (*Paralithodes camtschaticus*) at average ocean pH levels expected within the next 50 years. Ovigerous red king crab from the Bering Sea were held in seawater at an ambient pH of 8.0 (control) and a treatment pH of 7.7 in CO_2-acidified seawater. Embryos were photographed throughout the experiment under a microscope and measured using image analysis software (Fig. 4). Embryos reared in acidified water were larger in total length, but were similar in weight and had smaller yolks than those in control water. Females in acidified seawater had longer hatch duration, though there was no difference in fecundity.

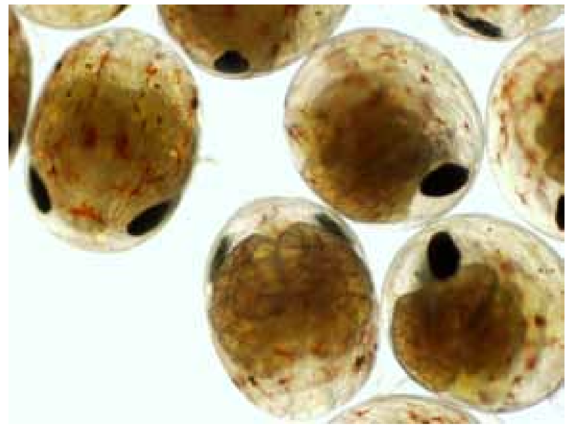


Figure 4. Late stage red king crab embryos photographed under a microscope.

Figure 5. Newly hatched red king crab larvae.

At hatching, larvae (Fig. 5) were collected and pooled from multiple females within the same treatment. A series of fully crossed experiments was performed in which embryo treatment was crossed with larval treatment; larvae that had been exposed to control water as embryos were held in both acidified and control water, as were larvae that had been exposed to acidified water as embryos. Larval survival was reduced by exposure to acidified water at both the embryo and the larval stages, and the effect was additive, such that larvae exposed to acidified water at both stages had the lowest survival rate of all (Fig. 6). Larvae held in acidified water were more calcified than those held in control water (Fig. 7).

Throughout the experiment, carapace samples from mature females were taken from molted shells and from new shells 2 weeks after molting. The samples were analyzed for calcium content. Females held in acidified water had higher calcium content in their shells than females held in control water, especially in their new shells 2 weeks after molting.

To assess juvenile survival, growth, and calcification, juvenile red king crab were placed in three pH treatments. Juvenile survival decreased with pH, with 100% mortality occurring after 95 days in pH 7.5 water (Fig. 8). Although the morphology of juvenile red king crab (Fig. 9) was not affected by acidification, they exhibited slower growth in water acidified to a pH of 7.8. Ocean acidification did not affect the calcium content of red king crab, but the condition index decreased.

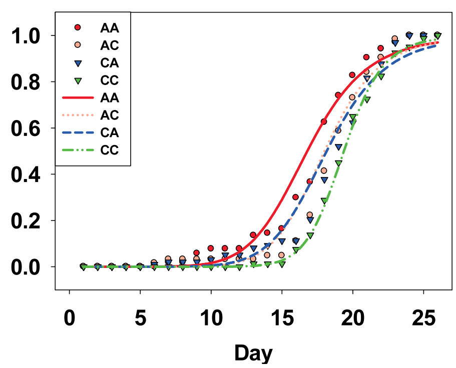


Figure 6. Proportional mortality of starved larvae held in control (C) and acidified (A) water. In the legend, the first letter designates the embryonic treatment and the second the larval treatment. Points represent the proportional mortality in all replicates during the experiment, and lines the predicted mortality based on the best fit model.

Tanner Crab Experimental Studies

The goal for the Tanner crab (*Chionoecetes bairdi*) research was to examine the effects of ocean acidification on aspects of the reproduction and larval development of Tanner crabs. Our objectives were to test the effects of ocean acidification on 1) fecundity, embryo viability, embryo development, and hatching success; 2) larval condition and survival; 3) calcification in both the mothers and the larvae; and 4) juvenile growth, condition, calcification, and survival.

The initial experiments were done on Tanner crab juveniles with similar methods as for juvenile red king crab. Juveniles were held in ambient pH = ~8.0, pH = 7.8, and pH = 7.5 seawater for nearly 200 days at ambient temperatures. Juvenile survival decreased at the lower pH (Fig. 8), growth rate was lower in the pH 7.5 treatment, and calcium content was lower. Morphology (Fig. 9) and condition did not differ among the treatments.

Subsequent experiments were done on adult females with embryos and on larvae. Adult female Tanner crab and their larvae were exposed to increased CO_2 at two treatments (pH 7.8 and 7.5) and a control pH (pH 8.0). The embryo developmental stage was determined and embryo morphology was observed. Embryological development data is currently being analyzed. The best fitting model for larval survival showed that larvae died slightly faster at pH 7.5 than larvae in pH 7.8 or in control treatments (Fig. 10).

Conclusions on King and Tanner Crab Experimental Research

The results of the experimental red king and Tanner crab studies thus far indicate that ocean acidification may have a substantial negative effect on red king and Tanner crab stocks. Reduced survival at the larval and juvenile stages is likely to reduce recruitment and subsequently affect the number of mature male crabs available for commercial fisheries. Variability in calcification and condition between species and life history stages suggests that there are different physiological responses to increased dissolved inorganic carbon concentration. Regardless, increased physiological costs are likely to lead to the higher mortality rates observed across these experiments. More research on the effects of ocean acidification on other life history stages and the molecular response is necessary to fully understand the effects it will have on red king crab, Tanner crab, and other federally managed crab species. Particular attention will be needed to dosing experiments that accurately mimic the *in situ* conditions encountered by crab at different life stages and to concurrent effects of other environmental stressors such as temperature.

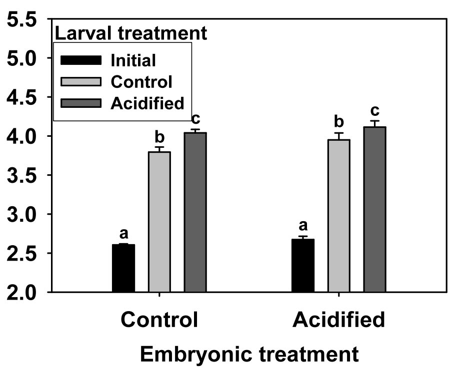


Figure 7. The effect of ocean acidification at the embryonic and larval stage on percent calcium content (m/m, dry mass) in larvae. Initial treatment represents larvae sampled the day after hatching. Bars represent the mean +1 standard error. Bars with different letters above them differ statistically.

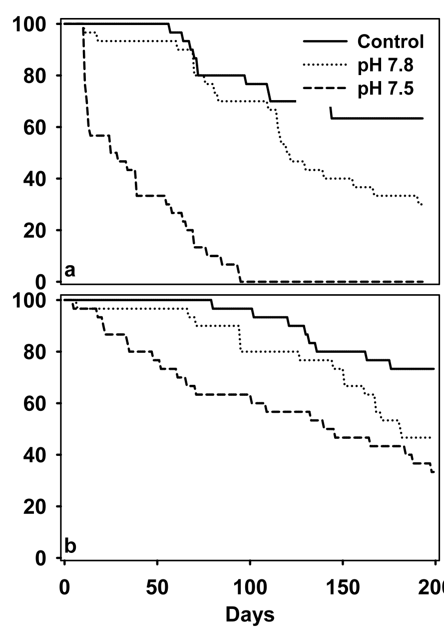


Figure 8. Survival of red king crab (a), and Tanner crabs (b) in control and treatment tanks over the duration of the experiment.

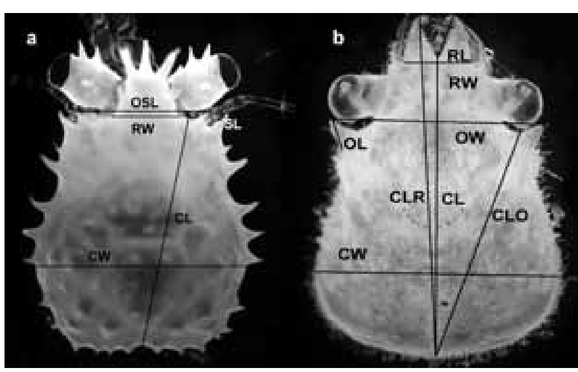


Figure 9. Measurement taken for morphometric analysis for a) red king crabs, and b) Tanner crabs. Measurement on red king crabs included carapace width (CW), carapace length (CL), rostrum base width (RW), orbital spine width (OW), and the first spine length (SL). Measurements on Tanner crab included carapace width (CW), carapace length (CL), carapace length to the rostrum (CLR), carapace length to the eye orbit (CLO), rostrum base width (RW), rostrum length (RL), orbital spine width (OW), and orbital spine length (OL).

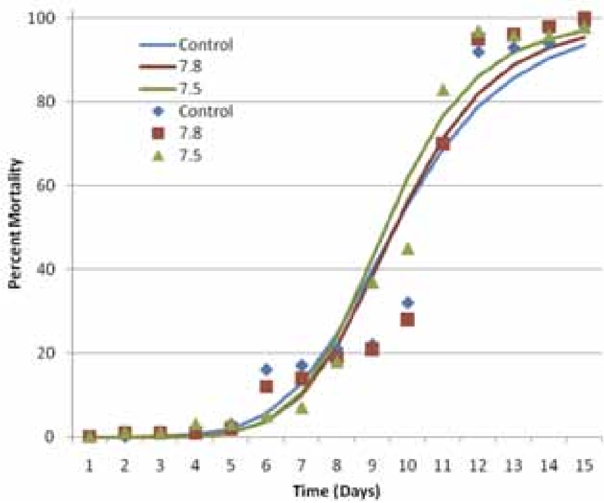


Figure 10. Survival of starved Tanner crab larvae in three treatments. Points represent the average survival at each day and lines represent the best fit mortality models.

King Crab Genetics Research

Genetic studies utilizing the samples from Kodiak Laboratory experimental research have been contracted to Jonathon Stillman at the University of California, Berkeley. Functional genomics can assess how an organism responds to environmental change by studying how genomes are regulated under specific environmental conditions. Gene expression products (mRNA) will be monitored as indicators of stress level, condition, health, and other physiological parameters in larval and juvenile red crab to determine sublethal effects of increased CO_2. Utilizing these methods as response variables in a controlled laboratory CO_2 dosing study will provide a powerful tool for assessing the physiological response of crabs to ocean acidification.

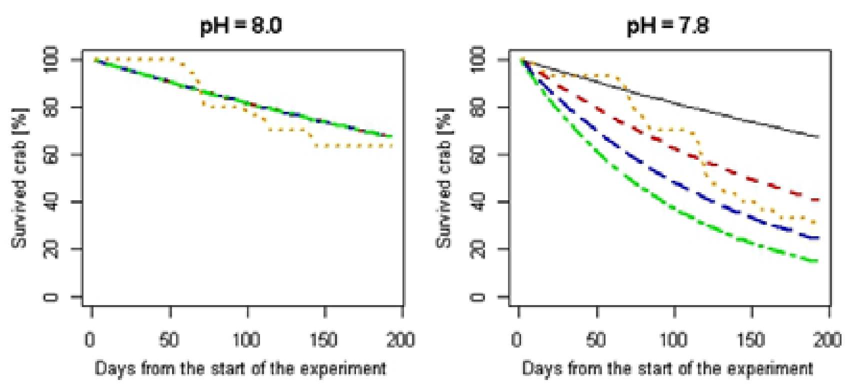
In 2008-10 larval and adult red king crab samples were tested to see if gene expression could be assessed using cDNA microarrays that have been developed for porcelain crabs, (*Petrolisthes* spp.). Results suggested that there was sufficient sequence homology for a large number of genes that the porcelain crab microarray would work to analyze a wide diversity of transcripts and gene expression patterns in red king crab. The initial results also suggested that there may be a set of genes commonly expressed across all crab larvae.

To support the crab genomics project, juvenile red king crab were exposed to three temperature treatments (ambient, ambient +2°C, and ambient +4°C) and three pH treatments (7.5, 7.8 and ambient) to test the effects of increased CO_2 and temperature on juvenile survival. The objectives of this project were to use microarray analysis to fully characterize the manner in which red king crab transcripts bind to the array, characterize the transcriptome of red king crab, compare the red king crab transcriptome to sequences in porcelain crabs, and to compare genetic data to data on mortality and growth as a result of previous experimental studies. Initial funding was secured in late 2011, the initial experiments for juvenile crab were completed in June 2012, and analyses are currently under way.

King Crab Bioeconomics

The bioeconomic modeling research has been conducted by AFSC economist Michael Dalton in collaboration with André Punt and Dusanka Poljak at the University of Washington School of Aquatic and Fishery Sciences. Existing models that estimate future impacts of ocean acidification have been applied mainly to corals and mollusks, and for the latter, these estimates have been fairly modest. However, existing models do not typically differentiate ocean acidification effects among life-history stages that vary in their degree of vulnerability and have been limited in their comparisons at the population level with other stressors such as commercial fishing. By coupling a pre-recruitment component with post-recruitment dynamics, the Bristol Bay red king crab bioeconomic model incorporates effects of ocean acidification on vulnerable juvenile crabs in combination with effects of commercial fishing on the Bristol Bay red king crab population as a whole. The Bristol Bay red king crab pre-recruitment component is a stage-structured model that includes effects of ocean acidification as a stressor via its impact on survival and the time to grow from one stage to the next. Survival rates in the pre-recruitment model were tuned to match the results of the survival experiments for Bristol Bay red king crab conducted at the Kodiak Laboratory for the sizes of crab to which those experiments pertain (see Fig. 11). Post-recruitment dynamics in the bioeconomic model are based on a simplified version of the full Bristol Bay red king crab stock assessment model that was fitted to the existing data for the Bristol Bay red king crab commercial fishery.

Many types of projections under management strategies can be made using the coupled bioeconomic model, and preliminary results suggest that ocean acidification could have substantial effects on the Bristol Bay red king crab fishery. For example, the proxy for fishing mortality at the maximum sustained yield (F_{MSY}), the value of fishing mortality leaving 35% of the spawning biomass per recruit ($F_{35\%}$), is projected to be much lower if effects of ocean acidification on the survival of



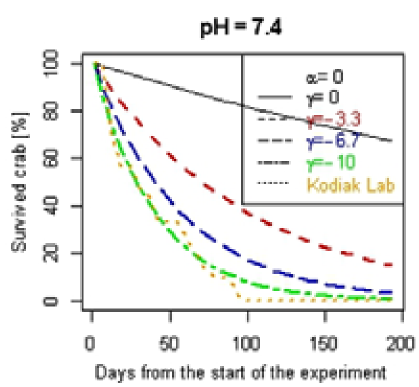


Figure 11. Modeled crab survival vs. survival of juvenile red king crab in the Kodiak Laboratory research experiment. In the experiment, 90 red king crab were monitored from the first crab stage (about 2 months of age, i.e. at the start of the first benthic stage) over 192 days under the three pH levels, and surviving crab were recorded. Plotted survival rates from the model match the crab age in the experiment (i.e. day zero is the start of the first benthic stage). The parameter α determines the rate at which stage duration is impacted by a change in pH and the parameter γ determines the rate at which survival is impacted by a change in pH. The results in the figure are based on the assumption that survival is proportional to the number of molts within a stage.

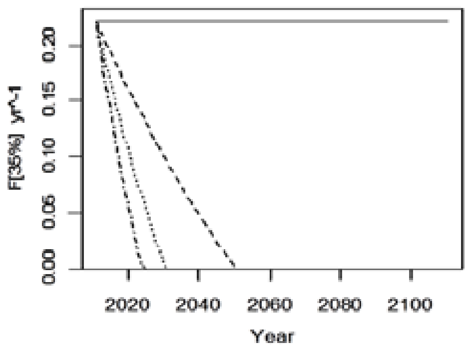


Figure 12. $F_{35\%}$ versus year for the no ocean acidification impact scenario (solid line) and three scenarios in which ocean acidification impacts the survival of pre-recruit Bristol Bay red king crab.

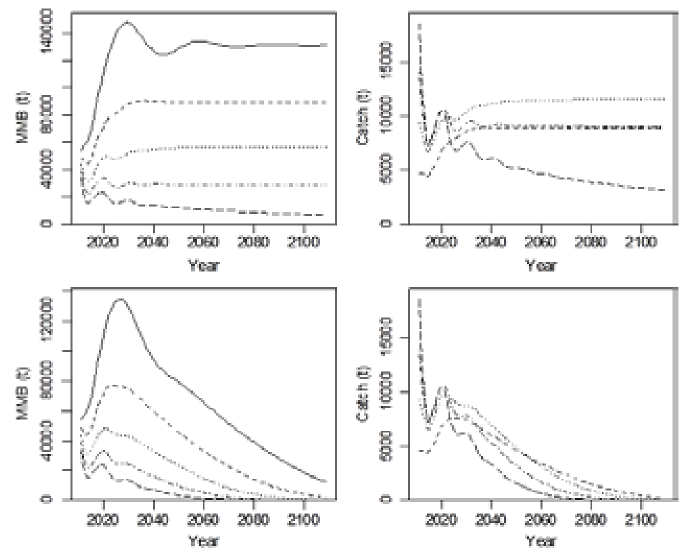


Figure 13. Time-trajectories of mature male biomass (tons) at the time of spawning (left panels), and the catch (right panels) for two of four ocean acidification scenarios (no ocean acidification impact, upper panels; level of ocean acidification impact which best matches the survival rates in the Kodiak experiments based on a pH of 7.8, lower panels). Results are shown for five levels of constant exploitation rate (solid line no future fishing; dotted line $F_{35\%}$ under the assumption of no ocean acidification impact).

juvenile crab are included in the model. Figure 12 shows the impact of ocean acidification on $F_{35\%}$ as a function of time, and hence, the target fishing mortality rate to achieve the current target level of male mature biomass-per-recruit. This fishing mortality rate equals zero just after 2020 for the most extreme scenario, which implies that mortality due to ocean acidification effects alone will be sufficiently high at this time to drop the stock to the target level even without any fishing. Predictions of long-term catch and mature male biomass for a range of constant fishing mortality rates are presented in Figure 13. These plots illustrate the consequences for the fishery if no changes are made to how management operates except to reduce harvests when abundance is lower. As expected, fishing at $F_{35\%}$ (dotted line in the upper panels) leads to the largest long-term catch. However, mature male biomass declines over time irrespective of fishing mortality for the level of ocean acidification impacts which best matches the survival rates in the Kodiak experiments based on a pH of 7.8. The projected impacts of ocean acidification on the Bristol Bay red king crab fishery are summarized in Figure 14 by showing shifts over time in the yield curve that plots mature male biomass versus catch in equilibrium for the scenario which best matches the survival rates in the Kodiak Laboratory experiments based on a pH of 7.8. In particular, the maximum sustainable yield (and associated mature male biomass) drops by ~50% every 20 years.

Gadid Research

Research on the effects of ocean acidification on Alaskan marine fishes is being conducted by Tom Hurst at the AFSC's Newport Laboratory, Oregon, in collaboration with Jeremy Mathis at the University of Alaska.

Marine fishes have an internal skeleton composed primarily of calcium phosphate and are generally assumed to be less sensitive to the effects of ocean acidification than those invertebrates which precipitate external skeletons of calcium carbonate. Further, it has been suggested that the high metabolic capacity and ability to increase intercellular buffering capacity provides most marine fishes the physiological capacity to cope with projected levels of ocean acidification. However, there are few studies which have tested those assumptions, and it is possible that early life stages with less developed acid-base regulation may be more susceptible to the effects of ocean acidification. The few studies to date have yielded mixed results, with no clear patterns emerging about which species might be most vulnerable to ocean acidification. While several studies have found that growth was not negatively affected by elevated CO_2, others have documented reduced survival and increased incidence of morphological deformities in early life stages reared in high CO_2 conditions. Further, the potential range of effects that may be induced by ocean acidification are only beginning to be understood. For example, experiments have demonstrated that elevated CO_2 levels alter the growth rates of the otolith (ear bone) and disrupt olfactory and auditory cues in some species. Additional work is needed to study the range of responses to projected ocean acidification in fishes, especially in the temperate and boreal marine species that support much of the world's fishery production.

The first part of the project was to develop a system for the rearing of marine fish eggs, larvae, and juveniles under controlled temperature and CO_2 conditions (Fig. 3). The flow-through system feeds water conditioned to four CO_2 levels to sixteen 100-L rearing tanks. The system also includes UV sterilization of water, allowing fish to be tested under quarantine conditions.

Given the direct links from individual growth rate to survival probability and population productivity, the focus of experiments to date has been to examine the growth responses of early life stages of walleye pollock (*Theragra chalcogramma*) to elevated CO_2 levels (Fig. 15). So far, the results suggest that walleye pollock are relatively robust when exposed to elevated CO_2. In both short-term (6 week) and long-term (6 month) exposures with juveniles, growth rates were not negatively affected by elevated CO_2 levels, even at levels well beyond those predicted for high latitude seas over the next 100 years. In fact, during one phase of the experiment, fish under high CO_2 levels actually grew faster than the ambient controls. In the short-term experiment, elevated CO_2 increased the rate of otolith deposition (Fig. 16) but did not affect otolith elemental composition. Further, measurements of consumption rates indicated that fish were not simply eating more in order to offset increased metabolic demands of hypercapnia (the presence of excessive amounts of CO_2 in the blood), a strategy which would be fine for captive culture fish but might not be available to fish in the wild.

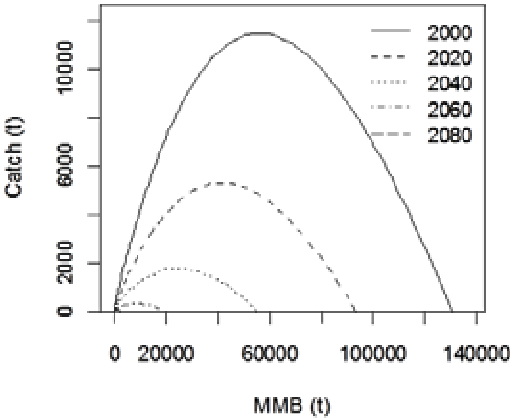


Figure 14. Equilibrium yield (tons) versus for mature male biomass (tons) for 5 years. These results are based on the ocean acidification scenario which best matches the survival rates in the Kodiak experiments based on a pH of 7.8.

Figure 15. Yearling pollock size measurement for growth assessment.

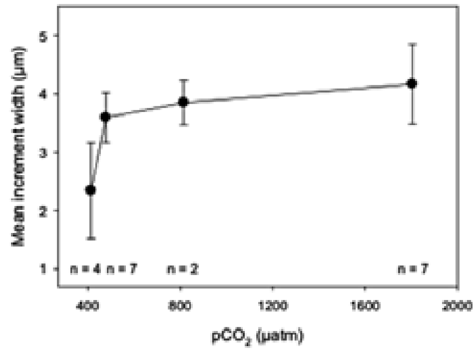


Figure 16. Mean otolith increment width (µm) of yearling walleye pollock reared under elevated CO_2 levels. Points are the mean (± std. dev.) fish pooled across three replicate tanks in each treatment.

In addition to simply extending the duration of exposure, the long-term experiment also included seasonally-reflective warm (8°C) and cold (2.5°C) phases. Most ocean acidification experiments have been conducted at the upper end of the species' thermal range, and where temperature has been manipulated, tropical fishes have been tested at temperatures near or above current exposure limits. However, it is important to recognize that arctic and sub-arctic fishes will continue to be exposed to low temperatures in winter. It has been hypothesized that ocean acidification may restrict fishes' "thermal window" by reducing physiological performance at low as well as high temperatures. Low temperatures are known to reduce the effectiveness of ion balance at both the cellular and organismal level, a response which may depress feeding ability. The degree to which low temperature responses interact with or exacerbate the effects of other physiochemical stressors is largely unknown. For walleye pollock, it was important to determine if the effects of ocean acidification are more pronounced at the upper or lower end of the thermal range because potential interactions with low temperature stress would disproportionately affect the high latitude populations in the Gulf of Alaska and Bering Sea, which support major commercial fisheries. Fortunately, the resilience displayed by juvenile walleye pollock at high temperatures extended into the lower temperature range.

A second series of experiments examined whether eggs and larvae might be more vulnerable to the effects of ocean acidification than the larger juveniles are. Five batches of eggs were collected from laboratory-maintained broodstocks and were incubated until hatch across a range of CO_2 conditions. There was a statistically significant delay in time to hatch at the highest CO_2 level, the average difference was less than 1 day and was less than the difference observed between the different batches of eggs. Body size at hatch did not differ among CO_2 treatments. Experiments with larval walleye pollock will conclude the experimental series on early life stages of walleye pollock. Those experiments are currently being completed, and preliminary results again suggest that growth rates are no worse under elevated CO_2 levels than current conditions. While not exhaustive of potential interactive environmental factors, these experiments demonstrate a general resiliency of growth energetics among juvenile walleye pollock to the direct effects of CO_2 alterations predicted for the Gulf of Alaska and Bering Sea in the next century.

While that resiliency is good news, unfortunately it is not the end of the story. Recent work has demonstrated that exposure to elevated CO_2 levels altered sensory and behavioral responses in some coral reef fishes that did not appear to suffer from depressed growth at high CO_2 levels. Under elevated CO_2 conditions, fish exhibited maladaptive responses to the scent and auditory cues of preferred nursery habitats and exhibited maladaptive responses to predator scents. It is believed that the physiological compensation of increased levels of HCO_3- to buffer against pH changes in the blood (which alters oxygen binding) may alter the function of a critical neurotransmitter. Whether such sensory and behavioral disruptions could also occur in cold water fishes is not yet known. Future experiments are planned to examine the behavioral characteristics of young walleye pollock under ocean acidification conditions.

Coral Research

Coral research has been conducted by Robert Stone at Auke Bay Laboratories in collaboration with John Guinotte (Marine Conservation Institute), Anne Cohen (Woods Hole Oceanographic Institution), and Stephen Cairns (Smithsonian Institution). Corals are widespread throughout Alaska, including the continental shelf and upper slope of the Gulf of Alaska, the Aleutian Islands, the eastern Bering Sea, and as far north as the Beaufort Sea. They are found from the shallow subtidal zone to depths over 6,000 m, and many fish and crab species use them as habitat. Decreases in oceanic pH and resulting decreases in calcium carbonate saturation could have profound effects on corals dependent on the extraction of calcium carbonate from seawater for skeletal building. Corals will be affected differently depending on their skeletal composition (aragonite vs. calcite), geographical location, and depth relative to the already particularly shallow saturation depth in the North Pacific Ocean.

The skeletal composition is unknown for most species of deep-sea corals worldwide and is known for only a handful of the 140 taxa documented from Alaskan waters. Extensive archives at the Auke Bay Laboratory and Smithsonian Institution were sorted, and 130 specimens were selected comprising 61 taxa from all major groups of corals (scleractinians, gorgonians, true soft corals, stoloniferans, pennatulaceans, and hydrocorals) for laboratory analyses. Multiple specimens were selected for taxa of particular ecological importance (i.e. those that form large single-species assemblages). In addition, specimens of the same species were selected from multiple depth and geographic zones.

Laboratory analyses are being performed at the Department of Geology and Geophysics at the Woods Hole Oceanographic Institution. X-ray diffraction was used first to determine the aragonite/calcite ratios and then Inductively Coupled Plasma Mass Spectrometry was used on the high magnesium calcite specimens to determine their Mg content. Corals composed of high Mg calcite are the most soluble and consequently, these corals, particularly those residing at depths deeper than the saturation depth, are most at risk to decreases in oceanic pH unless they have adapted physiological processes to counter the effects.

The mineralogy data will be used in conjunction with species distribution data (depth and geographical) and the present and projected aragonite and calcite saturation horizons in Alaska to predict the effects of ocean acidification on coral resources of the North Pacific Ocean. At the completion of this project a comprehensive risk assessment for all corals in Alaskan waters and recommendations for future research will be provided.

Future Research

Future research on ocean acidification at the Alaska Fisheries Science Center will continue to build on the existing research program focused on nearshore monitoring and physiological response of crabs, fish, and coldwater corals.

King and Tanner crab will continue to be the focus of crab studies at the Kodiak Laboratory, with expanded studies on blue king crab (*Paralithodes platypus*) which live in relatively shallow water and golden king crab which live at such extreme depths that they are likely already adapting to a corrosive environment. Experimental treatments for red king crab will add temperature as a covariate with increased CO_2 to assess the additive effects of these parameters on crab condition. New studies to expand the response variables considered for crab will include determination of hemocyte pH as a potential mechanism affecting the transport of calcium with the hemolymph and respirometry to assess metabolic condition. Bioeconomic models will continue to be developed to include additional species and mortality information from multiple life history stages.

Fish research at the Newport Laboratory will continue to assess the direct effects of oceanic pH on the growth, development, and survival of early life stages. Studies will be expanded to include Pacific cod (*Gadus macrocephalus*) and northern rock sole (*Lepidopsetta polyxystra*). Experimental treatments will include temperature and food limitation. Otolith calcification and behavior will be added as additional response variables.

Large primnoid coral loaded with brittle stars on Dickins Seamount, Gulf of Alaska. Photo by NOAA Office of Ocean Exploration.

Coral research will continue to explore the mineralogy of Alaskan corals by analyzing additional coral taxa and broadening spatial measurements of the current taxa. Comparisons in mineralogy will be made with coral species found at different saturation states in the North Atlantic Ocean. Methods will be refined to identify variability in skeletal composition and density in coral colonies. Risk assessment models will be developed for Alaskan corals.

Additional Reading

Caldeira K., Wickett M. E. 2003. Anthropogenic carbon and ocean pH. Nature, 425, 365-365.

Feely R.A., Sabine C.L., Lee K., Berelson W., Kleypas J., Fabry V.J., Millero F.J. 2004. Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. Science, 305, 362-366.

Feely, R.A. et al. 2004. Impact of anthropogenic CO2 on the $CaCO_3$ system in the oceans. Science 305:362-366.

NOAA Ocean Acidification Steering Committee. 2010. NOAA Ocean and Great Lakes Acidification Research Plan, NOAA Special Report, 143 pp.

Sadler, D., 2011. Hawaii ocean time-series (HOT) data, station Aloha. http://hahana.soest.hawaii.edu/hot/.

Sigler M.F., Foy R.F., Short J.W., Dalton M., Eisner L.B., Hurst T.P., Morado J.F., Stone R.P. 2008. Forecast fish, shellfish and coral population responses to ocean acidification in the North Pacific Ocean and Bering Sea: An ocean acidification research plan for the Alaska Fisheries Science Center. AFSC Proc. Rpt. 2008-07. www.afsc.noaa.gov/Publications/ProcRpt/PR2008-07.pdf

The National Observer Program Advisory Team Meets at the AFSC

Each year 47 different fisheries throughout the nation are monitored by fishery observers deployed by the National Marine Fisheries Service (NMFS). These observers log over 77,000 observer days collecting fishing effort and catch data from U.S. commercial fishing and processing vessels for a variety of conservation and management concerns. NMFS coordinates observer program management through its Office of Science and Technology/National Observer Program (NOP). The NOP seeks to support regional observer programs and increase their usefulness to the overall goals of the agency.

The National Observer Program (NOP) was formed in 1999 and is a means for NMFS to address observer issues of national importance. Additionally, the NOP develops policies and procedures to support NMFS observers and observer programs. These policies and procedures address the varied needs of regional observer programs, enhance data quality, and provide consistency in areas of national importance.

The objectives of the NOP are to 1) coordinate the National Observer Program Advisory Team (NOPAT); 2) communicate and advocate the mission of the NOP and each regional observer program; 3) develop and support national standards and policies to create high quality, cost effective, efficient, and productive observer programs; and 4) characterize and qualify the activities and resources of NMFS observer programs and advocate for full support.

The NOPAT is comprised of representatives from each region and each headquarters office. The NOPAT functions to work with the NOP staff to identify issues of national concern, to recommend or establish priorities for national research and problem solving, and to support information collection and program implementation. The NOPAT meets at least twice annually to provide an opportunity for NMFS Observer Program managers from around the country to discuss fiscal and operational issues.

In September, the AFSC was host to the semi-annual NOPAT meeting. A highlight of the meeting was the first in-person meeting of the safety committee, a sub-committee of the NOPAT. This subcommittee is made up of regional staff appointed by the NOPAT to ensure consistency in safety standards among the different observer programs and to address priorities as directed by the NOPAT. Information covered during this subcommittee meeting was summarized and presented to the NOPAT during their meeting. In addition to regional observer program updates, the meeting touched on vessel safety improvements, electronic monitoring, catch share program updates and the 7th International Fisheries Observer and Monitoring Conference which will be held in Chile in March 2013. The next NOPAT meeting is scheduled for February 2013.

By Allison Barns

These observers log over 77,000 observer days collecting fishing effort and catch data from U.S. commercial fishing and processing vessels for a variety of conservation and management concerns.

Cetacean Assessment & Ecology Program

Aerial Surveys of Arctic Marine Mammals Project: Preliminary Results from the 2012 Field Season

The Aerial Surveys of Arctic Marine Mammals (ASAMM) project is the successor to the Bowhead Whale Aerial Survey Project (BWASP) and the Chukchi Offshore Monitoring in Drilling Area (COMIDA) marine mammal aerial surveys. BWASP started in the late 1970s surveying the Beaufort and Chukchi Seas and has continued uninterrupted since; surveys in the Chukchi Sea were conducted as part of BWASP from 1979 to 1991 and as part of COMIDA from 2008 to 2010. The ASAMM project is conducted by the National Marine Mammal Laboratory (NMML), funded by the Bureau of Ocean Energy Management (BOEM), and permitted through the National Marine Fisheries Service (NFMS) and the U.S. Fish and Wildlife Service. Daily reports from the 2012 field season as well as previous years' reports are available on the NMML website.

In order to minimize and mitigate the effects of anthropogenic activities on arctic marine mammals, information on marine mammal ecology is needed for all seasons in which activities could occur.

The lengthened open-water season and reduced sea-ice coverage in summer and fall in the Arctic foretell increased human activities in this region, including shipping, fishing, recreation, and oil and gas exploration, development, and production. In order to minimize and mitigate the effects of anthropogenic activities on arctic marine mammals, information on marine mammal ecology is needed for all seasons in which activities could occur. ASAMM is the only project providing broad-scale visual information about the distribution, relative abundance, and behavior of marine mammals in the Alaskan Arctic during summer and fall including, but not limited to, regions of interest to the oil and gas industry.

The objectives of the ASAMM study are to 1) describe the annual migration of Western Arctic bowhead whales across the Alaskan Arctic, including significant inter-year differences and long-term trends in the spatial distribution and timing (duration and start date) of the migration; 2) document relative abundance, spatial and temporal distribution, and behavior (including calving/pupping, feeding, hauling out) of marine mammals (cetaceans, ice seals, walruses, and polar bears) in the Alaskan Arctic; 3) provide near real-time data and maps to BOEM and NMFS on marine mammals in the Alaskan Arctic, with specific emphasis on endangered species, such as bowhead whales; 4) provide an objective, wide-area context for understanding marine mammal ecology in the Alaskan Arctic to help inform management decisions and interpret results of other small-scale studies; 5) provide, when requested by BOEM's representative, limited integrative products such as graphics of summarized observations for use by BOEM analysts in National Environmental Policy Act (NEPA) and Endangered Species Act (ESA) analyses and documentation; and 6) provide timely information on environmental conditions, including ice conditions, to organizations (e.g., the National Ice Center, Alaska Eskimo Whaling Commission, and BOEM) as directed by BOEM's representative.

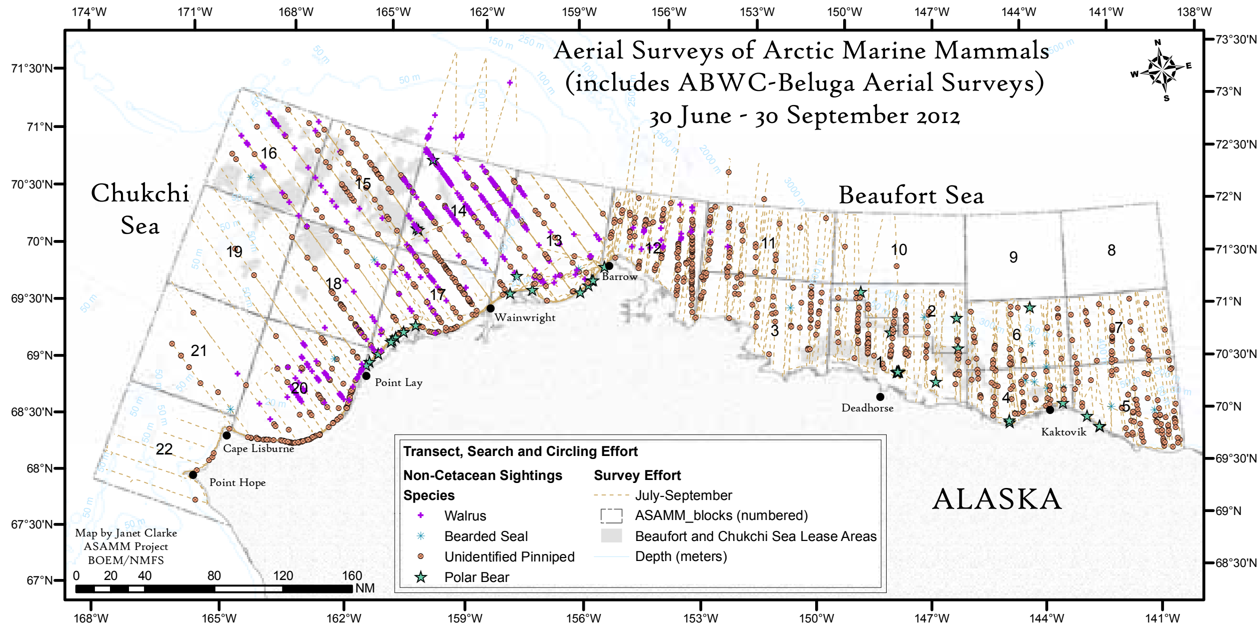


Figure 1. Cetacean sightings from ASAMM aerial surveys and ABWC beluga aerial surveys, 30 June-30 September 2012.
Map by Janet Clarke.

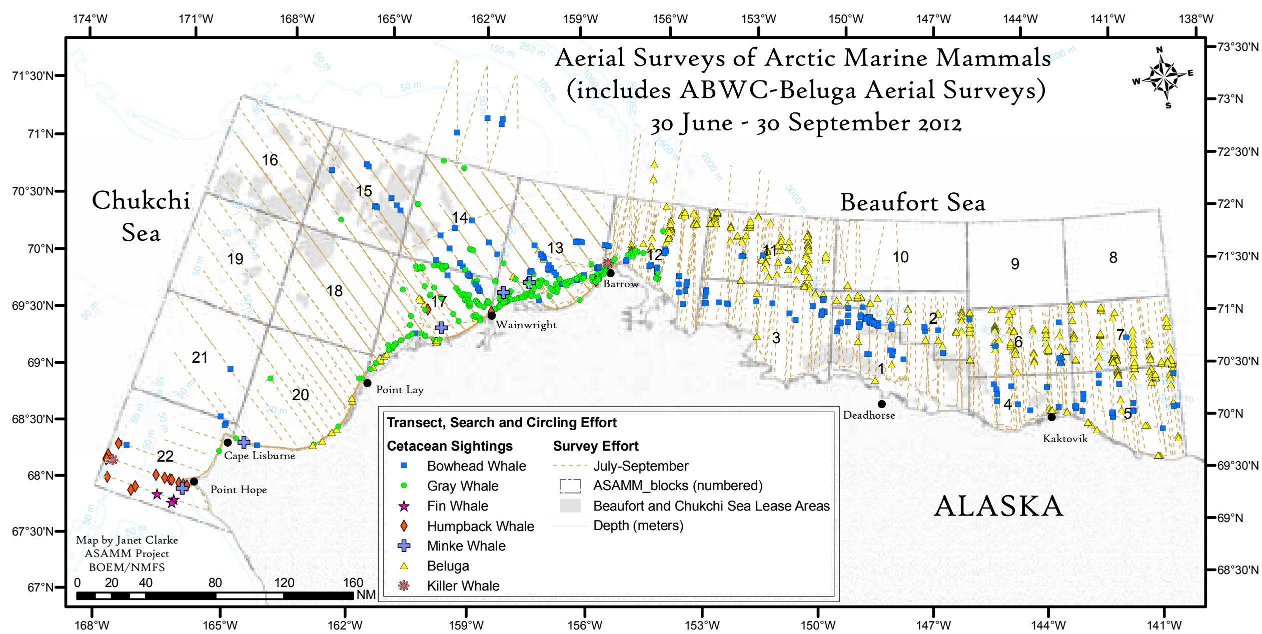


Figure 2. Non-cetacean sightings from ASAMM aerial surveys and ABWC beluga aerial surveys, 30 June-30 September 2012.
Map by Janet Clarke.

ASAMM surveys are conducted in the western Beaufort and northeastern Chukchi Seas (68°N-72°N latitude and 140°W-169°W longitude), extending from the coast to a maximum of approximately 315 km offshore, encompassing 230,000 km^2. Two teams are required to cover the study area: one team, based out of Barrow, Alaska, surveys the northeastern Chukchi Sea and the other team, based out of Deadhorse, Alaska, surveys the western Beaufort Sea. Fixed-wing, twin-turbine Aero Commander aircraft have been used for all surveys in 2012. These aircraft have a 5.5-hour flight endurance and are outfitted with bubble windows for downward visibility. Line-transect surveys are flown every day, weather and logistics permitting, at an altitude of 1,200 ft in the Chukchi Sea and 1,500 ft in the Beaufort Sea.

In 2012, Chukchi Sea surveys were conducted from 1 July to 31 October and Beaufort Sea surveys from 19 July to 20 October. Additional surveys, flown by NMML and sponsored by the Alaska Beluga Whale Committee (ABWC), were designed to survey the eastern Chukchi Sea beluga stock; these surveys were flown 30 June-12 July from the coast out to 45 nautical miles offshore in the northeastern Chukchi Sea and in the region of Barrow Canyon. Cetacean sightings and non-cetacean sightings from these surveys, 30 June-30 September 2012, are plotted on maps in Figures 1 and 2, respectively.

Overall, weather patterns in 2012 have remained similar to patterns in other recent years. However, sea ice remained longer in the northern part of the study area, including near Hanna Shoal, in summer 2012 than in recent years (2009-2011) despite the record minimum extent of sea ice in the Arctic.

Western Arctic Bowhead Whales

The distribution of bowhead whales (Fig. 3) during the 2012 fall migration remained consistent with historical data collected from 1982 to 2011, with a few exceptions. Since 1987, broad-scale aerial survey coverage in the western Beaufort Sea has been mainly limited to the months of September and October to cover the fall migration of bowhead whales. Information on the summertime use of the western Beaufort Sea by bowheads was lacking until recently, and it was presumed that most bowheads spent their summers feeding in the eastern Beaufort Sea. The Alaska Department of Fish and Game's (ADF&G) satellite-tagging program (funded by BOEM) to track bowhead whale movements has documented the bowhead whale migration from their Bering Sea wintering grounds to summering grounds in the eastern Beaufort Sea. This tracking program has also documented bowhead whales moving throughout the Chukchi and Beaufort Seas more than previously thought, including documentation of bowhead whales in the western Beaufort Sea during the summer. In July 2011, the ADF&G tracked a tagged bowhead to the western Beaufort Sea, and the ASAMM team from Barrow then found 16 bowhead whales in the area of the tagged whale. Based on this information, the ASAMM survey season in the western Beaufort Sea was extended to mid-July in 2012. Bowhead whales were found during 13 of 23 ASAMM aerial surveys conducted from 19 July to 29 August 2012. Bowheads were distributed primarily along the outer continental shelf of the western Beaufort Sea, including 58 sightings totaling 115 whales (including 11 calves). The bowhead whale fall migration in the northeastern Chukchi Sea may have been somewhat earlier in 2012, as bowheads were also sighted in this area more frequently and in greater numbers in September 2012 than in past years.

Figure 3. Bowhead whale, 20 August 2012. Photo by Cynthia Christman.

Figure 4. Gray whale mother and calf pair, 14 July 2012. Photo by Cynthia Christman.

Gray Whales

The distribution of gray whales in 2012 also remained consistent with historical data collected from 1982 to 2011. Gray whales have continued to use Chukchi Sea foraging grounds between Point Barrow and Point Lay, but they were consistently sighted further offshore in 2011-12. In 1982-91, gray whales were sighted feeding in the Hanna Shoal region, but few gray whales have been sighted there in recent years (2008-12). In 2012, more gray whale calves were sighted in the Chukchi Sea than in any previous survey year in this region (Fig. 4). Calf distribution in 2012 was primarily in nearshore, shallow water, which may provide protection from predators; killer whales were sighted by ASAMM observers in multiple locations in the northeastern Chukchi Sea in 2012 and have been documented in this region by others in previous years. During the 2012 survey of the gray whale northward migration along the California coast (conducted by the Southwest Fisheries Science Center), calf counts were also high compared to surveys in previous years. It is possible that conditions were favorable for foraging in 2011 and many females were able to accumulate sufficient energy reserves to reproduce in 2012. Another possibility is that other habitats where gray whale cow-calf pairs have been documented in the past, such as just west of Point Hope, Alaska, and along the Chukotka Peninsula in Russia, may not have been as favorable for cow-calf pairs in 2012.

Belugas

Belugas observed in the study area in late summer and early fall are from the eastern Chukchi Sea stock and the Beaufort Sea stock. The distribution of belugas in 2012, particularly in the western Beaufort Sea and Barrow Canyon, remained consistent with historical data collected from 1982 to 2011. In the northeastern Chukchi Sea, relatively few belugas were sighted in 1982-91 and 2008-10, particularly in the summer months. Conversely, in 2011, belugas were distributed throughout the northeastern Chukchi Sea in all months, with more beluga sightings in 2011 (299) than in 2007-10 combined (157). In late June and early July 2012, more than 8,600 km were flown on coastal and offshore transects in the northeastern Chukchi Sea. Despite this effort, very few belugas were seen offshore; groups ranging in size from 1 to 300 belugas were observed within a few kilometers of shore. Large groups of belugas were observed feeding near entrances to Kasegaluk Lagoon on 4 days in late June and early July. Beluga distribution and habitat preference (belugas per km per depth zone) in the western Beaufort Sea heavily favored the continental slope and Barrow Canyon in 2012.

Other Cetaceans

In addition to cetacean species typically seen during our aerial surveys in this area, several species not commonly encountered were documented during the 2012 survey, including humpback, fin, minke, and killer whales. These four species were primarily sighted in two areas: nearshore between Icy Cape and Point Barrow, and west and south of Point Hope. None were seen in the western Beaufort Sea. Humpback, minke, and killer whales were seen in both areas, whereas, fin whales were seen only in the southern area. Most of the humpback whales were seen in the southern area, a region where gray whales have been consistently seen in past years. Humpback, minke, and fin whales exhibited feeding behavior, and both fin and killer whale calves (Fig. 5) were observed. The killer whales were not observed feeding; however, several large whale carcasses were observed in the study area, one of which appeared to be missing its lower jaw, suggesting possible killer whale predation. None of these species were sighted during historical surveys in 1982-91. Since broad-scale aerial surveys recommenced in the northeastern Chukchi Sea in 2008, only one fin whale (July 2008), one humpback whale (July 2009), and six minke whales (2011) have been sighted. Although all of these species have been detected acoustically in the northeastern Chukchi Sea, particularly in the southern area, the historical scarcity of sightings from broad-scale aerial surveys is likely indicative of their relative rarity in this region. The 2012 ASAMM sightings may represent a continuing trend towards greater cetacean species diversity and abundance in the northeastern Chukchi Sea.

Walruses

Pacific walruses were observed in the northeastern Chukchi Sea in the summer and fall 2009-11, and large walrus haulouts on land were encountered by early September 2009 and 2010 and by mid-August 2011 (the earliest recorded date of a walrus haulout on the northern Alaska shoreline). Sea ice was absent in, and north of, the study area by late summer 2009-11, likely resulting in walrus movement closer to shore and, consequently, in the formation of large walrus aggregations on land. As of late September 2012, walruses had not hauled out on land. The persistence of sea-ice remnants near Hanna Shoal throughout summer and fall 2012 likely provided enough at-sea haulout space, making land haulouts unnecessary in August and September.

Figure 5. Killer whales and calf, 20 August 2012. Photo by Cynthia Christman.

Other Pinnipeds

The distributions of ringed, spotted, and bearded seals overlap in the Alaskan Beaufort Sea and the survey altitude of the ASAMM aircraft allowed us to positively identify only large walruses and bearded seals. Most pinnipeds are therefore recorded as unidentified pinnipeds (likely including ringed and spotted seals in addition to small walruses and bearded seals) and small, unidentified pinnipeds (likely including ringed and spotted seals and possibly juvenile bearded seals). In 2012, pinnipeds were seen both on the continental shelf and in deeper areas of the continental slope, similar to their distribution in 1982-2011.

Polar Bears

Polar bear sightings in the Beaufort Sea in 2012 have been mainly in the areas of Cross Island and Barter Island, with scattered sightings both nearshore and offshore. The villages of Kaktovik and Nuiqsut conduct fall subsistence hunts for bowhead whales from Barter Island and Cross Island, respectively, so polar bears aggregate at those locations to feed at the resulting bone piles. As of late September, four bears were also sighted swimming offshore near little or no sea ice approximately 44 km, 50 km, 78 km, and 80 km from shore. Polar bear sightings in the Chukchi Sea were either on or near ice floes or on or near shore. Several of the bears sighted on shore were near gray whale, walrus, or unidentified marine mammal carcasses. Polar bear sightings recorded in the Chukchi Sea in 2012 have surpassed the numbers documented in 2008-11. Polar bear sightings in the Beaufort Sea in 2012 have surpassed the numbers in 2009-11 but, as of late September, were less than in 2008.

Collaborations

ASAMM also fosters collaborations with various researchers from local, state, and federal agencies. The large study area allows ASAMM surveys to collect visual data on several physical and biological factors that would otherwise not be available and to share this information in a timely manner. Recent collaborations include, but are not limited to 1) providing real-time walrus ice-haulout information to U.S. Geological Survey (USGS) personnel to assist with satellite-tagging efforts; 2) providing walrus and polar bear sighting data to the USGS, U.S. Fish and Wildlife Service (USFWS), and ADF&G; 3) cooperating with the ABWC and North Slope Borough Department of Wildlife Management (NSB DWM) on aerial surveys focused on eastern Chukchi Sea belugas; 4) providing biweekly bowhead whale sighting data to the U.S. Coast Guard (USCG) in support of Arctic Shield 2012; 5) providing Level A stranding reports for marine mammal carcasses to the NSB DWM, USFWS, and NMFS; 6) locating wayward meteorological-oceanographic buoys for eventual retrieval by owners; and 7) sending sea-ice images to the USCG, NOAA research vessels, and the National Weather Service Sea Ice Desk to ground-truth ice images available from satellites. These collaborations, in addition to near real-time posting of daily flight reports and allowing public access to historical data, make the ASAMM project valuable in a broader scientific context.

By Amelia Brower, Janet Clarke, Megan Ferguson, Cynthia Christman, and Christy Sims

Midwater Assessment & Conservation Engineering

Research to Reduce Crab Mortality from Trawl Footropes and Improve Tools for Near-Bottom Walleye Pollock Capture

During the cruise, scientists measured and assessed thousands of Tanner and snow crabs that had contacted bottom trawl footropes to estimate their mortality rates and to see whether that rate would be reduced by changes to footrope design.

Figure 1. Crabs being sorted from catches of special nets fished behind trawl footropes.

Conservation engineering scientists with the Center's RACE Division conducted research aboard the chartered fishing vessel *Great Pacific* 1 – 21 September continuing studies to reduce effects of fishing gear on Bering Sea crab resources. During the cruise, scientists measured and assessed thousands of Tanner and snow crabs that had contacted bottom trawl footropes to estimate their mortality rates and to see whether that rate would be reduced by changes to footrope design. Crabs were captured after footrope encounters with nets suspended under the trawl (Fig. 1). Assessments for reflex impairments were used to evaluate the probability of delayed mortality (Fig. 2). This work was funded by the North Pacific Research Board and continued cooperative research efforts with the Bering Sea bottom trawl fleet to reduce effects on Bering Sea crabs. An earlier result of these efforts was changes to trawl sweeps that are now used during all flatfish trawling in the Bering Sea. Those sweep changes eliminate almost all direct seafloor contact, reducing crab mortality and effects on seafloor habitat. Footrope changes tested on the *Great Pacific* also emphasized reducing direct seafloor contact to the extent possible while maintaining their function in capturing fish.

Figure 2. Crab being measured and assessed for reflex impairments.

The second objective of this research cruise was an initial study of alternative trawl groundgear for capturing pollock concentrated near the seafloor. Pollock trawlers are required to use pelagic trawls to capture pollock. However, when pollock concentrate near the seafloor, fishing nets designed to capture fish in midwater and towed along the seafloor can cause both inefficient capture and the potential for bycatch and damage to benthic organisms. Scientists made initial observations of alternative sweep and footrope configurations designed to achieve effective pollock herding and capture, while minimizing seafloor contact and effects on benthos. Observations included the proportion passing under different footrope designs and herding behavior ahead of raised sweeps.

Fish catches during this cruise were passed through a video assessment system. This device is being tested as an alternative method for rapidly identifying and measuring fish catches. This simple system consists of an enclosure with lighting and a high-resolution camera/recorder, mounted over an inclined chute. Automated tools are being developed to analyze the resulting video, providing species and size for each recorded fish.

By Craig S. Rose

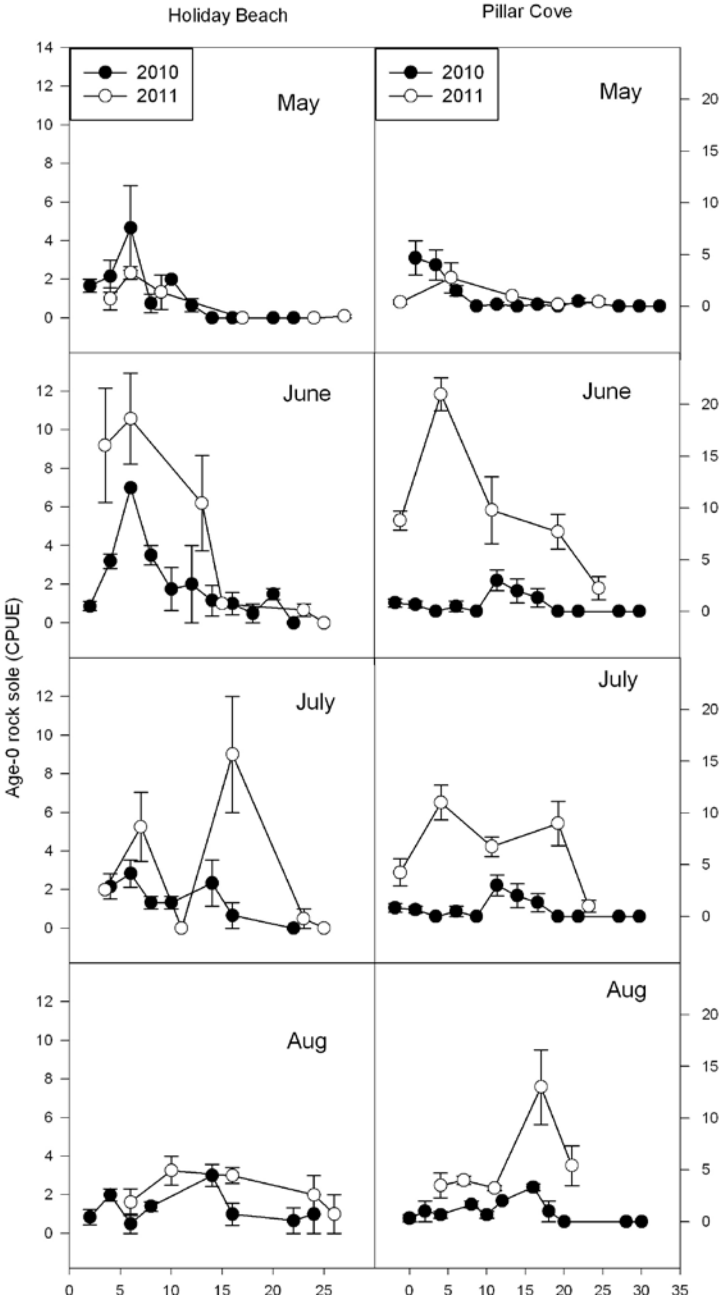


Figure 3. Catch per unit effort (CPUE) of northern rock sole is initially restricted to shallow depths in May and June at two nursery sites off Kodiak Island, Alaska in 2010 and 2011. Data are based on bottom scrape samples collected by 1-min tows from a 1m epibenthic sled. Data are plotted as mean catch per tow ±1.

Fisheries Behavioral Ecology: Newport Laboratory

Northern Rock Sole Early Life History: Oceanography, Settlement, and Nursery Habitat

Northern rock sole (*Lepidopsetta polyxystra*) represent a commercially and ecologically important groundfish in Alaska, and like other flatfish species, they undergo a metamorphosis during the transition from a pelagic to benthic lifestyle. To date, the North Pacific Research Board has funded a series of projects examining habitat processes on the distribution and vital rates of this species in nursery areas around Kodiak, Alaska. Collectively, these projects have identified several important habitat variables for growth and survival. However, the mechanisms by which larvae are delivered to juvenile nurseries rock sole remain poorly understood and have raised several fundamental questions regarding essential fish habitat for this species. For example, do larval rock sole select habitat at settlement? If so, what habitat variables contribute to settlement and early post-settlement survival? Finally, do these early settlement processes subsequently contribute to overall variation in abundance, growth, and survival in post-settled juveniles among nursery areas?

Figure 4. Image of the 2-m columns used in thermocline trials at the Newport Laboratory

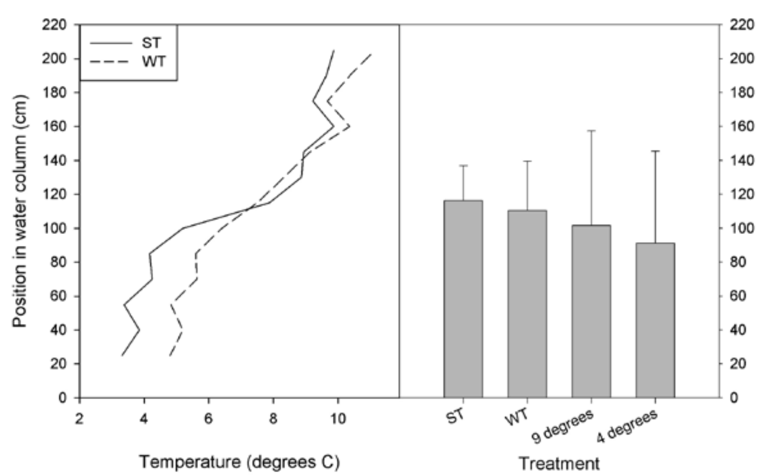


Figure 5. Temperature profile of the strong (ST) and weak thermocline (WT) treatments (left panel) and mean position of rock sole larvae over all observations in each of 4 temperature treatments (right panel). Data is based on means ± 1 standard error.

Recently collected field data from known northern rock sole nursery sites show that newly settled rock sole juveniles are initially restricted to the shallowest region of juvenile nursery areas (< 3 m in depth) where substrates are unfavorable for burial and infaunal prey items (Fig. 3). One hypothesis is that thermoclines in deeper regions of the nursery prevent access to favorable substrates during settlement. Indeed, temperature data from the Kodiak nursery sites show 2°-3°C of stratification in deeper parts of the nursery whereas shallow regions remain unstratified throughout the settlement period. In addition, a recent AFSC study of juvenile rock sole distributions along the Inner Front of the Bering Sea suggests that changing thermal regimes control rock sole larval distribution and supply to nursery sites. To investigate these processes further, rock sole larvae were reared for a series of behavioral experiments at the AFSC's Newport Laboratory. After 90 days of development, individual larvae were introduced to a series of 2-m water columns nested in a large tank (2.5 m x 2.5 m x 2.5 m) where vertical position, behavior, and settlement was recorded over a 3-hour period (Fig. 4). Water column treatments ranged from isothermic (4° or 9°C throughout) to thermally stratified conditions with either 4°C temperature change over 20 cm (strong thermocline: ST) or 100 cm (weak thermocline (WT) across the water column. Results indicated that the larvae concentrate at the thermocline break but demonstrate more spatial variation in the water column when conditions are isothermic (Fig. 5). Rates of settlement were highest in the isothermal treatment at 4°C, suggesting thermoclines do restrict competent larvae from settling. These data help explain the narrow depth range occupied by newly settled rock sole in Kodiak nurseries and support observations of annual changes in the spatial distribution of juvenile rock sole in the Bering Sea. Ongoing research is examining the consequences of settlement in poor quality habitat and whether post-settlement dispersal limits occupation of more favorable areas of the nursery.

By Benjamin J. Laurel and MaryKate Swenarton (Rutgers University)

Recruitment Processes Program—Fisheries-Oceanography Coordinated Investigations

Bering and Chukchi Seas: Panoply of Seafaring in 2012

The Recruitment Processes Program had a busy summer field season in the eastern Bering and Chukchi Seas. The program collaborated on an age-0 walleye pollock and ecosystem survey in the eastern Bering Sea with the AFSC Ecosystem Monitoring and Assessment and the Midwater Assessment and Conservation Engineering Programs and the Pacific Marine Environmental Laboratory's Ocean Ecosystem Research Division (the PMEL part of the FOCI Program) aboard the NOAA ship *Oscar Dyson* from 16 August through 14 October (Fig. 6). Each program brings a wealth of experience and expertise to this newly collaborative survey. In addition to determining the number, distribution, and condition of age-0 walleye pollock, benthic sampling was undertaken at night to begin determining the number, distribution, and habitat types used by age-0 flatfish such as yellowfin and flathead sole. The cruise also occupied the 70-m isobath transect, one of our sentinel monitoring lines to examine changes in the north-south distribution of water properties and plankton.

The four programs also collaborated on a large-scale midwater survey of the northern Bering and Chukchi Sea's using the chartered vessel F/V *Bristol Explorer*. This vessel worked from 1 August to 28 September occupying a grid of stations. Recruitment Processes is responsible for analyzing the distribution and abundance of larval fish, while other groups are determining the hydrography and water column chemistry, and the distribution and abundance of phyto- and zooplankton and pelagic fishes (Fig. 7). A second vessel chartered by the AFSC Groundfish Assessment Program conducted bottom trawls at the main gridpoint stations. The data from the two ships will be used to create an ecosystem perspective of the northern Bering and Chukchi Seas and will be compared to surveys from previous years to understand whether or not significant changes are occurring due to loss of summer sea ice. Note that the summer arctic ice was at a record low during this past summer, although the prevailing winds transported first year and multi-year sea ice into our sampling region during the surveys.

The Recruitment Processes Program is collaborating with the National Marine Mammal Laboratory (NMML) and the Pacific Marine Environmental Laboratory (PMEL) on an examination of the linkages between climate, sea-ice, krill, and baleen whales in and around oil and gas lease sites in the Chukchi Sea, (the CHAOZ project—Chukchi Acoustics, Oceanography, and Zooplankton). With funding from the U.S. Bureau of Ocean Energy Management (BOEM), the group conducted shipboard sampling and observations of physics, lower trophic levels and marine mammals on the R/V *Aquila* (8 August – 5

Figure 6. Members of the Recruitment Processes, Ecosystem Monitoring and Assessment, and Midwater Assessment and Conservation Engineering Programs work together to process a survey trawl catch from the eastern Bering Sea. This particular catch yielded many large jellyfish (*Chrysaora melanaster*). Photo by Janet Duffy-Anderson

Figure 7. Scientists from the AFSC sort small pelagic fishes from a surface trawl in the Chukchi Sea during Leg 1 of the cruise. Photo by Alex Andrews.

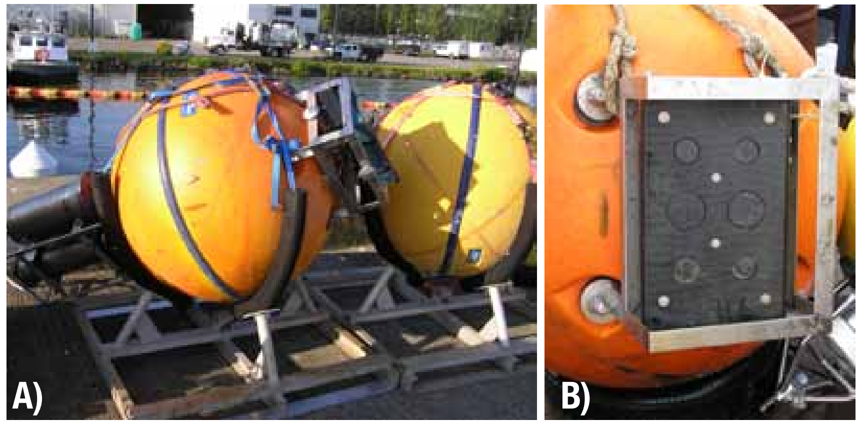


Figure 8. Newly built six-frequency acoustic device. This is a joint project between AFSC and PMEL to design, build, and utilize these instruments in the Chukchi and eastern Bering Seas. A) Instrument mounted in a buoy. The buoy is sitting in a cradle on the dock waiting to be loaded onto the R/V *Aquila*. The instrument consists of a dark colored PVC block with six transducers (on top of the buoy), an electronics case containing the computer that operates the instrument and two battery cases (all below the buoy-left side of picture). In this figure the transducer faces are covered with foam for protection before deployment. B) close up of transducers (50 to 735 kHz) mounted in PVC block. Photos by Jeffrey Napp

September). The project is also responsible for maintaining moorings with biophysical instruments that sample year round for things such as water temperature, ice thickness, amount of sunlight under the ice, nutrient concentrations, krill size and abundance, and the presence/absence of vocalizing marine mammals. This is important because the region is inaccessible for much of the year to most research ships, except ice-breakers. Thus without moorings we would only be able to monitor the environment during the ice-free summer. One of the instruments deployed is our newly built six-frequency acoustic profiling device (Fig. 8). Patterned off the Tracor Acoustic Profiling Systems Next Generation instruments (TAPS6-NG), these instruments use a suite of six acoustic frequencies to estimate the size and abundance of krill in the water column at the mooring sites. This information is important to help us determine food availability for the protected bowhead whales that migrate through this region twice each year. During the cruise PMEL also serviced the four sentinel moorings in the eastern Bering Sea which are used to detect change in this highly productive ecosystem (Fig. 9).

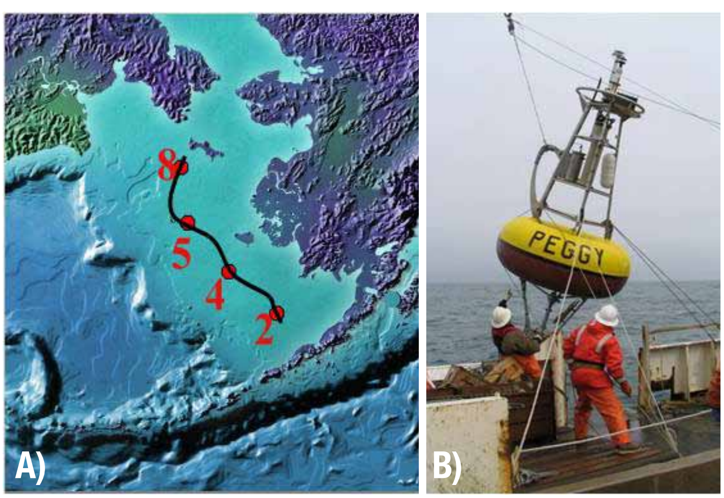


Figure 9. Sentinel moorings in the eastern Bering Sea maintained by NOAA's Pacific Marine Environmental Laboratory A) Location of eastern Bering Sea moorings, B) Surface buoy with meteorological instruments deployed at M2 during the summer.

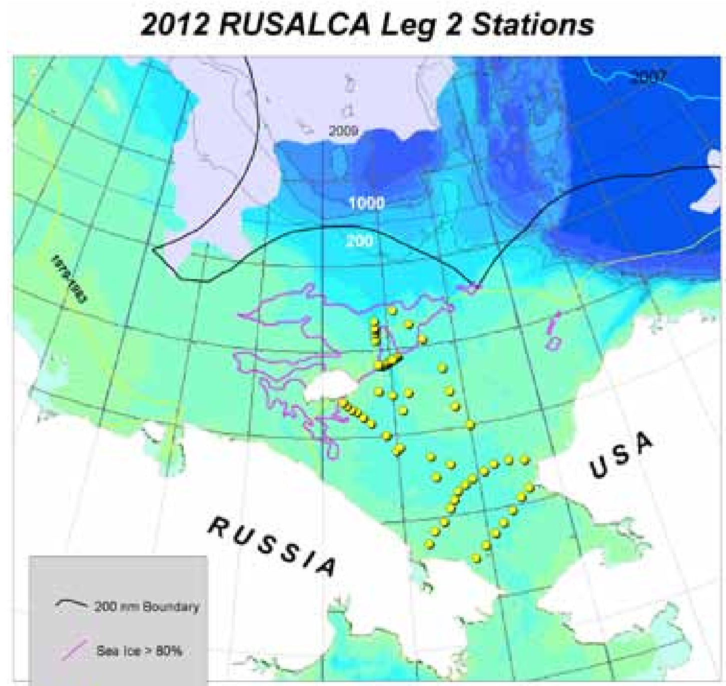


Figure 10. Station map for Leg 2 of the 2012 RUSALCA cruise where ichthyoplankton sample were collected for the Recruitment Processes Program. Comparison of this year's and past year's stations can be made by going to the Ichthyoplankton Cruise Database and searching for station maps from the cruises 1KR09 and 1 KR04.

Last, but not least, the Recruitment Processes Program obtained ichthyoplankton samples from the Russian-U.S.A. Long-Term Census of the Arctic cruise. This was the third biological cruise for RUSALCA. Previous cruises were in the summer of 2004 and 2009. A cooperative agreement between the two countries allows sampling on both sides of the international dateline and provides us with the samples necessary to better understand the dynamics of the Chukchi Sea ecosystem, which spans the territorial waters of both countries. This year's cruise aboard the R/V *Professor Khromov* (23 August – 16 September) spent most of its time sampling on the western side of the Chukchi Sea (Fig. 10).

By Jeffrey Napp

FISHPAC Cruise Studies Fish Habitat and Updates Nautical Charts for the Bering Sea

Three branches of NOAA are working together as part of the FISHPAC project to coordinate fish-habitat research and nautical charting in the eastern Bering Sea (EBS). Both efforts require quantitative environmental observations about the seafloor over sizable geographic areas and use innovative technology and efficient methods to acquire data. The AFSC Habitat Research Group (HRG) is building basin-scale numerical models to explain the distribution and abundance of EBS species. The resulting quantitative relationships not only satisfy the Congressional mandate to identify and describe essential fish habitats (EFH), but also can be used to gauge the effects of anthropogenic disturbances on EFH, improve fish-stock assessments, and predict the redistribution of species into northern waters as a result of environmental change. The NOAA's Pacific Hydrographic Branch is responsible for hydrographic surveys and nautical charting to ensure safe, efficient, and environmentally sound marine transportation in Alaskan waters. Activities between these two groups are facilitated by a NOAA Corps hydrographer assigned to the HRG.

Figure 11. Members of the 2012 FISHPAC field party.

A major multi-mission research cruise was conducted in the EBS in 2012, involving a 12-member team of HRG scientists, Navy technicians, and a consulting engineer (Fig. 11). The primary purpose of the cruise was to investigate whether seafloor backscatter data can be used to improve EFH descriptions. Although largely a scientific study, the FISHPAC project also collected hydrographic-quality bathymetric data to update nautical charts of areas with outdated or nonexistent information. The study area consisted of five 115-145 nautical mile tracklines across the EBS shelf over depths ranging from 37 to 126 meters (Fig. 12). These survey lines were chosen to pass directly over 26 RACE bottom-trawl-survey stations at which a wide range of fish and invertebrate abundances has been observed. Over the period 12-28 July, each line was navigated three times with continuous shipboard operations. On every pass, backscatter and bathymetry were collected using the ship's two multibeam sonars (Reson models 7111 operating at 100 kHz and 8160 at 50 kHz). Three other sonars were utilized on the first and third passes over the lines, including a conventional side scan sonar (Klein 5410, 455 kHz) and a prototype long-range side scan sonar (Klein 7180, 180 kHz) with an independent single-beam echosounder mounted on the towfish (Elac Nautik, 38 kHz). Following a review of side scan imagery, geological and biological sampling was conducted on the second passes over the lines and constituted groundtruthing of the sonar data. Two sediment grabs and digital still photos were collected at 4-6 points on each trackline. One of these grabs will be used for a laboratory analysis of sediment properties, and the other will be processed to characterize invertebrate organisms living in the substrate. Video data were also collected and will be converted to still-image mosaics of the seafloor. Geophysical properties of the seabed as well as sound velocities in the water column were measured at each groundtruthing location, and elsewhere as needed, using a free-fall cone penetrometer. Occasional conductivity-temperature-depth (CTD) casts provided additional sound-velocity data to ensure high quality hydrographic products. Subsea positions for all instruments were determined with an ultra-short baseline positioning system that interfaced with the ship's navigational system. After nearly 3,800 GB (3.7 terabytes) of data are processed, statistical analyses will identify the most cost-effective sonar system. The best performing system will be used to map and characterize the seabed of the EBS shelf and to update EFH descriptions for all affected species. These same acoustic data may also be useful for stock assessment purposes, if survey trawl performance (catchability) is related to seafloor characteristics.

By Bob McConnaughey

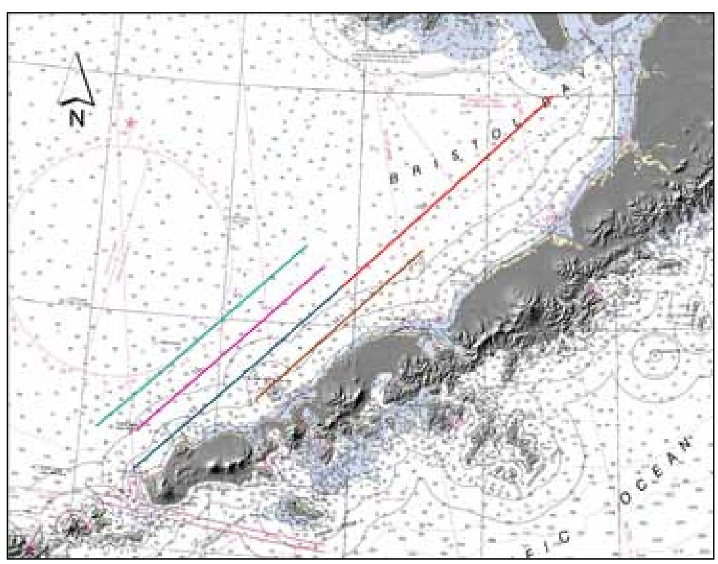


Figure 12. Survey tracklines for the multi-mission 2012 FISHPAC cruise in the eastern Bering Sea.

Habitat Scientists Participate in Arctic Reconnaissance Cruise on *Fairweather*

The Arctic is becoming more accessible as perennial sea ice retreats. As such, there is an increasing likelihood of new fishing, shipping, and exploration activities in the region. Planning efforts by NOAA and others are underway but are often hindered by a lack of baseline information. For example, the North Pacific Fishery Management Council recently tasked the AFSC to synthesize existing ecosystem information and develop a research plan for understanding the effects of bottom trawls on the previously unfished northern Bering Sea shelf. Similarly, the NOAA Office of Coast Survey (OCS) has developed an Arctic Nautical Charting Plan "to build the foundation for Arctic shipping," emphasizing the need to identify northern shipping routes and ports of call. To address these needs, the OCS planned a reconnaissance survey from Dutch Harbor, Alaska, to Kotzebue Harbor on the NOAA ship *Fairweather* and invited AFSC Habitat Research Group (HRG) scientists to participate. Our scientific objective was to tow the Klein 7180 long-range sidescan sonar system (LRSSS) to investigate latitudinal trends in seabed characteristics (backscatter and bathymetry) and to continuously measure turbidity, colored dissolved organic matter and chlorophyll-a using the 660 nm (red) optical transmissometer on the LRSSS. These data will provide a first look at seafloor and water-column habitats in the area and could support an evaluation of potential sampling gears. The cruise also provided an opportunity for the OCS to consider utility of the towed LRSSS for reconnaissance surveying, as compared to more conventional ship-mounted systems.

Fig. 13. Trackline for the South Arctic Reconnaissance Survey by NOAA ship *Fairweather*, 1-6 August 2012. The bold line indicates the area surveyed with the Klein 7180 long-range side scan sonar (LRSSS) and is overlaid on the line indicating where backscatter and bathymetry were collected with the ship's two multibeam echosounders. Yellow squares indicate trawl-survey locations characterized with the LRSSS. The transit covered 1,051 linear nautical miles.

The Arctic is becoming more accessible as perennial sea ice retreats. As such, there is an increasing likelihood of new fishing, shipping, and exploration activities in the region.

Figure 14. Free-fall cone penetrometer ready for deployment. Sensors in the body of the instrument measure deceleration as the device penetrates the seafloor and comes to rest below the surface, providing information about the vertical structure of sediments while the ship is underway. Another sensor in the yellow tail region measures sound velocities in the water column which are used to provide high-quality acoustic data.

The 2012 South Arctic Reconnaissance Survey followed completion of the scheduled FISHPAC cruise in the eastern Bering Sea. After a brief in-port period in Dutch Harbor, a team of three HRG scientists and two Navy technicians resumed survey operations on the *Fairweather*. The 1-6 August leg consisted of a northerly transit across the Bering Sea, through the Bering Strait to the Chukchi Sea, and into Kotzebue Sound, roughly 26 nmi north of the Arctic Circle. The trackline planned for this leg ran generally north to include 38 AFSC bottom-trawl-survey stations but was repeatedly modified due to poor weather and a significant westerly swell (Fig. 13). During the transit, acoustic backscatter and bathymetry data were continuously acquired with the ship's two hull-mounted Reson multibeam echosounders and the LRSSS. A free-fall cone penetrometer was used to collect sound velocity data and to characterize geotechnical properties of the seafloor (Fig. 14). The combination of poor weather and shallow water eventually prompted the suspension of LRSSS and penetrometer operations at a point to the west of Cape Romanzof. Sound velocity data were subsequently collected using a single-sensor free-fall instrument deployed with the ship's computerized winch. Final LRSSS coverage included 18 AFSC bottom-trawl-survey stations; penetromenter drops were completed at nine of these.

By Bob McConnaughey

The 2012 South Arctic Reconnaissance Survey followed completion of the scheduled FISHPAC cruise in the eastern Bering Sea.

Fisheries Resources Pathobiology

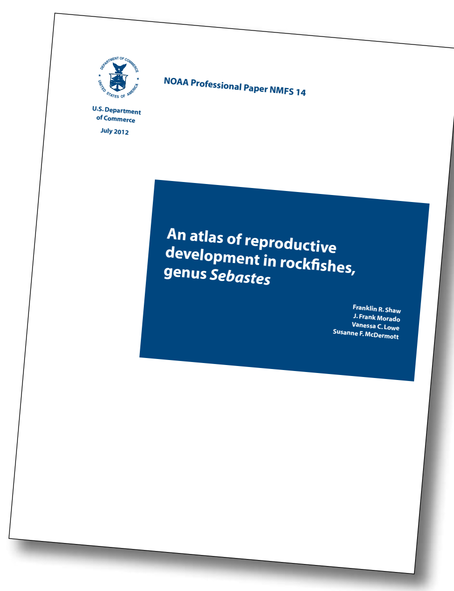
Rockfish Reproductive Development Atlas

What started as a master's thesis project for former AFSC scientist Frank Shaw has resulted in "An atlas of reproductive development in rockfishes, genus *Sebastes*" published in the NOAA Professional Paper series in July 2012. The atlas is the product of a joint effort by Frank Shaw, Frank Morado, Vanessa Lowe, and Susanne McDermott. Final efforts leading to publication were headed by Frank Morado and Vanessa Lowe.

The atlas is a microscopic study of the major development events that occur during spermatogenesis, oogenesis and embryogenesis, including atresia in six species of *Sebastes* (*S. alutus, S. elongatus, S. helvomaculatus, S. polyspinis, S. proriger*, and *S. zacentrus*). Reproductive development in all six species was consistent, demonstrating 11 phases of testicular, 12 phases of ovarian and 33 stages of embryonic development. The results suggest that the presented reproductive development may apply to all species of *Sebastes* regardless of the number of broods produced annually. The comparative study was initiated as an effort to gather information on life history parameters which are critical for proper management of harvested species.

The atlas is available on the NMFS Scientific Publications Office website in pdf format (click on *Professional Papers* section) and may be cited as "Shaw, Franklin R., J. Frank Morado, Vanessa C. Lowe, and Susanne F. McDermott. 2012. An atlas of reproductive development in rockfishes, genus *Sebastes*. NOAA Professional Paper NMFS 14, 77 p."

By Frank Morado and Vanessa Lowe



Resource Ecology & Ecosystem Modeling Program

Eastern Bering Sea Continental Shelf and Slope Groundfish Surveys

Large and abundant predators were the focus of this year's stomach sample collection from the eastern Bering Sea bottom trawl surveys of the continental shelf and slope. In total, 1,498 stomach samples were collected during the survey of the eastern Bering Sea slope, and 5,260 stomach samples were collected during the survey of the eastern Bering Sea shelf. A fairly high number of samples from Pacific cod, walleye pollock, arrowtooth flounder, Kamchatka flounder, Greenland turbot, and Bering skate were collected from both surveys. Pacific halibut, flathead sole, and Bering flounder were only collected during the shelf survey. Nine additional skate species were collected mostly in one survey or the other (or only rarely) depending on their distribution (or abundance). Combined, these predators account for a large portion of the post-larval predation mortality on many commercially important species of fish and crab in the eastern Bering Sea.

Two pairs of congeneric flatfish species – Kamchatka flounder and arrowtooth flounder, and Bering flounder and flathead sole – have a high degree of overlap in their pair-respective morphology, geographic distribution, and food habits. Thus, each pair is collected as a unit, but analyses of the stomach contents and entry into the database are species specific. Congeneric species of skates display more distinction in their geographic and depth distribution, and their food habits differ somewhat due to differences in body size and available prey within their distributions. In addition to providing current information on predation mortality and energy transfer through the eastern Bering Sea foodweb, these samples will provide additional ecological information on the differences in food habits among closely related species.

By Troy Buckley and Sean Rohan

Fish Stomach Collection and Lab Analysis

During the third quarter of 2012, Resource Ecology and Ecosystem Modeling (REEM) program staff analyzed the contents of 2,014 groundfish stomachs in the laboratory and participated in 10 legs of the summer groundfish surveys. Five predator species were analyzed from the eastern Bering Sea, and Pacific halibut were analyzed from the Gulf of Alaska. This resulted in 8,801 records being added to the AFSC Groundfish Food Habits database. In preparation for stable isotope analysis, approximately 200 muscle and liver tissue samples from Alaskan groundfish were tinned in preparation for gas isotope-ratio mass spectroscopy. Groundfish stomach samples were collected during AFSC surveys of the eastern Bering Sea continental shelf and slope, and the Aleutian Islands region. Stomach samples also were collected during cooperative surveys of demersal and epipelagic waters of the Chukchi Sea. During fisheries operations in the eastern Bering Sea, fishery observers collected stomach samples from 68 arrowtooth flounder, 828 walleye pollock, and 1 Pacific cod.

By Troy Buckley, Geoff Lang, Mei-Sun Yang, Richard Hibpshman, Kimberly Sawyer, Caroline Robinson and Sean Rohan

Aleutian Islands Groundfish Survey

Staff with the REEM program participated in the 2012 Aleutian Islands bottom trawl survey. Staff on board the chartered fishing vessels *Sea Storm* and *Ocean Explorer* conducted 4,018 stomach scan analyses from 19 marine fish species: walleye pollock, Pacific cod, arrowtooth flounder, Pacific halibut, Kamchatka flounder, Atka mackerel, blackspotted rockfish, flathead sole, northern rockfish, northern rock sole, Pacific ocean perch, southern rock sole, shortspine thornyhead, yellow Irish lord, Bathylagidae, myctophids, squids, red-bended rockfish, and armorhead sculpin. This year we aimed to get 100% identification of the prey fish to species level through on-deck examination, lab identification, and genetic identification, when necessary. Therefore, all unidentified prey fish found in the stomachs on board were frozen and brought back to the lab for identification.

By Mei-Sun Yang, Troy Buckley, Geoff Lang, Richard Hibpshman, Kimberly Sawyer, and Caroline Robinson

Arctic Ecosystem Integrated Survey

From 12 August to 24 September REEM personnel participated in the AFSC's bottom trawl survey of the eastern Chukchi Sea aboard the chartered fishing vessel *Alaska Knight*. Scientific trawling operations were performed at stations uniformly located across the continental shelf of the eastern Chukchi Sea between the Bering Strait and Pt. Barrow, within the U.S. Exclusive Economic Zone. At each sampling station after standard catch processing, stomach samples were collected from selected fish species present in the catch and were preserved for analysis to be performed later in the Food Habits Lab at the AFSC. The sampling strategy was designed to include all species of fish that might be encountered, but with added emphasis on more abundant or larger-mouthed species. A total of 1,930 stomachs were collected from 38 species of fish, including Arctic cod, saffron cod, Arctic staghorn sculpin, and Bering flounder. For many species, the number of samples collected was low due to small catches or infrequent capture. However, about 75% of the species we sampled during this survey were also collected during the 2010 survey of Norton Sound and the northern Bering Sea and these samples may provide supplemental information about the food habits of the same species inhabiting the Chukchi Sea. The stomach contents data from the Chukchi Sea specimens, along with the survey catch data, will be used to expand existing information about food habits and predator-prey relationships as well as update existing food web models of the Alaskan Arctic.

By Andy Whitehouse and Troy Buckley

Alaska Marine Ecosystem Considerations for 2013: Draft Report Released September 2012

The Ecosystem Considerations report is produced annually for the North Pacific Fishery Management Council as part of the Stock Assessment and Fishery Evaluation (SAFE) report. The goal of the Ecosystem Considerations report is to provide an overview of marine ecosystems in Alaska through ecosystem assessments and tracking time series of ecosystem indicators. The ecosystems under consideration include the eastern Bering Sea, the Aleutian Islands, and the Gulf of Alaska. This year, the report includes a preliminary Arctic ecosystem assessment.

The intent of adding the Alaskan Arctic to the Ecosystem Considerations report is to provide an overview of general ecosystem information that may form the basis for more comprehensive future Arctic assessments that would be useful for fishery managers making decision on the authorization of new fisheries. Consistent with ecosystem assessments of the eastern Bering Sea, Gulf of Alaska, and Aleutian Islands, we intend for the future Arctic assessments to include a list of indicators that directly address ecosystem-level processes and attributes that can inform fishery management advice by communicating indicator history, current status, and possible future directions.

The draft report includes additional new and updated sections. The section describing ecosystem and management indicators includes updates to 23 individual contributions and presents 3 new contributions. These include: 1) Trends in surface carbon uptake by phytoplankton during late summer to early fall, 2) Gulf of Alaska ichthyoplankton abundance indices, and 3) Spatial variability of catches in Bering Sea and Gulf of Alaska crab fisheries.

The September draft report was reviewed by the Council's Groundfish Plan Teams and Science and Statistical Committee. An updated draft will be presented to the Plan Teams in November, and a final report will be presented to the Science and Statistical Committee and Council Advisory Board in December when the 2013 groundfish quotas are set.

By Stephani Zador

Economics & Social Sciences Research Program

The Utility of Daily Fishing Logbook Data for Fisheries Management in Alaska

Mandatory daily fishing logbooks provide a potentially valuable source of at-sea catch and effort information in Alaska. However, their utility to fishery scientists and managers is limited since logbooks are neither verified for accuracy nor digitized to make them readily available. While fishery observers from the North Pacific Groundfish Observer Program monitor a portion of trips made by groundfish vessels > 60 feet in length and all trips made by vessels > 125 feet in length, vessels < 60 feet in length or using jig or troll gear or fishing for Pacific halibut are generally not subject to observer coverage. For the unobserved portion of the fleet, essential information on the spatial distribution of hauls, haul-specific weight estimates, daily discard estimates, transit time to and from the fishing grounds, days inactive, and crew size information (prior to the implementation of eLandings in 2007) is lacking. Furthermore, because vessels 60-124 feet in length choose which of their trips are observed, estimates of discarded catch or fishing effort on observed trips may be different than that of unobserved trips. Logbook data would provide a key source of information to examine whether the location, duration, and catch of fishers differ between observed and unobserved trips.

This study explores the current logbook system and its reporting requirements and analyzes digitized logbook data from catcher vessels participating in the 2005 Gulf of Alaska trawl fishery to determine the utility of these data to fishery scientists and managers. We compare the relative attributes and deficiencies of the digitized logbooks to observer and fish ticket data. Based on our comparisons, we suggest a replacement of the current paper logbook program with either a streamlined electronic logbook program or a vessel monitoring system with sensors to record gear deployments. Both approaches will enable greater accuracy and spatial coverage for catch location, discard location, and effort of vessels that are not fully observed, which is the most valuable aspect of the logbook data from a research perspective.

By Stephen Kasperski, Stephan Gmur, Alan Haynie, and Craig Faunce

Conservation Values in Marine Ecosystem-Based Management

Proactive ecosystem-based management represents a turning point in ocean management because it formally recognizes the need to balance the potentially competing uses of the ocean, including aquaculture, energy production, conservation, fishing, and recreation. A significant challenge in implementing this balancing act arises from explicitly incorporating conservation in a decision-making framework that facilitates trade-offs between benefits from conservation and conventional commercial uses. We foreshadow these challenges using empirical estimates of the benefits and costs of conservation actions for the endangered western stock of the Steller sea lions in Alaska. We show that the public's conservation values for the western stock of Steller sea lions can be much greater than the economic gains from commercial fisheries (e.g., up to ~8 times for one large fishery). The discrepancy highlights the forthcoming politically contentious decisions on the allocation of ocean resources, and our analysis highlights the critical research gaps needed to better inform these decisions. Our findings provide a starting point for a much needed conversation on how to incorporate conservation into ecosystem based management and, more specifically, coastal and marine spatial planning. Without explicit consideration of these issues, it is unclear whether coastal and marine spatial planning will better conserve ocean resources than the status quo. The paper describing this research has been accepted for publication in *Marine Policy*.

By J.N. Sanchirico, D.K. Lew, A.C. Haynie, D. Kling, and D.F. Layton

Alaska Recreational Charter Boat Operator Research Development

To assess the effect of current or potential regulatory restrictions on Alaska charter boat fishing operator behavior and welfare, it is necessary to obtain a better general understanding of the charter vessel industry. Some information useful for this purpose is already collected from existing sources, such as from the Alaska Department of Fish and Game (ADF&G) logbook program. However, information on vessel and crew characteristics, services offered to clients, and costs and earnings information are generally not available from existing data sources and thus must be collected directly from the industry through voluntary surveys. In order to address the identified data gaps, AFSC researchers are conducting a survey of Alaska charter business owners.

The survey instrument collects annual costs and earnings information about charter businesses and the general business characteristics of Alaska charter boat operations. Some specific information collected includes the following: equipment and supplies purchased by charter businesses, services offered to clients and associated sales revenues, and crew employment and pay.

Initial scoping and design of the survey was based on consultation with staff from the NMFS Alaska Regional Office, ADF&G, North Pacific Fishery Management Council, and International Pacific Halibut Commission regarding analytical needs and associated data gaps and experience with collecting data from the target population. To refine the survey questions, AFSC researchers conducted focus groups with charter business owners in Homer and Seward, Alaska, in September 2011 and conducted numerous interviews in 2012 with additional Alaska charter business owners. The study was endorsed by the Alaska Charter Association, the Deep Creek Charterboat Association, and the Southeast Alaska Guides Organization.

Following OMB approval under the Paperwork Reduction Act, the survey was fielded with the help of the Pacific States Marine Fisheries Commission during spring 2012 to collect data for the 2011 season. At present, the data for the 2011 season are being validated and assessed. Once this process is complete, analysis of the data to better understand the economics of the charter boat operator sector will begin. For example, a regional economic model will be developed using IMPLAN data (a commercially available set of data for conducting regional economic analyses) and the employment, cost, and earnings data from this survey. The model will be used to examine the contribution or impacts of the charter boat sector on the regional economy. The survey will be repeated in 2013 and 2014 to collect data for the 2012 and 2013 seasons, respectively.

By Brian Garber-Yonts, Dan Lew, Amber Himes, and Chang Seung

Developing a Multi-regional Computable General Equilibrium Model (MRCGE) for Alaska and West Coast Fisheries

Many of the vessels operating in Alaska fisheries are owned and crewed by residents of West Coast states, especially Washington and Oregon. Some of these vessels also tend to participate in West Coast fisheries during the year. Expenditures made by these vessels generate income in port and may also have multiplier and spillover effects in other regions. Assuming that all expenditures are made locally will significantly overestimate economic impacts in a region. Taking account of the regional distribution of expenditures made by Alaska fishing vessels in Alaska, West Coast states, and elsewhere in the United States, will enhance our ability to model the overall economic impacts of Alaska fisheries and West Coast fisheries. Starting from an Alaska single-region computable general equilibrium (CGE) model that we developed previously, we developed a multiregional CGE model. We first constructed a three-region (Alaska, West Coast, and rest of the United States) social accounting matrix (SAM) using i) data that was previously used to develop a single-region Alaska CGE model, ii) data developed by NWFSC for the IO-PAC model of West Coast fishery sectors, and iii) data on interregional trade from IMPLAN. Using the SAM, we developed a multiregional CGE for the three regions.

Using the model, we examined the economic impacts of changes in i) the volume of fish caught off Alaska, ii) the demand for Alaska seafood by both the United States and the rest of the world, and iii) currency exchange rates. We also examined the sensitivity of model results to key trade parameter values. We found evidence for both spread and feedback effects among different regions. The results from this modeling project were summarized in a paper which was submitted to *Ecological Economics*.

By Chang Seung and Edward Waters

The Challenges of Marine Protected Areas for Multispecies Fisheries

Spatial closures, like marine protected areas (MPAs), are prominent tools for ecosystem-based management in fisheries. However, the adaptive behavior of fishermen—the apex predator in the ecosystem—to MPAs may upset the balance of fishing impacts across species. While ecosystem-based management emphasizes the protection of all species in the environment, the weakest stock often dominates management attention. We use data before and after the implementation of large spatial closures in a North Pacific trawl fishery to show how closures designed for red king crab protection spurred dramatic increases in Pacific halibut bycatch due to both direct displacement effects and indirect effects from adaptations in fishermen's targeting behavior. We identify aspects of the ecological and economic context of the fishery that contributed to these surprising behaviors, noting that many multispecies fisheries are likely to share these features. Our results highlight the need to either anticipate the behavioral adaptations of fishermen across multiple species in reserve design, a form of implementation error, or to design management systems that are robust to these adaptations. Failure to do so may yield patterns of fishing effort and mortality that undermine the broader objectives of multispecies management and potentially alter ecosystems in profound ways. This work was published in 2012 in *Ecological Applications*.

By Joshua K. Abbott and Alan C. Haynie

The Role of Economics in the Bering Sea Pollock Fishery's Adaptation to Climate Change

One component of the Bering Sea Integrated Ecosystem Research Project (BSIERP) is a spatial economic model that predicts changes in fishing activity in the Bering Sea pollock fishery that may result from climate change. Seasonal sea ice in the Bering Sea is predicted to decrease by 40% by 2050, resulting in more frequent warm years characterized by reduced winter ice cover and a smaller cold pool (<1.5ºC bottom temperature). Retrospective data from the pollock catcher/processer fishery were used to study the behavior of harvesters in past climate regimes to make inferences about future behavior in a warmer climate. We found that in the pollock fishery large differences in the value of catch resulting from the pursuit of roe-bearing fish in the winter fishing season result in disparate behavior between the winter and summer fishing seasons. In the winter season, warm years and high abundances drive more intensive effort early in the season to harvest earlier-maturing roe. In the summer season, a smaller cold pool and high abundances are correlated with decreased effort in the northern reaches of the fishing grounds. Spatial price differences are associated with changes in the distribution of effort of approximately the same magnitude. Although biological evidence suggests that the predicted increased frequency of warmer regimes may result in decreasing abundances, the historical data is insufficient to predict behavior in warm, low abundance regimes. Our study provides insight into the economic drivers of the fishery, many of which are related to climate, and illustrates the difficulty in making predictions about the effects of climate change on fisheries with limited historical data. Over the past year presentations on aspects of this work were presented at several forums, including the Alaska Marine Sciences Symposium, the North American Association of Fisheries Economists meetings, the Ecosystem Studies of Sub-Arctic Seas meetings, and the American Fisheries Society annual meetings. A manuscript has been submitted to the *Canadian Journal of Fisheries and Aquatic Sciences.*

By Alan Haynie and Lisa Pfeiffer

Productivity Growth and Product Choice in Fisheries: the Case of the Alaskan Pollock Fishery Revisited

Many fisheries worldwide have exhibited marked decreases in profitability and fish stocks during the last few decades as a result of overfishing. However, more conservative, science- and incentive-based management approaches have been practiced in the U.S. federally managed fisheries off Alaska since the mid 1990s. The Bering Sea pollock fishery is one such fishery and remains one of the world's largest in both value and volume of landings. In 1998, with the implementation of the American Fisheries Act (AFA) this fishery was converted from a limited access fishery to a rationalized fishery in which fishing quota were allocated to cooperatives who could transfer quotas, facilitate fleet consolidation, and maximize efficiency. The changes in efficiency and productivity growth arising from the change in management regime have been the subject of several studies, a few of which have focused on the large vessels that both catch and process fish onboard (catcher-processors). In this study we modify existing approaches to account for the unique decision making process characterizing catcher-processor's production technologies. In particular, we focus on sequential decisions regarding what products to produce and the factors that influence productivity once those decisions are made using a multiproduct revenue function. The estimation procedure is based on a latent variable econometric model and departs from and advances previous studies since it deals with the mixed distribution nature of the data. Our productivity growth estimates are consistent with increasing productivity growth since rationalization of the fishery, even in light of large decreases in the pollock stock. These findings suggest that rationalizing fishery incentives can help foster improvements in economic productivity even during periods of diminished biological productivity.

By Ron Felthoven and Marcelo de Oliveira Torres

Updating the North Pacific Fishing Community Profiles

The new template adds a significant amount of new information to help provide a better understanding of each community's reliance on fishing.

A NOAA Technical Memorandum finalized in October 2011 documents the process we are undertaking to update the *Community Profiles for North Pacific Fisheries – Alaska*. In addition, the communities to be included in the updated document were reevaluated to ensure that communities with significant reliance on commercial, recreational, and subsistence fishing are included. This resulted in a total of 196 communities that will be profiled, including the 136 communities that were profiled in the 2005 *Community Profiles for North Pacific Fisheries – Alaska* (Community Profiles; Sepez et al 2005) and an additional 60 communities that were not previously included. The Economic and Social Sciences Research (ESSR) program staff spent the majority of 2011 developing a template for the new community profiles, researching and compiling data sources needed for the profile update, and working with the Alaska Fisheries Information Network to compile all of the data for the profiles into a database for use during the profile update process. The new template adds a significant amount of new information to help provide a better understanding of each community's reliance on fishing. The community profiles comprise additional information including, but not limited to, annual population fluctuation, fisheries-related infrastructure, community finances, natural resources, educational opportunities, fisheries revenue, shore-based processing plant narratives, landings and permits by species, and subsistence and recreational fishing participation, as well as information collected from communities in the Alaska Community Survey, which was implemented during summer 2011, and the Processor Profiles Survey, which was implemented in fall 2011.

A team of research assistants was assembled in November 2011 to start the process of revising the profiles. Throughout 2012, this team has been systematically revising all of the existing community profiles and drafting new profiles for the additional 60 communities. Each of the 196 communities has been sent a copy of their updated profile and is being encouraged to provide comments. All comments received will be incorporated into the profiles to the extent feasible. A final version of each community profile is expected to be completed by early October 2012. In October and November 2012, regional profiles will be drafted that summarize overall involvement in fishing by communities in each of the major regions of Alaska.

Final versions of the regional profiles and community profiles will be made available on the AFSC website. Program staff have been working with Center GIS specialists to develop an interactive website where the user can view commercial, recreational, and subsistence data through a web mapping tool. The user will also be able to download non-confidential data per community and each community's profile. The web mapping tool is expected to launch in fall 2012 and can be reached via the existing community profiles website.

By Amber Himes-Cornell, Kristin Hoelting, Peter Little and Conor Maguire

Focus on Forage Fishes

Two words have gotten a lot of attention in the fisheries news over the last year: "forage fishes". So what are they, and what's the big deal? Although the definition can be hazy, forage fishes are generally small, energy-rich fishes that serve a key ecosystem role as prey for larger fish, marine mammals, and seabirds. Pacific herring, capelin, eulachon, and Pacific sand lance are some of the main forage fish species in Alaska marine waters. Forage fishes can also include juvenile stages of larger fishes. For example, juvenile walleye pollock and juvenile salmon are important prey items in Alaska.

Because they are such an important part of the ecosystem, forage fishes have emerged as a major conservation concern worldwide. In some areas there are massive commercial fisheries for forage species, such as the sardine and anchovy fisheries off the coast of Peru. Removing too many of these fishes has the potential to disrupt the functioning of ecosystems. In Alaska, conservation and management of forage fishes varies depending on the species. Juvenile groundfish and salmon are regulated by the state and federal management practices that cover their adult stages. Pacific herring are targeted by commercial fisheries and are managed by the state of Alaska; in federal fisheries they are considered "Prohibited Species" and cannot be retained. The primary way that forage fish conservation is promoted in Alaska's federal fisheries is through protection of a forage fish group that includes almost all of the forage fishes found in Alaska, from smelts (capelin, eulachon) to krill. For this group, commercial fishing is prohibited and retention of bycatch is sharply limited to provide incentives to avoid such bycatch. This conservation measure is part of the AFSC's ecosystem approach to fisheries management: these fishes are considered so critical to the ecosystem that no fishing should be allowed on them at all.

Monitoring forage fish populations is an essential part of continuing forage fish conservation, but doing so presents many challenges. The survey methods employed to monitor abundance of commercial fishing (mostly using a bottom trawl) are not well suited for catching small fishes that often live in the upper parts of the water column. As a result, REFM scientists are researching how to use proxy data as indicators of forage fish abundance. For example, a nearshore survey conducted in partnership with the Alaska Department of Fish & Game and using a net with very small meshes may provide insight into capelin and eulachon abundance. Acoustic data is being used to generate data on the abundance of krill. It may also be possible to use the presence of forage species in predator diets (for example, halibut and tufted puffins) as an indicator of which species are abundant. The latter approach is based on the notion that predators are likely to be much more effective samplers of the environment than a scientist with a net. More information on forage fishes in Alaska can be found on the Ecosystem Considerations page and in the forage fish appendix to the annual Stock Assessment and Fishery Evaluation reports for the Gulf of Alaska.

By Olav Ormseth

Acoustic data is being used to generate data on the abundance of krill. It may also be possible to use the presence of forage species in predator diets (for example, halibut and tufted puffins) as an indicator of which species are abundant.

The increasing access restrictions in many marine fisheries through license reductions and moratoriums have the potential to limit fishermen's ability to diversify their income risk across multiple fisheries.

Income Diversification and Risk for Fishermen

Catches and prices from many fisheries exhibit high interannual variability leading to variability in the income derived by fishery participants. The economic risk posed by this may be mitigated in some cases if individuals participate in several different fisheries, particularly if revenues from those fisheries are uncorrelated or vary asynchronously. We construct indices of gross income diversification from fisheries at the level of individual vessels and find that the income of the current fleet of vessels on the U.S. West Coast and in Alaska is less diverse than at any point in the past 30 years. We also find a dome-shaped relationship between the variability of individuals' income and income diversification which implies that a small amount of diversification does not reduce income risk, but higher levels of diversification can substantially reduce the variability of income from fishing. Moving from a single fishery strategy to a 50-25-25 split in revenues reduces the expected coefficient of variation of gross revenues between 24% and 65% for the vessels included in this study.

The increasing access restrictions in many marine fisheries through license reductions and moratoriums have the potential to limit fishermen's ability to diversify their income risk across multiple fisheries. Catch share programs often result in consolidation initially and may reduce diversification. However, catch share programs also make it feasible for fishermen to build a portfolio of harvest privileges and potentially reduce their income risk. Therefore, catch share programs create both threats and opportunities for fishermen wishing to maintain diversified fishing strategies.

By Stephen Kasperski and Dan Holland

Age & Growth Program

Age and Growth Program Production Numbers

Estimated production figures for 1 January – 30 September 2012. Total production figures were 30,150 with 7,473 test ages and 248 examined and determined to be unageable.

Species	Specimens Aged
Alaska plaice	565
Atka mackerel	1,714
Bering flounder	864
Big skate	113
Blackspotted rockfish	789
Dover sole	459
Dusky rockfish	47
Flathead sole	2,655
Great sculpin	51
Kamchatka flounder	1,058
Longnose skate	216
Northern rock sole	906
Northern rockfish	541
Pacific cod	2,848
Pacific ocean perch	1,972
Rougheye rockfish	482
Sablefish (black cod)	1,199
Southern rock sole	384
Walleye pollock	11,970
Yellowfin sole	1,517

By Jon Short

2012 International Council for the Exploration of the Sea (ICES) Annual Science Conference

Anne Hollowed, Matt Baker, Craig Kastelle, Susanne McDermott, and Stan Kotwicki (RACE) attended the 2012 ICES Annual Science Conference held in Bergen, Norway, 17-21 September 2012. This conference provides a forum for an international community of marine scientists, professionals, stakeholders, and students to gather and share their work. This is carried out through theme-based sessions, which include both oral and poster presentations. The 2012 ICES conference had a diverse program of sessions, with particular focus on aquaculture sustainability and its relationship to wild capture fisheries and ecology of the Arctic in the context of climate change. Sessions also included ecological theory (evaluating limits to ecological resilience and marine habitat connectivity), ecosystem function and dynamics, fisheries assessments (e.g., survey importance), fisheries management (e.g., evaluation of overfishing, evolution of management frameworks, and the use of science in marine spatial planning), and fisheries policy (e.g., traceability of fish products and mitigating fishery discards). The conference also featured plenary lectures by Trevor Branch (Assistant Professor, University of Washington, Seattle), Karin Kroon Boxaspen (Senior Scientist, Institute of Marine Research, Bergen), and Carl Folke (Director, Beijer Institute of Ecological Economics, Stockholm) and an invited lecture by Sidney Holt.

Anne Hollowed co-convened the theme session "Subarctic-Arctic Interactions: Ecological Consequences" along with Ken Drinkwater (Norway), Olafur Astthorsson (Iceland), and George Hunt (USA). The theme session provided a forum for scientists to discuss findings from ecological studies focused on the interactions of Subarctic and Arctic marine ecosystems. Exchanges of water masses and their associated flora and fauna strongly link the marine Arctic and the Subarctic. In the Arctic, temperatures have undergone significant warming, and there has been reduced sea ice in recent years. At the same time marked changes at various trophic levels in the ecosystems of these high latitude areas have also been observed. Climate change scenarios indicate that in the future both Subarctic and Arctic regions are likely to experience greater warming and transformation.

The conveners sought papers that improved understanding of how climate variability and change will affect the structure and function of these marine ecosystems in the future, including biogeochemical processes. Papers that improved our knowledge of the role of physical, chemical, and biological fluxes between the Subarctic and the Arctic and the fate of the transported organisms were of particular interest. Papers that covered multiple trophic levels or investigated biophysical coupling were also especially encouraged, as were comparative papers between different Arctic and Subarctic regions.

The session received an excellent response from the scientific community with 27 oral presentations from scientists from eight countries (Canada, France, Faroe Islands, Iceland, Japan, Norway, the Russian Federation, and the United States). The session started with an overview paper showing the importance of climate forced rates of exchange between the Arctic and Subarctic in the Western Atlantic. Subsequent talks highlighted the role of advection and fronts in structuring Arctic and Subarctic ecosystems. Afternoon talks shifted to issues of climate change impacts on the spatial distribution of marine species, fish dependent economies, and ecology of Subarctic and Arctic systems. The following day several talks focused on lower trophic level responses to climate induced changes in oceanography. The final talks of the session included several modeling studies that tracked climate change impacts through the foodweb. These studies provided insight into potential direct and indirect effects of shifting environmental conditions on the interactions between Arctic and Subarctic species.

The discussion session focused on the management implications of sub-Arctic and Arctic exchanges. It was recognized that there is a strong need for accurate projections of the implications of climate change on Subarctic-Arctic exchanges to allow managers to develop strategies for sustainable management. Anne Hollowed and Matt Baker gave oral presentations in the theme session "Subarctic-Arctic Interactions: Ecological Consequences." Craig Kastelle gave an oral presentation in the session "Beyond Routine Ageing: Otoliths

The discussion session focused on the management implications of sub-Arctic and Arctic exchanges. It was recognized that there is a strong need for accurate projections of the implications of climate change on Subarctic-Arctic exchanges to allow managers to develop strategies for sustainable management.

and other Bony Structures as Windows into Fisheries, Fish Ecology, and the Environment." Susanne McDermott gave an oral presentation in the joint ICES/PICES session entitled "Multidisciplinary Perspectives in the Use (and Misuse) of Science and Scientific Advice in Marine Spatial Planning." Stan Kotwicki gave an oral presentation in the session "The Contribution of Acoustics-derived Indices for Ecosystem-based Fisheries Management: Technological and Analytical Challenges and Recent Advances." Stan gave another talk in the session "Consequences of Improved Survey Performance on Assessments and Management Advice? Do Innovations in Survey and Sampling Design and Technology Make Any Difference?" Their abstracts follow.

Potential Movement of Fish And Shellfish Stocks from the Subarctic to the Arctic Ocean: Part B Evaluation of the Vulnerability of Fish and Shellfish Stocks to Changing Environmental Conditions

Anne B. Hollowed, Harald Loeng, and Benjamin Planque

An assessment of the likelihood that 17 fish or shellfish stocks or stock groups will move from the Subarctic areas into the Arctic Ocean is conducted. In this paper we assess the vulnerability of fish and shellfish stocks to exposure to climate induced environmental changes in Arctic and Subarctic ecosystems resulting from climate change. We assess the sensitivity and adaptability of 17 stocks from five ecosystems: the Barents Sea, the Eurasian shelves of the Arctic, the Bering Sea, and the Chukchi and Beaufort Seas. These comparisons reveal that several species are considered as candidate species to migrate into the high Arctic in the future, but it is anticipated that only six stocks have a high probability of establishing viable resident populations in the region. The ability of species to survive in the Arctic depends on how they respond to the physical and biological conditions of the region. Marine fauna that currently reside in the area exhibit adaptations that make them well suited for the challenging conditions of the Arctic. Examples of these adaptations include the following: i) capability of rapid growth to maximize the benefit of a short production season; ii) specific physiological characteristics to survive in cold conditions; iii) capability of inhabiting deep-ocean conditions to avoid ice in winter; iv) diversity of diets; v) broad spawning range, with low site fidelity, vi) high migration/dispersal rates; and vii) phenotypic plasticity.

Habitat & Climate: Species Distribution and Interaction in Arctic and Subarctic Systems Delineating Ecological Regions and Identifying Biophysical Drivers of Community Composition

Matthew Baker and Anne Hollowed

Species dynamics and interactions across systems are uniquely influenced by the constraints of physical habitat and differential response of species to common physical variables. Understanding spatial structure in marine systems and delineating meaningful spatial boundaries is integral to ecosystem approaches to fisheries management. We develop and apply multivariate statistical methods to define spatially coherent ecological units or ecoregions, as one approach to defining management units in large marine ecosystems. We examine the role of habitat in moderating species distributions and interactions. We use random forest and other multivariate statistical methods to assess the importance of habitat in defining species distributions and quantify the importance of dominant physical variables for individual species. We also quantify multi-species or community composition turnover along environmental gradients and use these outputs to identify discrete ecoregions within large marine ecosystems. We evaluate the relative importance of predictor variables and apply clustering methods to define important regional boundaries. Spatial management and multispecies management of marine fisheries resources require robust methods to synthesize physical and biological data to identify regional structure within ecosystems and determine the relative impacts of various environmental and biological drivers. By integrating physical and biological data, we propose a quantitative method to partition ecosystems along ecologically significant gradients, which can serve as the basis for defining spatial management units applicable to ecosystem based management. We demonstrate this approach by identifying species distributions and delineating distinct ecoregions in the eastern Bering Sea. We also illustrate how dynamic physical drivers, such as climate, shift habitat gradients and alter ecoregion boundaries under different temperature regimes.

Age Validation of Pacific Cod Using Stable Oxygen Isotopes ($\delta^{18}O$)

Craig R. Kastelle, Thomas E. Helser, Dan G. Nichol, Delsa M. Anderl, Jennifer McKay, John W. Valley, and Ian J. Orland

Measurements of stable oxygen and carbon isotopes ($\delta^{18}O$ and $\delta^{13}C$) were obtained from Pacific cod (*Gadus macrocephalus*) ear bones (otoliths) using micro-sampling coupled with mass spectrometry. Up to 9-10 discrete measurements were obtained by micro milling from any one annual growth zone. Otoliths from nine Pacific cod that were tagged with temperature recording tags and at liberty between 1-2 years in the eastern Bering Sea and Gulf of Alaska were analyzed. The $\delta^{18}O$ in the otoliths is partly a function of water temperature. Therefore, sequential $\delta^{18}O$ measurements representing the full lifespan of the fish were examined for seasonal variations. We further investigated the relationship between temperature and $\delta^{18}O$ in the otoliths with the use of an ion microprobe and mass spectrometry. The goals of this study were to 1) validate Pacific cod ageing criteria of typical growth-zone counts with seasonal signatures of otolith $\delta^{18}O$, and 2) verify the relationship between otolith $\delta^{18}O$ and temperature using archival tag temperatures. In more than half of the samples, Pacific cod otolith $\delta^{18}O$ showed the expected cyclical pattern consistent with seasonal variation in temperatures. In some of these, the number of $\delta^{18}O$ maxima showed a close correspondence to the estimated age from growth-zone counts, validating standard age interpretation methods, but overall the results were not completely definitive. However, there was a statistically significant relationship between $\delta^{18}O$ and archival tag temperatures (r=0.74, p<0.01). The finer resolution measurements from the ion microprobe were compared to those based on micromilling to evaluate otolith $\delta^{18}O$ and temperature.

Can Marine Protected Areas Achieve Their Goals as Management Tools in Northern Regions? Practical Lessons from Alaska, New England, and Norway

Susanne F. McDermott, Erik Olsen, Lene Buhl Mortensen, Esben Morland Olsen, Deborah Hart, Alan Haynie, William Stockhausen, Paul Spencer, John V. Olson, Tore Johannessen, Erlend Moksness, Geir Dahle

Ecosystem based marine spatial planning is an environmental management approach that recognizes all interactions within a marine system, including humans. Marine protected areas (MPAs) have become increasingly popular as management tools of ecosystem based marine spatial planning. While many MPAs have been successfully established in tropical reef systems, fewer MPA examples exist in temperate or subartic systems (e.g. North Pacific, Bering Sea) where species diversity is lower, abundance of single species is higher, and many fish species exhibit large amounts of movement in one or more of their life history stages, thus covering large geographic areas. We review MPAs in three different ecosystems: in the Northeast Atlantic (Norway), in the Northeastern U.S. Atlantic waters (George's Bank) and in the Northeast Pacific (Alaska). We discuss the effectiveness of these closures with regards to their initial objectives and expected and unexpected effects. We evaluate the effectiveness of MPAs as management tools in the different ecosystems and management scenarios. This paper was developed as a collaborative project between the Alaska Fisheries Science Center (Seattle), Alaska Regional office (Anchorage), Northeast Fisheries Science Center (Woods Hole), and the Institute of Marine Research (Bergen).

Improving Survey Derived Indices of Abundance by Combining Bottom Trawl and Acoustic Data

Stan Kotwicki, Patrick Ressler, Jim Ianelli, and André E. Punt

The abundance of semi-pelagic species is commonly estimated using acoustic-trawl and bottom trawl surveys, both of which sample a restricted vertical zone. Acoustic instruments are effective in the water column, but have a near-bottom acoustic dead zone, in which fish near the seafloor cannot be detected. Bottom trawl surveys cannot account for fish that are located above the so-called effective fishing height in the bottom trawl blind zone. These blind zones create negative biases in abundance estimates derived from either method. Here, we present a method for deriving less biased, improved indices of abundance by incorporating estimates of bottom trawl efficiency parameters derived from combining acoustic and bottom trawl data. Bottom trawl efficiency parameters used are: effective fishing height, density-dependent efficiency, and catchability ratio between acoustic and bottom trawl abundance data. This method was applied to the time series of abundance indices derived from bottom trawl and acoustic-trawl surveys of walleye pollock in the eastern Bering Sea. Two new time series of indices of abundance were estimated. First, the bottom trawl survey time series was corrected to account for the density dependence of the bottom trawl efficiency. Second, a new time series of combined acoustic-trawl and bottom trawl survey data was estimated. Both of the new time series were compared with old bottom trawl and acoustic-trawl survey specific indices with respect to relative trends, uncertainty, and expected biases.

Combining Bottom Trawl and Acoustic Data to Quantify Expected Biases in Abundance Estimates from Bottom Trawl and Acoustic Surveys

Stan Kotwicki, Alex De Robertis, Jim Ianelli, André E. Punt and John Horne

Abundances of semi-pelagic fishes are often estimated using acoustic-trawl and bottom trawl surveys, both of which sample a limited fraction of the water column. Acoustic instruments have a near-bottom acoustic dead zone (ADZ), in which fish near the seafloor cannot be detected. Bottom trawl surveys cannot account for fish that are located above the effective fishing height (EFH) of the trawl. We present a modeling method that combines acoustic and bottom trawl abundance and habitat data to derive ADZ correction and bottom trawl efficiency parameters. Our results show that predictions of fish abundance in the ADZ can be improved by incorporating bottom habitat features such as depth and sediment particle size, as well as pelagic habitat features such as water temperature, light level, and current velocity. We also obtain predictions for trawl efficiency parameters such as EFH, density-dependent trawl efficiency, and proportionality coefficients for trawl and acoustic data by modeling bottom trawl catches as a function of acoustic measurements and the environmentally dependent ADZ correction. This method is applied to walleye pollock in the Eastern Bering Sea to quantify expected biases associated with each survey method and the dependence of the biases on environmental variables. The catchabilities of acoustic and bottom trawl survey methods are dependent on environmental variables, and the sampling biases are not stationary in time and space as is commonly assumed for survey data. Applying models that combine both bottom trawl and acoustic data can mitigate these problems for stock assessment as well as spatial dynamics studies.

In addition to the Center's participation in the 2012 ICES symposium, Susanne McDermott attended a trilateral U.S./Norway/Canada workshop that took place 14 September in Bergen. The purpose of the workshop was to evaluate the progress to date and suggest future pathways for collaborative research among the three countries. The AFSC has been involved for many years in collaborative projects and AFSC interests currently focus on collaboration in these major areas: polar research projects, ocean acidification, comparative ecosystem studies, and advanced sampling technology. Mike Sigler is the point of contact for future collaborative projects.

By Susanne McDermott, Anne Hollowed, Matt Baker, Craig Kastelle, Stan Kotwicki, Mike Sigler and Sandra Lowe

Fisheries and the Environment (FATE) annual science meeting

The annual Fisheries and the Environment (FATE) science meeting was held 1-2 August 2012 at the Southwest Fisheries Science Center (SWFSC) in Santa Cruz, California. FATE scientists are tasked with incorporating fisheries and environmental data to improve stock and integrated ecosystem assessments. More than 50 scientists with NOAA Fisheries six regional science centers attended the meeting where topics presented included the relationship of fisheries to climate, lower trophics, physics, and modeling.

Examples of presentations included: "Linking demersal fish abundance to climate: matching impact with stage to elucidate mechanisms"; "Does the phenology of plankton blooms affect the recruitment of spring spawning fishes on the northeast shelf?"; "Identification of abiotic and biotic factors in the diet of groundfish in the Gulf of Alaska"; "A summary of fronts & predators, how ENSO affects sardines, and correlating the PDO and sardines"; "Delineating ecosystem overfishing via analysis of ecosystem indicator inflection points"; "How precise and/or accurate do forecasts of FATE ecosystem indicators need to be to be useful to stock assessments?"; "A statistical method for estimating larval production from length frequency and age-length observations collected in ichthyoplankton surveys"; "Developing indicator-based ecosystem assessments for diverse marine ecosystems in Alaska."

One of the highlights of the meeting was a presentation by Todd O'Brian on COPEPOD and Time Series Analysis Tools. COPEPOD is a global plankton database of phytoplankton and zooplankton data sampled from around the world. These on-line tools and data offer users the opportunity to conduct spatial temporal analysis and visualization of zooplankton and ancillary (temperature, salinity, climate indices) data and is designed to be user friendly and versatile. Check it out at http://www.st.nmfs.noaa.gov/plankton/.

By Lisa Eisner and Stephani Zador

Forage Fish Symposium at Friday Harbor, WA

AFSC scientists Olav Ormseth and Stephani Zador participated in the symposium on the Conservation and Ecology of Marine Forage Fishes, held 13-14 September at the Friday Harbor Laboratories, Washington, hosted by the Northwest Straits Initiative in partnership with the Washington Department of Fish and Wildlife, U.S. Geological Survey, and the Puget Sound Partnership. The majority of the symposium participants were from the U.S. Pacific Northwest, but experts from outside the region were invited to lend broader perspectives. Olav gave the presentation "Management and monitoring of forage fishes in Alaska." The subject included defining a forage fish in Alaska, describing the complex management (or lack thereof) of this diverse group of fishes, and potential solutions to monitoring challenges. For example, some species such as sand lance are included in a fishery management plan for a forage fish group for which targeting is prohibited; juvenile Pacific salmon are managed by the state as adults; juvenile walleye pollock are managed federally as adults; and Pacific herring are both a state commercial species and a federally-prohibited species. Also, there are disparities among estimates of forage fish biomass due to lack of long-term surveys designed to catch forage fish. Potential monitoring solutions presented include combining all available sources of data to estimate uncertainty across methods, analyzing bycatch patterns in acoustic surveys, and using alternative measures of abundance such as forage-fish-eating seabird productivity and diets of forage-fish-eating seabirds and halibut. Forage fishes in Alaska have diverse biology, human use, and management but are an important part of our ecosystem approach to fishery management. Research is underway to better understand the status of these fishes in Alaska. More information on management and monitoring of forage fishes in Alaska is available in the Status of Stocks and Multispecies Assessment section of this report.

By Stephani Zador

Integrated Ecosystem Assessment (IEA) annual meeting

Regional representatives from each of the NOAA Integrated Ecosystem Assessment (IEA) Program's large marine ecosystems met in Boulder, Colorado, 4-7 September 2012 for the annual IEA workshop; Alaska IEA representatives K. Holsman and K. Aydin both attended the meeting (Aydin by phone). Also attending were Alaska representatives Alan Haynie and Steve Kasperski. Representatives presented updates on their regional IEAs including emerging results and ongoing progress towards implementing and updating regional IEAs. Additionally, speakers presented and led discussion sessions focused on each of the five IEA steps. Discussion sessions were used to share lessons learned and emerging results in order to inform continued IEA development and implementation across regions. K. Holsman presented Alaska IEA results and led the discussion about ecosystem risk assessment approaches; A. Haynie and S. Kasperski presented aspects of economic and social sciences components of IEAs. Lastly, representatives from each region met to prepare a FATE proposal (Hazen et al.) to synthesize various approaches and results from regional IEA scoping and indicator selection efforts; similar future synthesis of other IEA steps was also discussed.

By Kirstin Holsman

Fig. 15. NOAA personnel preparing a new HarborScan AUV for shoreside deployment at the NMFS Panama City Laboratory.

Groundfish Scientists Attend Workshop on Autonomous Underwater Vehicles

The NMFS Advanced Survey Technology Working Group convened a workshop at the Southeast Fisheries Science Center's Panama City Laboratory on 17-21 September 2012 to evaluate and develop expertise with autonomous underwater vehicles (AUVs). Representatives from NOAA Fisheries science centers, the NOAA Office of Coast Survey (OCS) and the U.S. Navy were invited to participate in discussions about owning and operating AUVs; NOAA AUV resources; technical attributes of AUVs that are applicable to fisheries research; and practical aspects of AUV deployment and use. The 4-day workshop included technical presentations the first day which reviewed the technology, available assets and mission-planning procedures. The group visited the National Unmanned Systems Shared Resource Center on day 2, where U.S. Navy representatives displayed several of their AUVs and related technologies. The remainder of that day was spent aboard the 135-ft *MV Lilly Bordelon* where workshop participants observed launch and recovery equipment and survey operations with different AUV systems. Some of the group returned to the *Lilly Bordelon* on day 3 while others observed a shore-based launch of a newly acquired AUV belonging to the OCS Hydrographic Systems & Technology Programs (Fig. 15). The final 2wo days of the workshop were devoted to a review of data and observations from the field deployments and preparations for a technical report summarizing information from the workshop. David Somerton and Bob McConnaughey represented the AFSC.

By Bob McConnaughey

International Coordination:

North Pacific Fisheries Commission

Loh-Lee Low served as the representative of the U.S. delegation at the 10th meeting of the Scientific Working Group (SWG) of the North Pacific Fisheries Commission during its Preparatory Conference (PrepConIII) of the Parties in August 2012 in Juneau, Alaska. The agenda items included progress on scientific research and activities assigned to the SWG and its workgroups by the Commission. Development of encounter protocols on vulnerable marine ecosystems (VMEs) for the North Pacific Convention area was a major topic of discussion. For this topic, the chair of PrepConIII (Bill Gibbons-Fly) provided a statement to remind participants of the United Nations mandates that are the basis for the NPFC, specifically the mandate to take steps to protect VMEs and associated species from destructive fishing practices, and expressed the need to bring the conversations that were taking place in the SWG on VMEs back to the plenary sessions.

Despite lengthy discussions, the participants were unable to agree upon the concrete next steps to take to develop the encounter protocols. A range of suggestions was presented, which include: 1) focus on data collection by identifying priority data collection areas and putting together proposals for collaborative data collection and research (Canada); 2) work on establishing a process for data handling or data sharing (Russia); 3) progress work on the five tasks assigned at SWG9 through the intersessional work group and partnering with other organizations that are undertaking similar work (U.S.); and 4) develop a common definition of VMEs (Japan). The Parties reached general agreement that providing data in advance of the next meeting of the SWG would be a logical next step to progress on the development of the encounter protocol task. They agreed to the development of a 5-year science research plan. Canada offered to take the lead on the development of the plan for discussion at the next SWG meeting or PrepCon and will work on the plan intersessionally with other participants. The participants also discussed the March 2012 stock assessment workshop for North Pacific armorhead and next steps in determining the status of this stock. The next meeting of the SWG will take place in 2013.

By Loh-Lee Low

International Coordination:

U.S.-Russia Inter-Governmental Consultative Committee (ICC)

Pat Livingston and Loh-Lee Low provided scientific support for the U.S. delegation at the 23rd meeting of the of U.S.-Russia Intergovernmental Consultative Committee (ICC) on Fisheries in Saint Petersburg, Russia, on 5-7 September 2012. The delegation of the Russian Federation (RF) was led by Dr. Alexandr Fomin, the Deputy Head of the Fisheries Agency of the Russian Federation, Ministry of Agriculture, and the delegation of the United States was led by Ambassador David Balton, Deputy Assistant Secretary of the U.S. State Department for Oceans and Fisheries. The agenda of the meeting covered cooperation in fisheries enforcement and scientific research, status and conservation of resources in the North Pacific (groundfish, salmon, marine mammals, seabirds, and crabs), cooperation and coordination on international fisheries issues, and progress on Russian ratification of the 1979 Maritime Boundary Agreement for the Bering and Chukchi Seas that both countries agreed to and temporarily implemented.

On enforcement of illegal, unregulated, and unreported (IUU) fishing activities in the North Pacific Ocean, Mr. Balton expressed gratitude for Russia's cooperation on fisheries enforcement and congratulated both sides on their productive working relationship. Cooperation on scientific research has also progressed well. The parties exchanged information on the status and management issues of transboundary stocks of groundfish, salmon, marine mammals (particularly on the protection of the endangered status of the western steller sea lion stock), and seabirds (with special need for protecting the endangered short tailed albatross).

Both sides also exchanged views on fish-fisheries issues of international and mutual concerns. Issues of cooperation needed in the following forum were discussed: the 16th annual conference for the conservation of pollock resources in the central Bering Sea, formation of the new North Pacific Fisheries Commission, the South Pacific Fisheries Commission, Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), North Pacific Anadromous Fish Commission, Rio-2012 U.N. Food and Agriculture Organization Committee, and the U.S. proposed Arctic Agreement.

The main discussion topic on Russian ratification of the 1979 Maritime Boundary Agreement for the Bering and Chukchi Seas was also addressed. The U.S. Congress has already ratified the Agreement but the Russian Party has yet to do so. Discussions are continuing that included new initiatives for joint and reciprocal surveys on the transboundary nature of the pollock resources on both sides of the maritime boundary line. The initiative has resulted in the NOAA ship *Oscar Dyson* conducting a pollock survey in the Russian EEZ of the northern Bering Sea in August 2012 and the Russian R/V *Kagonosky* scheduled to conduct an equivalent survey in the U.S. EEZ in the vicinity of the maritime boundary line in October 2012.

By Loh-Lee Low

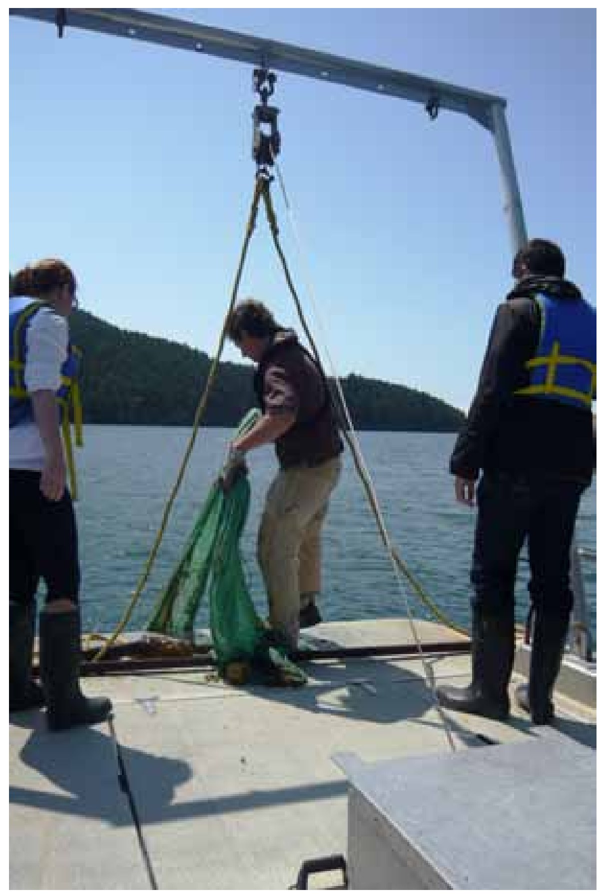
Research catch collected during the Shannon Point field trip is dumped into buckets for sampling by the AFSC interns. Photo by Susanne McDermott

Summer 2012 AFSC Internships

The month of September wrapped up another successful Summer Internship Program at the AFSC. This year we had a group of wonderful students who came to the AFSC for 10 weeks to learn new skills and gain work experience in a professional setting. In addition to working on their projects with their mentors, the interns experienced field trips to Bodega Bay and the Shannon Point Marine Science Center in Anacortes, the marine lab of Western Washington University. The trip included an excursion on their small research vessel where interns had hands-on experience with a remote controlled underwater vehicle (ROV) and sampled local invertebrates and fish with a beam trawl. This invaluable experience has been provided for the third year running by Professor Brian Bingham who also heads up the yearly MIMSUP event during which his students present their research at the Alaska Fisheries Science Center.

The AFSC 2012 summer interns also attended weekly lunch presentations given by different research groups at the Center. AFSC scientists with the Age and Growth Program, the Marine Mammal Laboratory, the genetics laboratory, as well as staff with National Ocean Services presented their research to the interns in an interactive and fun way. At the end of their interships, the interns presented their work in a small symposium attended by AFSC scientists in Seattle. Interns, mentors, and projects represented the diverse research conducted at our Center. Two interns were located in Juneau and presented their research results as posters during the STAR (STEM Teacher and Research) conference in San Jose, California, on 11 August 2012. This marks the first year that AFSC has participated in the STAR program, which is a 9-week summer research internship for aspiring science and mathematics teachers.

This year we had a group of wonderful students who came to the AFSC for 10 weeks to learn new skills and gain work experience in a professional setting.



The research catch collected by a beam trawl aboard the Shannon Point research vessel is brought aboard. Photo by Susanne McDermott

Summer 2012 interns, and Susanne McDermott, intern activities coordinator, on a field trip to Shannon Point marine center.
Photo by Brian Bingham.

At the end of their interships, the interns presented their work in a small symposium attended by AFSC scientists in Seattle.

The AFSC interns and their projects were:

- **Dustin Taylor** (ABL, Juneau):
  Rhinoceros Auklet Prey Composition and Quality
- **Brielle Kemis** (ABL, Juneau)
  Effects of Pristane on Growth of Juvenile Pink Salmon
- **Christina Gellar** (Mentor: Amber Himes, socio-economic group, REFM):
  Developing Indicators to Assess Vulnerability and Resilience of Alaskan Communities to Climate Change
- **Jennifer Gardner** (Mentors: Ingrid Spies, REFM and Jay Orr, RACE
  Solving the mystery of snailfish eggs with genetics
- **Nate Ryan** (Mentor: Anne Hollowed, REFM)
  Towards an Understanding of Community: Piecing together Biotic Interactions from Fish Distribution Data
- **Katherine Beame** (Mentors: Matt Baker and Libby Logerwell, REFM)
  Spatial and Temporal Distributions of Benthic Communities in the Eastern Bering Sea
- **Zachary Mankoff** (Mentors: Mike Canino and Melanie Paquin, RACE)
  Barcoding by Species: Building a genetic Database of Sculpins and other Fish
- **Jonas Oppenheimer** (Mentor: Charles Fowler, NMML)
  Pattern-based Control Rules: Resource Population Levels
- **Alexandra Ulmke** (Mentor: Phillip Clapham)
  Increase in shipping and impacts on marine mammals relating to diminishing sea ice in the Arctic
- **Sean Kinard** (Mentors: Tom Helser, Craig Kastelle and Beth Matta)
  Age validation of Walleye Pollock with bomb-produced radio carbon and growth analysis of yellowfin sole and Pacific Ocean perch.

By Susanne McDermott

Publications and reports for July–August–September 2012.
Authors citing affiliation with the AFSC are denoted in **boldface**.

Boldt, J.L., **T.W. Buckley**, **C.N. Rooper**, and **K. Aydin**.

2012. Factors influencing cannibalism and abundance of walleye pollock (*Theragra chalcogramma*) on the eastern Bering Sea shelf, 1982-2006. Fish. Bull., U.S. 110:293-306.

Conn, **P.B.**, **J.L. Laake**, and **D.S. Johnson**.

2012. A hierarchical modeling framework for multiple observer transect surveys. PLoS ONE 7(8): e42294.

Dougherty, **A.**, **K. Bailey**, **T. Vance**, and W. Cheng.

2012. Underlying causes of habitat-associated differences in size of age-0 walleye pollock (*Theragra chalcogramma*) in the Gulf of Alaska. Mar. Biol. 159:1733-1744.

Echave, **K.B.**, **D.H. Hanselman**, M.D. Adkison, and **M.F. Sigler**.

2012. Interdecadal change in growth of sablefish (*Anoplopoma fimbria*) in the northeast Pacific Ocean. Fish. Bull., U.S. 210:361-374.

Gaichas, **S.**, R. Gamble, M. Fogarty, H. Benoît, T. Essington, C. Fu, M. Koen-Alonso, and J. Link.

2012. Assembly rules for aggregate-species production models: Simulations in support of management strategy evaluation. Mar. Ecol. Prog. Ser. 459:275-292.

Gustafson, R.G., M.J. Ford, P.B. Adams, J.S. Drake, R.L. Emmett, K.L. Fresh, M. Rowse, E.A.K. Spangler, R.E. Spangler, D.J. Teel, and **M.T. Wilson**.

2012. Conservation status of eulachon in the California Current. Fish Fish. 13:121-138.

Hanselman, D.H., W.G. Clark, **J. Heifetz**, and **D.M. Anderl**.

2012. Statistical distribution of age readings of known-age sablefish (*Anoplopoma fimbria*). Fish. Res. 131-133:1-8.

Ivashchenko, Y.V., and **P.J. Clapham**.

2012. Soviet catches of right whales *Eubalaena japonica* and bowhead whales *Balaena mysticetus* in the North Pacific Ocean and the Okhotsk Sea. Endang. Species Res. 18:201-217.

Jones, **D.T.**, **C.D. Wilson**, **A. De Robertis**, **C.N. Rooper**, T.C. Weber, and J.L. Butler.

2012. Evaluation of rockfish abundance in untrawlable habitat: Combining acoustic and complementary sampling tools. Fish. Bull., U.S. 110:332-343.

Kruse, G.H., H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, **P.A. Livingston**, D. Woodby, and C.I. Zhang (editors).

2012. Global progress in ecosystem-based fisheries management. Alaska Sea Grant Rep. AK-SG-12-01, University of Alaska, Fairbanks. 396 p.

Kruse, G.H., H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, **P.A. Livingston**, D. Woodby, and C.I. Zhang.

2012. Steps for future progress in ecosystem-based fisheries management: What's next? Pages 375-380. *In* Kruse, G.H., H.I. Browman, K.L. Cochrane, D. Evans, G.S. Jamieson, P.A. Livingston, D. Woodby, and C.I. Zhang (editors), Global Progress in Ecosystem-Based Fisheries Management. Alaska Sea Grant, University of Alaska Fairbanks, AK.

Martinson, E.C., H.H. Stokes, and D.L. Scarnecchia.

2012. Use of juvenile salmon growth and temperature change indices to predict groundfish post age-0 yr class strengths in the Gulf of Alaska and eastern Bering Sea. Fish. Oceanogr. 21(4):307-319.

McClintock, **B.T.**, R. King, L. Thomas, J. Matthiopoulos, B.J. McConnell, and J.M. Morales.

2012. A general discrete-time modeling framework for animal movement using multistate random walks. Ecol. Monogr. 82:335-349.

Orr, **J.W.**

2012. Two new species of snailfishes of the genus *Careproctus* (Scorpaeniformes:Liparidae) from the Bering Sea and eastern North Pacific Ocean, with a redescription of *Careproctus ovigerus*. Copeia 2012:257-265.

Pietsch, T.W., **J.W. Orr**, and W.N. Eschmeyer

2012. *Mustelus felis* Ayres, 1854, a senior synonym of the leopard shark, *Triakis semifasciata* Girard, 1855 (Carchariniformes: Triakidae), invalidated by "reversal of precedence". Copeia 2012:98-99.

Rooper, **C.N.**, **M.H. Martin**, J.L. Butler, **D.T. Jones**, and **M. Zimmermann**.

2012. Estimating species and size composition of rockfishes to verify targets in acoustic surveys of untrawlable areas. Fish. Bull., U.S. 110:317-331.

Rudershausen, P.J., J.A. Buckel, G. Bolton, R.W. Gregory, T.W. Averett, and **P.B. Conn**.

2012. A comparison between circle hook and J hook performance in the dolphinfish, yellowfin tuna, and wahoo troll fishery off the coast of North Carolina. Fish. Bull., U.S. 110:156-175.

Shaw, **F.R.**, **J.F. Morado**, **V.C. Lowe**, and **S.F. McDermott**.

2012. An atlas of reproductive development in rockfishes, genus *Sebastes*. NOAA Professional Paper NMFS 14, 77 p.

Sturdevant, **M.V.**, **J.A. Orsi**, and **E.A. Fergusson**.

2012. Diets and trophic linkages of epipelagic fish predators in coastal Southeast Alaska during a period of warm and cold climate years, 1997–2011. Mar. Coast. Fish.: Dynam. Manag. Ecosys. Sci. 4:526-545.

Tenbrink, **T.T.**, and **T.W. Buckley.**

2012. Resource partitioning among *Myoxocephalus* sculpins, and their predator–prey relationships with *Chionoecetes* crabs in the eastern Bering Sea. Mar. Ecol. Prog. Ser. 464:221-235.

Van Kirk, K.F., T.J. Quinn II, J.S. Collie, and **Z.T. A'mar**.

2012. Multispecies age-structured assessment for groundfish and sea lions in Alaska, p. 147-168. *In* G. H. Kruse, H. I. Browman, K. L. Cochrane, D. Evans, G. S. Jamieson, P. A. Livingston, D. Woodby, and C. I. Zhang (editors), Global Progress in Ecosystem-Based Fisheries Management. Alaska Sea Grant, University of Alaska Fairbanks, AK.

Ver Hoef, **J.M.**

2012. Who invented the delta method? Am. Stat. 66:124-127.

Wade, **P.R.**, R.R. Reeves, and S. Mesnick.

2012. Social and behavioural factors in cetacean responses to overexploitation: Are Odontocetes less 'resilient' than Mysticetes? J. Mar. Biol. Vol. 2009: Article 567276, 15 p.

Technical Memo[1]

Romain, S., **M. Dorn**, and V. Wespestad.

2012. Results of cooperative research acoustic surveys of walleye pollock (*Theragra chalcogramma*) in the western Gulf of Alaska from September 2007 to September 2011. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-238, 35 p.

[1] The NOAA Technical Memorandum series NMFS AFSC (formerly F/NWC) is a Center publication which has a high level of peer review and editing. The Technical Memorandum series reflects sound professional work and may be cited as publications. Copies may be ordered from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161 or at www.ntis.gov.

The National Marine Fisheries Service
(NOAA Fisheries Service) is an agency within the
National Oceanic and Atmospheric Administration (NOAA)
of the U.S. Department of Commerce

The mission of the NOAA Fisheries Service is to provide stewardship of the nation's living marine resources through science-based conservation and management and promotion of healthy ecosystems

Alaska Fisheries Science Center
7600 Sand Point Way N.E.
Seattle, Washington 98115

www.afsc.noaa.gov/quarterly/