Studies of Northern Fur Seals Breeding at the Northern and Southern Extent of the Range
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A Tale of Two Stocks: Studies of Northern Fur Seals Breeding at the Northern and Southern Extent of the Range


This is a tale of two stocks of northern fur seals (Callorhinus ursinus): the Eastern Pacific stock and the San Miguel Island stock. The Eastern Pacific stock breeds mostly on the Pribilof Islands, Alaska, at the northern extent of the breeding range in the Bering Sea Large Marine Ecosystem (Fig. 1). This stock was listed as depleted in 1988 under the Marine Mammal Protection Act of 1972, but not all populations within the stock boundaries display similar population trends. Within the Eastern Pacific stock, the Pribilof Islands population, historically the largest breeding population in the world, has declined dramatically over the past 20 years, whereas a new breeding population at Bogoslof Island has increased exponentially since its discovery in 1980. In contrast, the San Miguel Island stock, which breeds mostly on San Miguel Island, California, at the southern extent of the breeding range in the California Current Large Marine Ecosystem (Fig. 1), is not listed as depleted because it has increased or been stable since its discovery in 1968.

Video 1. Learn more about the National Marine Mammal Laboratory’s northern fur seal investigations. Visit the AFSC Multimedia Gallery.
Natural History of Northern Fur Seals

The expansive range of northern fur seals covers seven different marine ecosystems (Kuroshio Current, Oyashio Current, West Bering Sea, Gulf of Alaska, California Current, and North Pacific Ocean). For 6 months of the year (mid-November to mid-May) fur seals are usually solitary and remain at sea migrating throughout the North Pacific Ocean. For most fur seals return to land once a year for the summer reproductive season (mid-May to mid-November) and form dense breeding aggregations on islands in Russia, Alaska, and California (Fig. 1). Northern fur seals have a polygynous breeding system. Adult males compete for access to breeding females by defending land territories. This has given rise to pronounced sexual size dimorphism with males up to 5 times the size of females. Adult males arrive at the colonies and set up territories in mid-May or early June and remain on land and fast for up to 3 months while defending their territories. Females aggregate in the territories for protection from other males and often breed with the territorial male, though not always (Photo 1).

Pregnant adult females arrive throughout June or July and give birth to single pups within 2 days after arriving ashore. Females remain ashore with their pups for up to 8 days and then breed before a series of feeding trips to sea, alternated with nursing visits ashore throughout the 4-month lactation period. Feeding trips may last more than 10 days and nursing visits up to 2 days. While the mother is away, the pup remains ashore and fasts. Weaning is relatively abrupt with the female or pup departing from the colony and not returning.

Once weaned, the pups spend up to 3 years traveling the North Pacific Ocean, remaining almost exclusively at sea. Historically, about 50% of the pups have died in their first year. Some yearlings and 2-year-olds return to the colonies, but most remain at sea; thus, little is known about the juvenile life stage. Females become reproductive at 3 or 4 years of age and are reproductive for most of their life span, which averages about 26 years. Males reach sexual maturity between 5 and 7 years of age and begin defending territories between 7 and 9 years of age. Breeding males have shorter life spans than females because of the energetic cost of fighting and fasting during the breeding season.

Despite a high affinity of both female and male northern fur seals to return to their natal sites to breed, there is very little genetic differentiation between stocks throughout their range. The only evidence of genetic differentiation is weak differences between the Russian populations and the Eastern Pacific stock. Northern fur seals from the San Miguel Island stock are not genetically distinct from those on St. George Island. Genotypic differentiations between the Russian populations and the Eastern Pacific stock. Northern fur seals from the San Miguel Island stock are not genetically distinct from those on St. George Island. Genotypic differencs between the Russian populations and the Eastern Pacific stock. Northern fur seals from the San Miguel Island stock are not genetically distinct from those on St. George Island. Genotypic differences between the Russian populations and the Eastern Pacific stock. Northern fur seals from the San Miguel Island stock are not genetically distinct from those on St. George Island.
In contrast with the decline observed at the Pribilof Islands, fur seal numbers at a new location at Bogoslof Island have increased dramatically in recent years. Located approximately 74 km west of Dutch Harbor, Alaska, Bogoslof Island was formed by a series of volcanic eruptions in the late 18th century. Since pups were first observed there in 1980, pup production has increased at an annual rate of 38.2% (SE = 2.60, P < 0.01) through 2011, and at an annual rate of 11.7% (SE = 0.90, P < 0.01) from 1997 to 2011 (Fig. 4). Pup production on Bogoslof Island, estimated to be 22,905 (SE = 921.5) in 2011, has surpassed recent estimates for St. George Island.

The Rise of the San Miguel Island Stock

The San Miguel Island stock of northern fur seals has quite a different history from the Eastern Pacific stock. Once considered part of the Eastern Pacific stock, breeding fur seals at San Miguel Island and the Farallon Islands, California, were reclassified in 1992 as their own distinct stock due to their disparate population trends, continuous geographic distribution but geographic separation during the breeding season from the Eastern Pacific stock, and high natal site fidelity. Evidence of northern fur seals on San Miguel Island, located 46 km offshore in southern California, dates back to the island’s occupation by Chumash Indians 12,000 years ago. Northern fur seal remains have been recovered from Chumash kitchen middens, but it is unknown if the animals bred on San Miguel Island or used it only as a hauling ground. There is some confusion about the history of commercial sealing of this stock because it was not considered distinct from the Guadalupe fur seal (Arctocephalus townsendi) until 1897, more than 40 years after most of the fur seals had been extirpated from the California Channel Islands.

Furthermore, a large historical breeding population was likely located at the Farallon Islands, 43 km west of San Francisco Bay. Heavy commercial harvesting during the summer breeding season extirpated this population in the 1800s.

Northern fur seals recognized San Miguel Island sometime in the 1950s and were first documented there in 1961 in photographs taken by George Silk, a photographer for Time-Life books. In 1968, biologists surveyed the northern fur seal population at San Miguel Island and identified 100 females, 36 pups, and 1 adult male at Adams Cove on the southwest end of the island where they shared space with California sea lions (Zalophus californianus) and northern elephant seals (Mirounga angustirostris) (Photo 3). In 1972, another breeding population was discovered on Castle Rock, a small offshore rock 2 km northeast of Adams Cove.

Evidence that the San Miguel population was founded by a mixture of animals from Pribilof Islands and Russian fur seals is based on identification of individuals by flipper tags deployed in these populations as part of the collaborative fur seal research that stemmed from the Interim Convention on Conservation of North Pacific Fur Seals of 1957. The tags uniquely identified individual animals to their birth or breeding sites. Tagging studies have been a cornerstone of fur seal population studies throughout the range; tagging studies of Russian and Pribilof Islands populations conducted from the 1940s to the 1970s provided the first comprehensive information on behavior, survival, reproduction, and movements of fur seals. Large-scale tagging programs conducted by NMML for the Eastern Pacific stock ceased in 1968. The need for recent information on survival and reproductive rates of the Eastern Pacific stock to better understand the current population decline led to the initiation of a new large-scale tagging program of pups and adult females in 2009. Fur seal pups at San Miguel Island have been tagged since 1975. Comparisons of the survival rates between the Eastern Pacific stock and the San Miguel Island stock determined from the tagging studies may provide insights into the role of survival and reproductive rates in the decline of the Pribilof Islands population.

Unlike the Eastern Pacific stock, the primary factors influencing the population dynamics for the San Miguel Island stock are fairly well known. The small size of the Adams Cove and Castle Rock populations allows for all the pups to be counted; NMML tagged seals from the spring through summer and then followed the tagged pup from the time it was born to the end of its first year. The tagging program is conducted in cooperation with the National Biological Service, the Bureau of Indian Affairs, and the U.S. Geological Survey.

Specifically, from 1998 to 2010, pup production on St. Paul Island decreased 5.46% (SE = 0.32, P < 0.01) annually, while on St. George Island it declined 2.90% (SE = 0.69, P < 0.01) annually. Overall, pup production on the Pribilof Islands has decreased 4.90% (SE = 0.32, P < 0.01) annually since 1998 (Photo 2). The recent decline in pup production at the Pribilof Islands, fur seal numbers at a new location at Bogoslof Island have increased dramatically in recent years. Located approximately 74 km west of Dutch Harbor, Alaska, Bogoslof Island was formed by a series of volcanic eruptions in the late 18th century. Since pups were first observed there in 1980, pup production has increased at an annual rate of 38.2% (SE = 2.60, P < 0.01) through 2011, and at an annual rate of 11.7% (SE = 0.90, P < 0.01) from 1997 to 2011 (Fig. 4). Pup production on Bogoslof Island, estimated to be 22,905 (SE = 921.5) in 2011, has surpassed recent estimates for St. George Island.
biologists have counted live pups at San Miguel Island in July of each year and estimated the population size since 1968. The San Miguel pup counts cycle with periods of rapid increase followed by significant declines related to El Niño events (Fig. 5). In the California Current ecosystem, El Niño conditions produce changes in the marine environment that result in redistribution and reduced availability of prey to adult and juvenile fur seals that affect survival and reproduction. The strong El Niño events of 1982–83 and 1997–98 reduced the pup births on San Miguel Island by 63% and 81%, respectively. Over a 7-year period following 1983, the number of pup births slowly increased to reach pre-1983 levels in 1990. The slow recovery of pup production indicated that fewer animals were alive to produce pups following El Niño and, therefore, that a significant number of juveniles and adults also had died as a result of El Niño. The recovery from the 1998 decline has been even slower, but interpretation of the recovery is complicated by the emergence of hookworm disease in the San Miguel Island stock in the early 1990s. Hookworm disease has killed up to half of fur seal pups born since 1999 and in the early 2000s emerged as the primary cause of mortality for pups. Even so, the overall population trend for the San Miguel Island stock includes describing age- and sex-specific broad-scale foraging patterns within the Eastern Pacific and San Miguel Island stocks as well as examining individual dive depths in relation to fine-scale biophysical measurements obtained from advanced oceanographic instruments. The research explores variability in foraging patterns within and among seasons (summer and winter) and among years. The goal is to identify environmental factors that influence foraging behavior and the possible consequences to population health, condition, reproduction, or survivorship.

In 2006, NAMML researchers deployed satellite-linked telemetry instruments on lactating adult female fur seals at St. Paul, Bogoslof, and San Miguel Islands during the summer breeding season and prior to the winter migration to compare patterns in foraging behavior among the populations and relate them to divergent population trends. The foraging habitat surrounding each of the three islands consists of three oceanographic domains: continental shelf (<200 m depth), slope (200-1000 m depth), and offshore (>1000 m). Bogoslof and San Miguel Islands have little shelf habitat available around the islands, whereas St. Paul Island is located on the large Bering Sea continental shelf. The oceanographic domains support different prey assemblages and give rise to foraging behaviors that vary within and among the islands. Satellite telemetry instruments were glued to the fur between the shoulders (Photo 4) and provided location information on the animals while at sea or on land for up to 8 months. In addition, some of these satellite transmitters deployed on Alaska animals during the winter also provided information on the seals diving behavior, which can identify important foraging grounds.

Breeding Season
During the summer breeding season, average foraging trip durations (2.7 days) and average maximum foraging trip distances (51.6 km) were shortest for Bogoslof Island females (n=20), which feed offshore, close to the island (Fig. 4). Females from St. Paul Island (n=20) mostly fed in geographically distinct areas from those at Bogoslof Island and exploited shelf and offshore habitats. Their average foraging trips were longer in duration (6.5 days) and in average maximum distance (293 km) than Bogoslof Island females. Females at San Miguel Island (n=8) had the longest average foraging trip duration (12.5 days) and greatest average maximum distance (341 km) among the colonies.

Migration
Adult females departed the islands in November and began their winter migration. Thirteen of 19 females instrumented at Bogoslof (n=9) and St. Paul (n=10) islands traveled from the Bering Sea, through the Aleutian passes, into the Gulf of Alaska, and into the North Pacific Ocean (Fig. 6). Of the 13 adult females that were tracked from Alaska, 5 were monitored for more than 90 days, and each ventured into the California Current ecosystem. They remained there and in the Gulf of Alaska ecosystem for 5–6 months foraging along the western slope of the continental shelf break and west into pelagic waters. By June, only one animal was still being tracked, and this female had departed the California Current and Gulf of Alaska ecosystems and was traveling toward her original departure site in Alaska. In contrast to the long distances traveled by the Alaska females, all nine females from San Miguel remained in the California Current and simply shifted their distribution farther offshore and northward compared to their summer foraging range but exploited similar continental shelf break and offshore habitats (Fig. 6). They spent little time in transit and spent most of their time feeding. None of the instruments on San Miguel animals functioned long enough to capture the full migration, but three females tracked into April began moving southward from northern California toward San Miguel Island and presumably returned to the island for breeding in June or July. There was considerable overlap between the San Miguel and Alaska female migration distributions in the California Current ecosystem—which highlights this region as an important winter foraging habitat for both the Eastern Pacific and San Miguel Island stocks.

Figure 6. Foraging distribution of northern fur seals instrumented at St. Paul and Bogoslof Islands, Alaska, and San Miguel Island, California, in 2008. Movement were centered around the colonies at all sites with little overlap between St. Paul (blue) and Bogoslof (green) islands and no overlap between the Alaska sites and San Miguel Island (red). Alaskaian animals migrated across the North Pacific Ocean during the winter, whereas San Miguel (yellow) animals remained in the California Current.
Small-scale Foraging Patterns

The National Marine Mammal Laboratory’s collaboration with the University of Washington Applied Physics Laboratory and School of Oceanography also has described northern fur seal foraging patterns on a smaller spatial scale that reflect seasonal, mesoscale, and fine-scale oceanographic variability in the California Current ecosystem. The seasonal features of the California Current ecosystem are important factors affecting the density, distribution, and abundance of fur seal prey during the winter. Integration of remotely sensed oceanographic environmental data off the Washington coast, obtained from surveys conducted using an autonomous underwater vehicle (Washington Coast Seaglider survey), were combined with northern fur seal diving and movement patterns to demonstrate the interplay between northern fur seal behavior and the mixed-layer depth (MLD), eddies, wind-driven coastal upwelling, and seasonal ocean production. For example, seasonal changes in fur seal diving depths from deeper to shallower correspond well with seasonal shoaling of the surface chlorophyll bloom (Fig. 7). As adult females from Alaska arrive to the California Current in January their diving depths are deeper and more variable compared to diving depths in May and June (Fig. 7).

Mesoscale variability such as coastal jets and eddies also affects the movement behavior of both San Miguel Island and Alaska fur seals. The animals’ distributions overlap during the winter, and they tend to forage along steep oceanographic gradients both horizontally and vertically (Figs. 6 and 7). Eddies form in the California Current ecosystem and can persist for several months to a year and promote production and aggregation of zooplankton and northern fur seal prey species such as fish and squid. Biophysical interactions between eddies and fur seals generally occur along eddy edges (Fig. 8). Presumably, eddy physical structure promotes good foraging opportunities for northern fur seals, which may partially explain why the distant Alaska migrants travel to the California Current ecosystem during the winter months and why the San Miguel Island fur seals remain resident.

Furthermore, broad-scale wind patterns can cause alterations in fine-scale biophysical structure, which ultimately affects fur seal movement and diving behavior (Fig. 9). For example, a shift in the dominant wind direction (Fig. 9d) is associated with coastal upwelling and advection of nutrients westward and can promote a strong surface and subsurface chlorophyll bloom (Fig. 9a, b). Fur seals responded to increased ocean productivity with a shift in movement from transitory to searching behavior and remained within 50 km from the continental shelf break in an area of high production (Fig. 9a, c). Fine-scale vertical variability and the surface chlorophyll bloom indicate a shoaling of the MLD close to the continental shelf break (~ 20 m depth, Fig. 9b). Fur seal diving depths, both during the daytime (white triangles; Fig. 9b) and nighttime (black triangles; Fig. 9b) were shallow and aggregated around the MLD, reflecting the depth and distribution of their prey. Thus, the spatial and temporal integration of fur seal behavior with seasonal, mesoscale, and fine-scale biophysical structures highlights important linkages between atmospheric patterns, ocean production, and fur seal prey.
Diet Differences Within and Between Stocks

Diet samples are collected within each stock to monitor how diet changes over time in relation to the diverse prey and marine habitats available to northern fur seals during the summer breeding season and winter migration. The research employs multiple techniques including stable isotope analysis and scat (feces) collection, which provide a more comprehensive view of the diet by encapsulating both small and large spatial and temporal scales of seal foraging. The goal is to determine if seal diets can help explain the divergent population trends observed within and between the two stocks.

Scat analysis involves the identification of prey hard parts (e.g., fish bones and cephalopod beaks) found in samples and is useful for providing information on specific prey taxa consumed. Stable isotope analysis is based on the premise that the stable isotope composition of a consumer’s diet is reflected in its tissues and that each tissue assimilates diet at different temporal scales due to dissimilar isotopic turnover rates within each tissue. For fur seals, plasma represents the diet integrated about 1-2 weeks prior to collection (i.e., foraging trip); red blood cells (RBCs) represent the previous month or two (i.e., breeding season); and fur represents diet from the breeding season and, to a lesser extent, the previous winter migration. The carbon (δ13C) and nitrogen (δ15N) isotope ratios of the fur seal tissues indicate foraging location and trophic level, respectively. Values of ratios of the fur seal tissues indicate foraging location and migration. The carbon (δ13C) and nitrogen (δ15N) isotope ratios of the fur seal tissues indicate foraging location and trophic level, respectively. Values of δ13C increase from high to middle latitudes, offshore to nearshore, and pelagic to benthic environments; δ15N values increase with each trophic level.

Diet studies were conducted at the same locations as the satellite telemetry studies: St. Paul Island in the Pribilof Islands, Bogoslof Island, and San Miguel Island. Scat analysis revealed that relatively few prey taxa had high occurrences (found in >10% of scats) at each location (Table 1). Prey identified from scats at each site was associated with a specific oceanographic domain. At St. Paul Island, scats from two different areas had different primary prey taxa: Vostochni Rookery on the northeast side of the island had high occurrences of on-shelf species (e.g., walleye pollock, Pacific herring, Pacific sand lance) and Reef Rookery on the south side of the island had high occurrences of both on-shelf (e.g., walleye pollock, Pacific herring) and off-shelf (e.g., myctophid) species. Bogoslof Island was characterized by high occurrences of off-shelf prey (e.g., gomatid squid and northern smoothtongue), whereas San Miguel Island had high occurrences of on-shelf schooling prey (e.g., northern anchovy, Pacific hake, Pacific sardine, rockfishes, and market squid).

Table 1. Percent frequency of occurrence (%FO ≥ 5%) of prey taxa retrieved from northern fur seal fecal samples collected at Bogoslof Island (BI, 2007), San Miguel Island (SMI), and two rookeries on St. Paul Island (SPI) in 2006. n represents the number of samples that had identifiable prey remains. Bold numbers indicate prey taxa with %FO > 10%.

<table>
<thead>
<tr>
<th>Prey taxa</th>
<th>SPI Reef (n = 20)</th>
<th>SPI Vostochni (n = 74)</th>
<th>BI (n = 41)</th>
<th>SMI (n = 27)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northern anchovy</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Northern smoothtongue</td>
<td>92.5</td>
<td>92.5</td>
<td>92.5</td>
<td>92.5</td>
</tr>
<tr>
<td>Walleye pollock</td>
<td>80.3</td>
<td>80.3</td>
<td>9.6</td>
<td>9.6</td>
</tr>
<tr>
<td>Pacific hake</td>
<td>55.6</td>
<td>55.6</td>
<td>91.9</td>
<td>2.4</td>
</tr>
<tr>
<td>Pacific sardine</td>
<td>51.9</td>
<td>51.9</td>
<td>22.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Market squid</td>
<td>6.8</td>
<td>6.8</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Gonatid squid</td>
<td>3.6</td>
<td>3.6</td>
<td>17.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Clupea harengus</td>
<td>17.0</td>
<td>17.0</td>
<td>25.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Pacific salmon</td>
<td>17.0</td>
<td>17.0</td>
<td>25.7</td>
<td>4.4</td>
</tr>
<tr>
<td>Gadus spp.</td>
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<tr>
<td>Myctophid spp.</td>
<td>5.4</td>
<td>5.4</td>
<td>17.1</td>
<td>3.7</td>
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<tr>
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<tr>
<td>Rockfish</td>
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<td>5.4</td>
<td>6.8</td>
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<tr>
<td>Pacific sand lance</td>
<td>5.4</td>
<td>5.4</td>
<td>17.1</td>
<td>3.7</td>
</tr>
<tr>
<td>Three-spine stickleback</td>
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<td>5.4</td>
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<tr>
<td>Irish lord</td>
<td>5.4</td>
<td>5.4</td>
<td>6.8</td>
<td>2.4</td>
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<tr>
<td>Sculpis</td>
<td>5.4</td>
<td>5.4</td>
<td>6.8</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Figure 10. The relationship between mean δ13C and δ15N of tissues collected from adult female northern fur seals at Bogoslof Island (in 2007), San Miguel Island, and two rookeries on St. Paul Island (Vostochni, Reef) in 2006. Error bars represent ± 1 SD. RBC: red blood cells.

Apart from a few discrepancies (e.g., at San Miguel Island scat diet data indicated on-shelf foraging; however, telemetry data indicated slope/off-shore feeding), the diet data corroborate the movement patterns from our satellite telemetry studies. Fur δ13C values were similar among the Alaska populations, suggesting that Alaska fur seals migrate to the same general areas during winter to feed. These individuals had lower δ13C values compared to their counterparts at San Miguel Island, indicating that during part of the fur growth, these animals were feeding in different oceanic domains. The satellite data support this finding, between molting periods, San Miguel Island females feed exclusively in the California Current ecosystem whereas Alaska female fur seals only spend 3-4 months in this ecosystem and the rest of the year in the North Pacific Ocean and Bering Sea.

Future Directions

The Northern Fur Seal Conservation Plan describes the importance of comparative studies across the range of northern fur seals to better understand ecological processes that affect fur seal population dynamics. As our research demonstrates, there are similarities in foraging behavior among the populations in the two stocks, but it is the differences among them that should help to explain the divergent population trends. Future studies will focus on connecting foraging behavior and oceanographic features to demographic parameters throughout the range with the goal of identifying what is driving the decline of the Eastern Pacific stock.

Additional Reading:
Arctic Fish Assessment in Near-shore and Lagoon Habitats

This summer the ABL Habitat and Marine Chemistry (HAMC) program commenced a 3-year study to assess the fish assemblages in Arctic near-shore and lagoon habitats. The project is led by Johanna Vollenweider and Ron Heintz, with collaborators from University of Alaska Fairbanks (Professor Brenda Norcross) and Florida International University (Kevin Boswell). The Arctic shoreline is a matrix of shallow lagoons and barrier islands on the edge of an expansive shallow shelf, and with the prospect of oil development, is the most vulnerable habitat to chronic long-term contamination should oil come ashore. There is a dearth of knowledge about fisheries populations and productivity in the near-shore because these shallow habitats are relatively inaccessible to deep-draft vessel surveys. Near-shore fish assemblages are different from those offshore; hence, these near-shore surveys will complement the offshore fish assessment surveys.

The objective of the HAMC study is to describe and quantify fish species in the shallow lagoons and areas and lagoons along the Arctic coastline, providing essential information in environmental assessments associated with oil and gas development and damage assessments, should a spill occur. In addition, a variety of biological characteristics that are poorly documented for Arctic species will be measured, including nutritional content, dietary information, and hydroacoustic methodology will be verified, and size-at-age—information needed to understand the ecological value and use of these vulnerable habitats.

We will use novel technologies from small, shallow-draft vessels to work in these difficult areas, and the use of hydroacoustic methodology will be verified, and samples will be collected for laboratory analyses using small otter trawls and beach seines. In summer 2012, HAMC scientists will conduct a site visit and pilot study based in Barrow, Alaska. During summer 2013 and 2014, surveys will be expanded along the Arctic coastline, providing essential information in environmental assessments associated with oil and gas development and damage assessments, should a spill occur. In addition, a variety of biological characteristics that are poorly documented for Arctic species will be measured, including nutritional content, dietary information, and hydroacoustic methodology will be verified, and size-at-age—information needed to understand the ecological value and use of these vulnerable habitats.

Finding Nemo is Easier Than Identifying Hydrocarbon Sources

Past oil spills ( Exxon Valdez, Selendang Ayu, and Deepwater Horizon) have taught us that oil spills will occur, that oil will linger (approaching 25 years with the Exxon Valdez spill), and that identification of the source oil will be complicated and controversial. Oil spills in the Arctic will be no different. The Arctic will be remote, with relatively few number of vessels operating, discovery wells, and natural oil seeps ensuring there will be plenty of contaminated material to analyze, and source identification in those oils will likely be contested.

By Johanna Nelson

First Phase of Alaska Marine Debris Survey Completed

ABL scientists have completed the first phase of several planned surveys of Alaska’s coast for marine debris. In June ABL completed surveys in southeastern Alaska, covering 36 sites along the 600 km of the outer coast. This year’s survey adds to a series of surveys ABL has conducted over the last 40 years. There is the added factor of possible debris from Japan’s March 2011 tsunami. ABL scientist Jacke Maselko is leading the field effort, which also includes Jason Rolle, acting Deputy Chief of the NOAA Marine Debris Program, and three others. Styrofoam fragments larger than 100mm (smaller pieces are inneminurable) and plastic single-use water bottles are the most prevalent debris. The amount and types of marine debris on Southeast Alaska’s shores was not unusual, but 27 large black-oval floats were observed at 11 of the 36 sites. Floats like these have been reported to NOAA by residents of Washington, Oregon, and Alaska in the last few months. Are these floats from the tsunami? Marine debris from Japan and other Asian countries has been seen over the years, so the trick is determining whether a particular item of debris is, in fact, from the tsunami or just typical marine debris seen most years.

Our 40 year-time series of surveys provides a good baseline for comparison, and the results from this summer’s work should provide a more complete picture. Surveys to the north and west will occur later this summer.

By Jacke Maselko
Adam Moles Retires

With an impressive 75 publications during his 40-year career, Dr. Adam Moles retired from Federal service on 1 July. Adam’s research at Auke Bay Laboratories (ABL) focused on the interactions of contaminants, habitat alteration, and disease for dozens of marine and freshwater species. He also served as scientific editor for the National Marine Fisheries Service from 2005 to 2008, overseeing the scientific content for the Fishery Bulletin and NOAA Professional Paper series. In recent years, he stepped away from research to take a more active role in planning and administration for ABL.

Starting as a bottle washer with ABL in 1972, Adam’s assigned tasks were to prepare hydrocarbon solutions for other scientists and clean up the oil-soaked apparatus between trials. Many of the hydrocarbon studies done by Adam and others at ABL from 1972 to 1988 provided a basis for the Center’s successful response to the Exxon Valdez oil spill in 1989.

The Exxon Valdez oil spill proved to be a watershed event for Adam. Laboratory experiments were supervised by field studies. Adam took this opportunity to pursue a Ph.D. and to focus on a wide variety of laboratory-based growth and behavior studies, often with limited funding. In particular, Adam pioneered the use of parasites as indicators of oil pollution. Some of his methods for monitoring water quality were adopted worldwide. Most notably by the city of Venice, Italy. Adam also proved adept at administrative tasks and took on many of the administrative chores at ABL. Adam enjoyed mentoring writers and served part-time as ABL editor. His favorite saying was “done climbing ladder, now lifting others.”

For many years, Adam taught English classes at the University of Alaska, as well as classes in fish diseases and microbiology. His hobby has always been medieval literature, going so far as to pick up a master’s degree in literature in 2003 at Oxford University, where his tutor, Douglas Gray, held the Tolkien Chair for Languages and Literature.

In retirement, Adam hopes to do some part-time teaching in English literature in Bellingham, Washington. After a lifetime in Alaska, he and his wife Terri are looking forward to seeing a bit more of the world. They’ve heard rumors about something called “sunshine.”

By Ron Heintz

FMA Observer Program Activities

During the second quarter of 2012 a total of 209 observers were trained, briefed, and equipped for deployment to vessels and processing facilities operating in the Bering Sea and Gulf of Alaska groundfish fisheries. Observers collected data onboard 207 vessels and at 17 processing facilities for a total of 11,158 observer days over this 3-month period.

New observer candidates are required to complete a 3-week training class with 120 hours of scheduled class time and additional training by staff as necessary. Returning observers are required to attend an annual 4-day briefing class prior to their next deployment in order to provide observers with necessary updates regarding their responsibilities. Prior to subsequent deployments throughout the year, all observers must attend a 1-day, 2-day, or 4-day briefing in Seattle; the length of the briefing is dependent on individual observer’s needs. During the second quarter of 2012, FMA staff in Seattle provided training for 56 new observers and briefed 143 observers in Seattle.

The Observer Training Center at the University of Alaska Anchorage was closed in March of this year; as a result, most observer training activities as well as safety and sampling gear disbursements are conducted now in Seattle. To accommodate observers deploying from and returning to Alaska, FMA field office staff in Anchorage now provide 1-day briefings and issue gear to observers who are rapidly redeploying. During this last quarter, 10 observers attended the 1-day briefing we now offer at our Anchorage field office.

After each deployment, observers meet with a staff member for debriefing to finalize the data collected. There were 21 debriefings in Anchorage and, due to a larger debriefing staff, 392 debriefings in Seattle. Note that the values for the numbers of briefings and debriefings do not represent a count of individual observers as many observers deploy multiple times throughout the year.

A highlight for our Division during this quarter was the addition of a new staff member, Gwynne Schnaittacher, who will represent FMA as the North Pacific Groundfish Observer Provider Liaison in Seattle. Gwynne serves as the primary point of contact for observer providers and for observers with provider concerns. As such, in coordination with supervisors and observer providers, Gwynne resolves operational issues, develops policies and procedures to manage the pool of observer providers, and monitors observer provider compliance with regulations and takes action on the primary point of contact for all training and briefing registration issues, and she schedules all debriefing requests and reviews and maintains observer files.

Gwynne joins us with extensive experience from the East Coast where, for over 6 years, she worked as the direct observer provider liaison between A.I.S., Inc. and the NMFS Northeast Fisheries Observer Program. In that role, her primary responsibility was to work closely with NMFS to ensure A.I.S. contractual parameters were achieved, such as data quality monitoring, sea day requirements, and scheduling debriefings and trainings. Gwynne was the supervisor of senior management staff at A.I.S. and was ultimately responsible for 70 observers. While in her position with A.I.S., Gwynne also maintained her certification as a NMFS Northeast Fisheries Observer by deploying on several commercial trips each year.

Gwynne received both her bachelor’s and master’s degree from the University of New Hampshire in zoology. In addition to her observer program involvement, Gwynne has conducted bycatch reduction studies on the East Coast in collaboration with local commercial fishermen. Outside of the work environment, she actively pursues adventure through international travel, hiking with her dog Moose, kayaking, mountain biking, and gardening.

The FMA Division is extremely pleased that Gwynne brings her skills, experience, and enthusiasm to this important position. Please join us in welcoming Gwynne to our team.

By Allison Barns and Patti Nelson

FMA North Pacific Groundfish Observer Provider Liaison Gynne Schnaittacher.
About 100 researchers studied Bering Sea ice and ecosystem conditions over 6-years to understand the processes that influence the eastern Bering Sea marine ecosystem. About 100 researchers studied Bering Sea ice and ecosystem conditions over 6-years to understand the processes that influence the eastern Bering Sea marine ecosystem. About 100 researchers studied Bering Sea ice and ecosystem conditions over 6-years to understand the processes that influence the eastern Bering Sea marine ecosystem. About 100 researchers studied Bering Sea ice and ecosystem conditions over 6-years to understand the processes that influence the eastern Bering Sea marine ecosystem.


In the past decade, Bering Sea shelf waters experienced a multi-year, very warm spell followed by a very cold spell. These events were compared to a 95-year long weather record. Such extreme events were rare but not unique. We found that while modest long-term warming due to climate change is expected in the North Pacific Ocean and southeastern Bering Sea, the historical records suggest that the most important climate feature over the next few decades will be large random variability.

A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Stabeno P.J., Farley E.V., Jr, Kachel N.B., Moore S., Mordy C.W., Napp J.M., Overland J.E., Pinchuk A.L., Sigler M.F.

Measurements made during the 6-year study show a potential impact of climate change on species from zooplankton to whales living on the Bering Sea shelf, a relatively shallow portion of the sea directly adjacent to Alaska.

From 1972 to 2000, there was high interannual variability of areal extent of sea ice during spring (March–April). In 2000, this shifted to a 5-year period (2001–05) of low ice extent during spring, which transitioned to a 4-year period (2007–10) of extensive sea ice. During the warm period, there was a lack of large copepods and euphausiids over the shelf, however, their populations rebounded during the cold period. Small crustacean zooplankton taxa did not appear to vary between warm and cold years.

Stratification on the eastern Bering Sea shelf, revisited. Ladd C., Stabeno P.J., Wisegarver E.

NOAA historical data demonstrated that stratification of the water was not simply a matter of whether or not the water column was warm or cold. Strong stratification during the summer prevents the refertilization of the surface waters and decreases the amount of production.


The presence or absence of sea ice was previously thought to have a large impact on the production of microscopic plant life (phytoplankton). We found that the wind accounts for a larger piece of the phytoplankton production puzzle, and this finding can be implemented for future models of the Bering Sea ecosystem.


Overall biomass of the epibenthic community declines with increasing latitude in the eastern Bering Sea, which is primarily driven by declining fish catches in the northern Bering Sea. The fish fauna in northern latitudes is increasingly dominated by gadids, with smaller species becoming more common in the north. The biomass of the invertebrate megafauna remains relatively consistent throughout the eastern Bering Sea, but invertebrates make up a larger proportion of the catch in bottom trawls conducted at higher latitudes.

Visual line transect surveys for cetaceans were conducted on the eastern Bering Sea shelf in association with pollock stock assessment surveys aboard the NOAA ship Miller Freeman in June and July of 1999, 2000, 2002, and 2004. Fin whales were the most common large whale in all years except 2004 when humpback whales were more abundant. Dall’s porpoise were the most common small cetacean in all years.


A predator’s foraging mode and their restrictions during breeding affect their response to prey persistence. We examined whether this association with ecologically important prey (euphausiids, age-1 pollock) is influenced by differences among predator species (baleen whales, sea lions, seabirds) in foraging modes (travel cost, surface feeder or diver) or whether the predator species is a central place forager or not.

A second special issue received 29 submissions with reviews now underway. To date, 58 peer-reviewed journal articles have been published by the Bering Sea Project.

Mike Sigler, HEPR
Jeff Napp, RACE

 Mike Sigler, HEPR
Jeff Napp, RACE
Eastern Aleutian Islands Humpback Whale (Megaptera novaeangliae) Satellite-Tagging Project

North Pacific humpback whales (Megaptera novaeangliae) migrate from temperate low-latitude breeding grounds to high-latitude feeding grounds each summer. The waters surrounding the eastern Aleutian Islands are dominated by strong tidal currents, water-column mixing, and unique bathymetry; these factors are thought to concentrate the small fish and zooplankton that comprise the typical humpback diet in Alaska, creating a reliable and abundant food source for whales in the Bering Sea. While humpbacks are probably the most studied large whales in the world, individual fine-scale habitat use and movement are still poorly understood, particularly in remote regions like the Bering Sea and the eastern Aleutian Islands. Most of what we know about humpback distribution and habitat use has been from analyses of historical whaling data and from modern photo-identification and genetic studies, yet these types of studies reveal only a small fraction of a whale’s behavior.

Satellite telemetry is being used worldwide to create detailed, fine-scale tracks of whale movement, revealing behaviors that were previously unknown. During summer 2007-11, members of the Cetacean Assessment and Ecology Program deployed satellite-telemetry tags on humpbacks off the coast of Unalaska Island (Fig. 1). These tags are designed to record the animal’s position while at the surface, 12 hours a day for up to several months. The tag data we collected during this study revealed the first fine-scale movement information for humpback whales in a North Pacific feeding ground. Ten satellite transmitters were deployed, yet only eight tags transmitted long enough to be evaluated. The whales were tracked for an average of 28 days (range = 7-67 days). Although all of our study whales were tagged in Unalaska Bay, they showed remarkable variation in speed, direction, and overall distance traveled, both within and between years. In 2007, one of the two tagged whales (21801 2007) made a trip to the Island of Four Mountains and returned to the northern side of Umnak Island, while the other (21809 2007) explored presumed feeding areas to the east of the tagging location between Unalaska Bay and Unimak Island (Fig. 2). Of the two whales tagged in 2008, one (21809 2008) remained within 50 km of Unalaska Bay for the duration of the tag and the other (21810 2008) traveled nearly three times farther that year, between Unimak Pass and the Pacific side of Umnak Pass (Fig. 2). The single whale tagged in 2009 (87769 2009) remained within Unalaska Bay during the 7 days of tag transmission (Fig. 2).

The two whales tagged in 2010 showed the most surprising variation from any other year. One whale (88720 2010) travelled from Unalaska Bay west to northeastern Umnak Island, then through Unimak Pass, presumably to forage on the Pacific side of the island (Fig. 2). The other animal tagged that year (88721 2010) left Unalaska Bay 3 days after it was tagged and moved at least 1,500 km (in 12 days) along the outer Bering Sea shelf to southern Chukotka, Russia (Fig. 3). After 4 days off the Russian coast, this whale moved east across the Bering Sea basin to Navarin Canyon (60° 30’N, 179° 20’W), where it remained until transmissions ceased. In all, whale 88721 2010 travelled over 3,000 km, roughly the equivalent of swimming from Seattle, Washington, to Houston, Texas, in 26 days! The animal tagged in 2011 (87771 2011) remained near-shore between Unimak Pass and Unimak Pass (Fig. 2) for the duration of the tag transmission.

These results support the findings of historical and current studies that humpbacks frequently congregate in shallow, highly productive coastal areas of the North Pacific Ocean and Bering Sea. However, these tracks also make it clear that individual whales are making independent decisions about movement and that these decisions can lead to surprisingly long-distance travel within a feeding season. This movement variation is difficult to predict or describe but could potentially have a major impact on stock structure definitions. Ironically, whale 88721 2010’s trip to the Chukotka coast occurred about a week after a NMFS Biological Review Team, charged with assessing the population structure of humpback whales, had decided that there was population separation between the eastern Aleutian Islands and Russia.

Fishing gear entanglement, a well-known cause of injury or death in the North Atlantic humpback population, has already been documented in nearly a quarter of the humpbacks photographed in Alaskan waters. Ship strikes, involving a wide range of vessels, are also increasing in Alaska. Impacts on humpbacks in the eastern Aleutians region and Bering Sea will likely increase with the influx of human activity from newly opened oil and gas lease areas in the Chukchi and Beaufort Seas. This study clearly shows that humpbacks are a highly mobile, multinational species, both within and between seasons. These data should highlight the need for cooperation between North Pacific coastal nations in creating effective research and management strategies that mitigate the known threats to humpbacks throughout all stages of their life cycle. Continued research involving satellite telemetry will help describe how these whales overlap with human activity throughout the North Pacific and will provide domestic and international governments with the information they need to take effective action against those threats.

By Amy Kennedy

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**Figure 1.** Satellite-tag deployment on a humpback whale off Dutch Harbor, Alaska.

**Figure 2.** Telemetry tracks for seven humpback whales tagged during summer 2007-11.

**Figure 3.** Telemetry tracks for all whales tagged during this study. Note that whale 88721 2010 travelled along the shelf break to coastal Russia before looping back, covering approximately 3,000 km in 26 days.
Polar Ecosystems Program

Bering Okhotsk Seal Surveys (BOSS):
Joint U.S.-Russian Aerial Surveys, 1 April – 23 May 2012

Researchers from the National Marine Mammal Laboratory’s (NMML) Polar Ecosystems Program (PEP), in collaboration with Russian colleagues, conducted synoptic abundance and distribution surveys for the four species of ice-associated seals (bearded, spotted, ribbon, and ringed seals) which are known to occupy and breed in the Bering Sea during the spring and summer (Fig. 4). The fieldwork was conducted using digital cameras and thermal imagers mounted in the belly ports of two U.S. and one Russian fixed-wing aircraft from 1 April to 23 May 2012.

The U.S. surveys consisted of flights originating from airports in Nome, Bethel, and Dillingham, Alaska. The U.S. team utilized airstrips in Gambell, on St. Lawrence Island, and St. Paul, in the Pribilof Islands, to reach the most remote areas of sea ice in the central Bering Sea. The Russian team began western Bering Sea surveys in mid-April from Ossora, Russia, on the Kamchatka Peninsula and worked their way north to the Bering Strait.

Most U.S. flights lasted 4-9 hours and were flown at an altitude of 1,000 ft (300 m) to maximize the area surveyed and minimize the chance of disturbance to seals and other wildlife. A NOAA Twin Otter (N56RF) housed three FLIR SC645 thermal imagers, which recorded continuous data in the 7.5-13.0 µm wavelength. Each thermal imager was paired with a Canon Mark III 1Ds digital single-lens reflex (SLR) camera with a 100-mm Zeiss lens. All six instruments were mounted in an open-air belly port (Fig. 5). The combined thermal swath width was approximately 1,500 ft (470 m) at an altitude of 1,000 ft. A contracted Aero Commander aircraft carried two sets of paired thermal imagers (SC645) and digital SLR cameras (Nikon D3X) and surveyed a maximum swath width of approximately 900 ft (280 m). The two aircraft flew a total of 39 surveys, which covered over 14,000 nautical miles (27,000 km) of trackline and collected more than 885,600 images.

Advanced thermal-imaging technology was used on both the U.S. and Russian survey aircraft to detect the warm bodies of seals against the background of the cold sea ice. High-resolution digital images will be used to identify the species of seals detected by the thermal imagers (Fig. 6). Novel statistical approaches will also be used to tackle the unique challenges presented by the moving and melting sea-ice habitat. A second survey in spring 2013 will complete the coverage and increase the precision of the population numbers. Ultimately, this project will provide the first comprehensive estimates of abundance for the four species of ice-associated seals found in the Okhotsk and Bering Seas.

By Erin Moreland, Michael Cameron, and Peter Boveng
Recruitment Processes

A Collaborative Effort to Improve Assessment of the Early Life History Stages of Important Commercial Fish Species in the Bering Sea

The Fisheries Oceanography Coordinated Investigations (FOCI), the Ecosystem Monitoring and Assessment (EMA), and the Midwater Assessment and Conservation Engineering (MACE) Programs have begun a comprehensive, collaborative effort to improve assessment of the early life stages of important commercial fish species in the Bering Sea. The effort will provide seasonal fisheries information, environmental and biological indices, and annual syntheses necessary to apply an ecosystem approach to management. Specifically, the coordinated research focuses on studying processes during the first year of life, a time when climate variation has a large affect on survival.

This spring, the first two in a series of collaborative seasonal cruises were completed. Scientists departed Kodiak, Alaska, aboard the NOAA ship Oscar Dyson for the Bering Sea on April 26, 2012 (cruise DY-12-04). Along the way they deployed long-term oceanographic moorings in Chiniak and Pavlov Bays and accomplished ichthyoplankton and CTD (conductivity-temperature-depth) sampling in Shelikof Strait (Gulf of Alaska). However, sea ice in the eastern Bering Sea covered the mooring sites and precluded retrieval of FOCI’s sentinel moorings there. Scientists quickly adapted and began an ichthyoplankton survey over the southwest Bering Sea shelf, which was originally scheduled for the second cruise (DY-12-05). The objectives of this survey were to assess the distribution and abundance of eggs and larval walleye pollock (*Theragra chalcogramma*), examine the interactions among climate, oceanography, and ichthyoplankton, and determine how physical and biological factors affect the transport and survival of fish larvae. At the end of the first cruise, the moorings were still covered with ice (see The Bering Sea: Current Status and Recent Events in PICES Press v. 20 no. 2, in press for an explanation).

The survey was resumed at the beginning of the second cruise (DY-12-05) which began on 15 May. Scientists were able to survey two known spawning grounds of walleye pollock over the shelf, the Unimak Island vicinity of the Alaska Peninsula and the Pribilof Islands. They also were able to begin surveying presumed spawning areas north of Pribilof Canyon but ran out of time and were unable to complete the survey as far as Zhemchug Canyon. This coverage was over a much larger geographic area than scientists were previously able to search. Most of the ice-free portions of the survey area were successfully sampled for ichthyoplankton (Fig. 1) and other zooplankton, along with temperature and salinity profiles at each bongo station. Data on distribution and abundance of zooplankton will provide information on prey fields for developing larvae. Throughout the cruise, walleye pollock larvae were collected to assess condition and study bioenergetics, work which will be conducted in the laboratory by AFSC scientists Ron Heintz and by Steve Porter. This work is central to understanding climate-mediated variation in condition of young walleye pollock in the spring and summer of the first year of life. Scientists were also able to complete mooring recoveries and redeployments for the two southern Bering Sea mooring sites (M2 and M4, Fig. 2). This will continue the long-term physical observations collected by the Pacific Marine Environmental Laboratory side of the FOCI program. These measurements are critical to studying climate change and oceanographic variability.

Stay tuned for the next article examining this first year of life study when the three programs collect late summer/early fall data on the Oscar Dyson (August – October) to see how the fish have been growing since last spring and whether or not they have managed to store enough energy to survive their first winter.

By Daniel Cooper and Janet Duffy-Anderson
Observers collected 221 stomachs during summer surveys in the Gulf of Alaska. This resulted in over 900 stomach samples from the eastern Bering Sea, and 101 stomachs from the Aleutian Islands, eastern Bering Sea continental shelf, and eastern Bering Sea continental slope. Preparations for collecting stomach samples during both surface and bottom trawl surveys of the Chukchi Sea also have been made. Stomach Content Analysis at sea (SCAN) is being conducted on both Aleutian Islands trawl survey vessels, and collection of all visually unidentifiable fishes will be returned to the lab for microscopic or genetic examination. Genetic examination of fish specimens collected from SCN used fishes in previous years has shown that the accurate visual identification by current laboratory personnel is very robust, even for very digested fish species. However, genetic identification of the small percentage of fishes that are not identifiable to at least the genus level suggests that the species composition of these fishes is not well represented by the visual identification pattern. An analysis of field-based ration estimates for walleye pollock, Pacific cod, and arrowtooth flounder: This comparative analysis is currently summarized in a draft manuscript tentatively titled “Field- and bioenergetic-based daily ration estimates for walleye pollock (Theragra chalcogramma), Pacific cod (Gadus macrocephalus), and arrowtooth flounder (Atheresthes stomias) from Alaska (USA).” For this we re-fit Wisconsin bioenergetic parameters to show consumption data for the three (or similar) species and compared bioenergetic rations to digestion corrected field-based ration estimates (using two different methods) and von Bertalanffy derived estimates of consumption (Fig. 1).

**Figure 1.** Weight-dependent annual ration estimates for walleye pollock, Pacific cod, and arrowtooth flounder from the eastern Bering Sea. Shaded polygons represent field-based ration estimates of selectivity (contour lines) and dashed blue lines, respectively), Ecosim predictions for the Bering Sea (Fig. 3). We now are in the processes of generalizing the MSM model code to accommodate additional species, initially anticipated to include Steller sea lions and Bering Sea flatfish species. The updated model and initial model results are being compiled in a draft manuscript titled “Incorporating bioenergetics into multi-species statistical catch-at-age models: an example from the Bering Sea.”

This allowed us to derive consumption parameters that can now be used to update regional MSM models. Additionally we have conducted a detailed analysis of allometric patterns in predation rate and prey selectivity (Fig. 2). These analyses have allowed us to parameterize the size-based foraging model used in MSM. We have applied the updated bioenergetic and foraging model parameters to the MSM model for the EBS. In particular, we have generated projections for the three species under various target harvest rates including (i) no fishing, and (ii) fishing to 40% of the unfished spawning biomass. Model predictions were compared to single species assessments from 2011 as well as Ecosim predictions for the Bering Sea (Fig. 3).

By Kirsten Holman, Kerstin Aydin, Jim Iailelli

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**Figure 2.** Length-based prey selectivity for cannibalistic walleye pollock predators consuming walleye pollock prey of various sizes (shaded squares), and model estimates of selectivity (contour lines). The horizontal and vertical bar graphs represent the row (i.e., suitability) or column (i.e., proportion of diet by weight) totals, respectively; solid lines represented foraging model estimates.
Forage Euphausiids Abundance in Space and Time (FEAST)

More and more, high resolution end-to-end models have started incorporating fish as one of their components. Such exercises are usually restricted to a few years, and do not include fisheries analyses. FEAST is a length-based, spatially explicit bioenergetics model that comprises the fish portion of the vertically integrated model of the Bering Sea Integrated Ecosystem Program (BSIERP). The vertical model itself contains five modules: 1) climate; 2) oceanography (ROMS); 3) lower trophic levels (NPZ); 4) fish; and 3) fisheries (FAPM). FEAST models 14 fish species linked to five zooplankton groups. Such exercises are usually restricted to a few years and do not involve fisheries analyses. FEAST in addition to its role in parameterization of the Bering Sea ecosystem model (BSIERP) in Space and Time (FEAST) has managed the stock assessments, e.g., length frequency, diet composition, and CPUE of each species. It continues to be used in the North Pacific Fisheries Management Council for informational as well as feedback purposes. Also, results from FEAST were presented in May at the Second International Symposium on Effects of Climate Change on the World’s Oceans in Yeosu, Korea.

By Iomone Ortiz and Kerim Aydin

Economics & Social Sciences Research Program

Regional Impacts and Bioeconomics of North Pacific Crab Stocks

The Economics and Social Science Research (ESSR) program, the AFSC Kodiak Lab, and Dr. Andrés Punt at the University of Washington School of Fishery and Aquatic Sciences are collaborating in the development of bioeconomic models for North Pacific crab stocks to evaluate the biological and economic impacts of ocean acidification and other issues relevant to management. These models separate life-history stages for growth and mortality of juveniles and adults, include fishery impacts by analyzing catch and effort in both biological and economic terms, and can integrate predictions for trends in ocean pH or other environmental factors. These models were originally designed to estimate maximum economic yield (MEY) with uncertain recruitment and population dynamics that are based on simplified versions of the full assessment models for each crab stock. Currently, bioeconomic models for Bristol Bay red king crab and eastern Bering Sea snow crab are operational. Figure 5 shows a hypothetical example with dynamic MEY paths for fishing mortality rates that start from a range of initial conditions and model parameters set to converge to the maximum sustainable yield proxy $F_{35\%}$ from the 2010 stock assessment model for EBS snow crab. Economic parameters in the bioeconomic model for EBS snow crab were calibrated using catch, effort, revenue, and cost data for the post-rationalization period 2006-10 from fish tickets, and the Bering Sea Aleutian Islands Crab Economic Data Report database. Based on these bioeconomic models, ESSR has begun developing a joint crab bioeconomic/regional economic model in order to calculate the economic impacts on employment, factor income, and household income of ocean acidification and the resulting consequences on Bristol Bay red king crab and eastern Bering Sea snow crab.

By Michael Dalton and Chang Seung

Coordinated Seabird Studies

Core operations supporting AFSC seabird studies continued throughout the last quarter. With the March closure of the Anchorage Observer Training Center, the number of observers trained by the Coastal Observation and Seabird Survey Team has increased. Seabird necropsy work continues as does the marine bird food habits project. Processing of specimens continues in support of collaborative work among the Alaska and Pacific Islands Regions and with the U.S. Fish and Wildlife Service. In addition to this core work we have been coordinating with the Freezer Longline Coalition to address further reductions to seabird bycatch. Past work completed by the AFSC Seabird Studies group illustrated the vessel-specific nature of seabird bycatch rates. We participated in the May skipper meeting held by the Freezer Longline Coalition and have been working with them and Washington Science Grant on a joint effort to visit vessels with higher bycatch rates and provide advice on streamer line configurations and activities. Two vessel visits were completed in June.

By Shannon Fitzgerald

Figure 4. The food-web underlying FEAST, showing level of detail for the groups modeled. Lines depict trophic flows, line thickness is proportional to magnitude of flow and color represents pelagic (green) or benthic (blue) routes.

Figure 5. MEY fishing mortality rates converge to $F_{35\%}$ for a range of starting points.
Atka Mackerel Tag Recovery Cruise in the Aleutian Islands and Examination of Tagged Steller Sea Lion Prey Field In Situ

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

This study is an ongoing research effort. From 1999 to 2016, approximately 80,000 tagged fish were released during AFSC chartered tag release cruises near Seguam Pass, Tanaga Pass, Amchitka Island, and Kiska Island. In May to June of 2011, a cooperative venture between the North Pacific Fisheries Foundation and the AFSC released approximately 8,500 fish near the Seguam Pass area, 9,000 fish at Tanaga Pass, and 10,000 at Petrel Bank. In August 2011, we conducted a summer recovery cruise in the same area (Fig. 6). The recent winter recovery cruise was conducted from 27 March to 17 April 2012. The cruise had three objectives. The first objective was to recover previously tagged fish in the open areas outside the travel exclusion zones during the winter months. Even though tags were released inside the closed areas, during the recent 2011 recovery cruise, recoveries were not conducted inside the travel exclusion zones to minimize potential negative impacts of Atka mackerel removal to the Steller sea lion prey fields inside the closed areas. The second objective of this study was to use catch composition data from the tows to estimate relative abundance indexes (CPUEs) for all major fish and invertebrate species present in the study areas. The third objective of this study was to characterize Atka mackerel habitat and develop methods for estimating indices of abundance of sea lion prey species with non-extractive methods such as camera tows.

During the 2012 cruise we conducted 54 hauls and examined 1,529 metric tons (t) of Atka mackerel for tags, equivalent to approximately 2.6 million individual fish. We recovered 49 tags; 13 at Seguam pass, 25 at Tanaga pass, and 11 at Petrel Bank, all of which were released during the 2011 tag release charter. All hauls were sampled for species composition and sexed length frequencies. In addition, we collected 420 biological samples such as stomachs, gonads, and age structures and obtained sexed length frequencies from 4,697 individual fish. Length distribution of Atka mackerel differed by area with the smallest fish obtained from Petrel Bank and the largest fish from Tanaga Pass (Fig. 7).

In order to examine the habitat and develop indices of abundance, we conducted 12 underwater tows with a portable underwater camera. We conducted the camera tows at the same locations as the tag recovery hauls. We were able to conduct five camera tows at Seguam Pass, four camera tows at Tanaga Island, and three camera tows at Petrel Bank.

Further analysis will be conducted to estimate population sizes of Atka mackerel in these study areas and understand relative abundance of other Steller sea lion prey species, invertebrates, and habitat types associated with these populations.

Satellite tagged Steller Sea Lion prey study

During November 2011, the AFSC’s National Marine Mammal Laboratory tagged a female adult Steller sea lion with a satellite tag. The female was also branded with the brand ‘=24’, hence for the purposes of this report we will refer to her under this name.

The female =24 had been transmitting location data since November 2011. She was located at Seminopchonoi Island and traveled to the southern part of Petrel Bank, at regular intervals, presumably to feed. FIT staff took the opportunity during this recovery cruise to run a hydroacoustic transect at the southern end of Petrel Bank. We conducted five tows in areas where the sea lion was frequently observed and where we found fish signal during the transects. We also conducted two camera tows in the vicinity of one of the feeding ‘hot spots’ of ‘=24’.

It appeared that the sea lion was diving consistently in two locations—one close to the canyon edge (haul 21) and one in the flat area to the south of the edge (haul 16). Future analysis of the hydroacoustic data will give further insight of the size of the fish aggregations in this area.

We conducted two tows in the vicinity of the canyon; on the canyon edge we found mostly Pacific ocean perch (78%) and sponges (13%) with a trace of Atka mackerel (2%). In the canyon itself we found a mix of adult walleye pollock (59%) and Pacific ocean perch (31%). We conducted two tows in the flat area to the south of the canyon. In haul 16 we found mostly northern rockfish (50%) and Pacific cod (30%) and in haul 20 we found mostly northern rockfish (65%) and Atka mackerel (18%). We also conducted a tow along the eastern edge of the shelf (haul 22) where we found mostly Atka mackerel (73%) and Pacific cod (12%).
Scientific Acoustic Data from Commercial Fishing Vessels: Eastern Bering Sea Walleye Pollock (*Theragra chalcogramma*)

The International Council on the Exploration of the Sea (ICES) Working Group on Fisheries Acoustics, Science and Technology has provided guidance on using commercial fishing vessels for collecting opportunistic acoustic data (OAD). However, an explicit approach for working with these non-traditional datasets has not been addressed. A scientific study was designed and conducted to test the feasibility of collecting and utilizing acoustic data from commercial fishing vessels fishing walleye pollock (*Theragra chalcogramma*) in the eastern Bering Sea as part of a Ph.D dissertation project. This study demonstrated methods for processing and analyzing acoustic data collected from commercial fishing vessels to investigate current issues in fisheries management. Although the opportunistic acoustic data in this study were uncalibrated and, therefore, could not be used for biomass estimates, it was found to be suited to investigating fisheries issues where an index of abundance proportional to biomass could be substituted. This study demonstrates the scientific application of opportunistically collected acoustic data from commercial fishing vessels operating in the winter eastern Bering Sea (EBS) walleye pollock fishery (Fig. 9). Due to their high resolution and wide spatial and temporal range, opportunistic acoustic data provided an excellent data source for investigating population spatial and temporal dynamics during the winter. These data were used to identify spatio-temporal dynamics of pollock aggregations over scales ranging from hundreds of meters to hundreds of kilometers and from minutes to months. Spatial analyses identified three levels of pollock aggregation (Fig. 10), and time series analysis identified dieback changes in pollock distribution in both the vertical and horizontal planes and an overall decline in pollock density over the study period.

Questions on the intensity of the EBS pollock fishery arising from the decline of Steller sea lion (*Eumetopias jubatus*) populations have been a focus of many studies, but a lack of informative data on winter pollock distributions has hindered these efforts. This data provided an abundance index that was used in a spatially-explicit depletion model to examine possible differences in fishery exploitation rates inside and outside of Steller sea lion critical habitat areas. Findings suggested that exploitation rates were relatively low (~6%), but that fishing inside SSL critical habitat was more than twice that observed outside critical habitat (Fig. 11, Fig. 12, and Table 1).

Table 1. Posterior median of mean fishing exploitation rates by year and combined for inside (SSL) and outside (outside SSL) of Steller sea lion critical habitat (SSLCH) with lower and upper 95% credible intervals (CI) generated by MCMC. Mean fishing exploitation were generated for each MCMC draw separately for inside and outside SSLCH as the sum of catch on day 90 divided by the sum of biomass for each year and for all four years.

<table>
<thead>
<tr>
<th>Year</th>
<th>SSL Lower CI</th>
<th>SSL Upper CI</th>
<th>SSL Combined Lower CI</th>
<th>SSL Combined Upper CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>0.0763</td>
<td>0.0757</td>
<td>0.0769</td>
<td>0.0609</td>
</tr>
<tr>
<td>2003</td>
<td>0.0903</td>
<td>0.0896</td>
<td>0.0910</td>
<td>0.0339</td>
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<tr>
<td>2004</td>
<td>0.1456</td>
<td>0.1445</td>
<td>0.1468</td>
<td>0.0394</td>
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<tr>
<td>2005</td>
<td>0.0745</td>
<td>0.0740</td>
<td>0.0751</td>
<td>0.0332</td>
</tr>
<tr>
<td>All Years</td>
<td>0.0900</td>
<td>0.0893</td>
<td>0.0907</td>
<td>0.0365</td>
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</tbody>
</table>

Figure 11. Maps of the posterior median pollock biomass (normal score of tons) by year at the 100 km\(^2\) model spatial resolution. Crossed circles are the posterior median centroids for each resolution and year.

Figure 12. Maps of posterior median fishing exploitation rates by year at the 100 km\(^2\) model spatial resolution. Crossed circles are the posterior median exploitation rates for each resolution and year.
The lack of comprehensive survey data on pollock distribution in the EBS during the spawning season is problematic for predicting possible effects of climate change in the EBS. The opportunistic acoustic data were used as an index of abundance to develop and evaluate a generalized additive model for projecting winter EBS pollock distributions using available data and oceanographic conditions. Sea surface temperature, bottom depth, distance to the ice edge, and cumulative catch were all found to be significant predictors of pollock density in the winter (Fig. 13, Fig. 14, and Fig. 15). Functional relationships between temperature, bottom depth, and pollock density were also found to overlap between summer and winter. These studies show the utility of opportunistic acoustic data for gaining insight into the spatial and temporal dynamics of winter pollock aggregations which have previously not been examined by fisheries scientists due to the lack of scientific quality data at the appropriate resolutions and ranges.

By Steve Barbeaux

Figure 13. Effects of A) sea surface temperature, B) bottom depth, and C) distance to ice edge on the normalized backscatter (sA) from the optimum projection model (OPM). Shaded areas are 2 standard errors around estimated effects.

Figure 14. Projections of EBS pollock preferred habitat on January 20 for A) 2002, B) 2003, C) 2004, D) 2005, and E) 2006. The 1 °C isotherm is indicated in the solid black line, the 100 m isobath by a dotted black line.

Figure 15. Prediction error from projections of EBS pollock preferred habitat on January 20 for A) 2002, B) 2003, C) 2004, D) 2005, and E) 2006. The 1 °C isotherm is indicated in the solid black line, the 100 m isobath by a dotted black line.

By Jon Short

**Age & Growth Program**

**Age and Growth Program Production Numbers**

Estimated production figures for 1 January – 30 June 2012. Total production figures were 17,841 with 3,729 test ages and 172 examined and determined to be unageable.

<table>
<thead>
<tr>
<th>Species</th>
<th>Specimens Aged</th>
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<tbody>
<tr>
<td>Alaska plaice</td>
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<tr>
<td>Atka mackerel</td>
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<td>Bering flounder</td>
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<tr>
<td>Blackspotted rockfish</td>
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<td>Dusky rockfish</td>
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<tr>
<td>Flathead sole</td>
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<td>Great sculpin</td>
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<td>Kamchatka flounder</td>
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<td>Northern rock sole</td>
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<tr>
<td>Pacific cod</td>
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<tr>
<td>Pacific ocean perch</td>
<td>415</td>
</tr>
<tr>
<td>Pouhua rockfish</td>
<td>249</td>
</tr>
<tr>
<td>Yellowfin sole</td>
<td>1,284</td>
</tr>
</tbody>
</table>

By Jon Short
Future climate change is expected to influence the abundance and distribution of marine fish species in complex ways, including changes in the local environmental characteristics and transport pathways experienced by early life stages that are typically pelagic, such as eggs and larval. Temperature and species composition and abundance, plasticity in feeding strategies, and ontogenetic differences.

A key outcome from discussions following the presentations was the recognition that one aspect of the impact of future climate change on species abundance and distribution patterns will occur through changes in the growth rates and subsequent survival of individuals. However, these changes may not be predictable from simple statistical relationships based upon (current) growth rates and expected changes in temperature. Instead, it is likely that future changes will be due to the dynamic interaction of several factors, including indirect effects on the abundance, composition, and relative energy content of key prey species. These indirect effects will act in concert with direct effects, such as changes in water circulation patterns and temperature, which will influence the spatial overlap and metabolic processes of predators and prey.

Thus, one important recommendation stemming from the discussions was that IBMs used to predict the impact of future climate change on species abundance and distribution should incorporate mechanistic bioenergetics models that account for effects of changes in prey abundance, energetic content, and species composition on individual growth rates. Workshop participants also acknowledged a general lack of data on the physiology of many fish and shellfish species, even for commercially- and/or ecologically-important ones, as well as a scarcity of marine physiologists who could potentially address these issues.
The 2012 Second ICES/PICES Conference for Early Career Scientists

The International Council for the Exploration of the Sea (ICES) and North Pacific Marine Science Organization (PICES), in conjunction with NOAA, sponsored the Second ICES/PICES “Conference for Early Career Scientists” 24-27 April in Majorka, Spain. The objective of the meeting was to encourage greater involvement of young scientists in international scientific investigations and to foster their involvement in the management of marine ecosystems. The meeting builds on the success of the ICES/PICES Early Career Scientists Meeting held in Baltimore, Maryland, in 2007 and the ICES Young Scientist Conference in Denmark in 1999. Interested early career marine scientists applied for an invitation from the Steering Committee. Applicants were required to be under 35 years in age or have completed a Ph.D. after 2007. Applicants were evaluated on their productivity, potential for novel science, and relevance of their research to the session themes.

Steven Barbeaux and Ingrid Spies of the Status of Stocks and Multiplicity Assessment (SSMA) program and Matt Baker, a postdoctoral researcher with Anne Hollowed, were accepted to attend. Anne Hollowed, SSMA program manager, was an invited key note speaker for the Theme 2 Session: Human Interactions with the Marine Environment. Steve Barbeaux gave an oral presentation and Ingrid Spies presented a poster in the Theme 2 Session: Human Interactions with the Marine Environment. Matt Baker’s poster was presented in absentia by Anne Hollowed in the Theme 1 Session: Impact of Change on Marine Ecosystems. Their abstracts follow:

Climate change effects on fish and fisheries: current outlooks and a roadmap for interdisciplinary research Anne B. Hollowed

Recent global assessment reports provide compelling evidence that climate change is occurring. In response to these reports, the marine science community has endeavored to provide new science to improve our ability to understand and predict these impacts on fish and fisheries. This presentation will examine the expected effects of climate change on ecosystem productivity, habitat quality and quantity, and how these changes will impact the spatial distribution, predator-prey interactions, and viral rates of marine biota. Case studies from around the world will be used to demonstrate how these expected changes will influence the quantity, quality, and availability of marine resources for human use. These case studies will demonstrate how the marine science community have united in an effort to develop mechanistic scenarios that are incorporated into stock projection models for use in evaluating the performance of management strategies under a changing climate.

Monitoring on a shoestring: the use of commercial fishing vessels as inexpensive sampling platforms for long-term biological and oceanographic monitoring Steven J. Barbeaux

Long-term monitoring is a key component of an ecosystem-based approach to fishery management. Data time series enable the examination of changes in oceanographic and community metrics. Government funding for long-term monitoring of biological and oceanographic processes has dwindled in recent years, while the mandate for this type of information has increased. If data-driven ecosystem-based management continues to be the goal, then methods for reducing the costs of data collection must be found while data quality is maintained. An example of this type of innovative approach can be found in the Alaska walleye pollock fishery where researchers have teamed with commercial fishers to deploy inexpensive temperature and depth data storage tags on trawl nets. At the same time, data on fish density and distribution are being collected using the fishing vessels’ own acoustic systems. These data are being used to validate oceanographic models, to assess the effects of oceanographic conditions on bycatch in the walleye pollock fishery, monitor the impacts of the fishery on the stock across a wide range of temporal and spatial scales, and evaluate the effects of oceanographic conditions on walleye pollock density and distribution. This project demonstrates a cooperative monitoring program in which researchers work with other sea-going stakeholders to inexpensively collect biological and oceanographic data that can be integrated into a long-term ocean observing system.

The hidden story: what are the potential genetic effects of different types of fisheries management? Ingrid Spies and Andrei Point

Under a precautionary approach to fisheries management, management units should correspond with a single genetic population or stock. Such an approach is intended to preserve individual populations, biodiversity, and the overall resilience of the stock complex. Although genetic population structure has been documented in many marine fish species, no clear method exists to translate this information into a meaningful management strategy. Here, we simulate marine fish populations with two types of genetic population structure: panmictic and discrete populations. Panmictic populations are managed as one unit and genetic diversity and the overall resilience of the stock are maintained. Discrete populations are managed as separate units.

Role of habitat in moderating species distributions and interactions Matt Baker, Anne Hollowed, M. Elizabeth Clarke, and Ray Hillborn

Several mechanisms drive ecosystem structure and stability in marine systems, including competition between species, climate, and fisheries extraction. Many systems subject to perturbation show stability in total biomass and structure, despite shifts in relative species abundance. This suggests sequential replacement related to compensatory dynamics. We examine species dynamics within and between functional guilds in the eastern Bering Sea to weigh evidence for compensation, resource partitioning, and common forcing via external drivers and examine how habitat governs species interactions. We applied random forests to determine the importance of environmental variables on individual species distributions. We then extended these models to species-specific catch time series, synthesizing cross-validated coefficient of determination and accuracy importance measures from univariate analyses to quantify compositional turnover along environmental gradients. These outputs were applied to define distinct regions within large marine ecosystems based on unique aggregations of community composition and physical habitat. We also applied centroid-based clustering methods to time series trends of species abundance to explore evidence for substructure in exploited stocks within this system. We are currently integrating these methods to inform approaches to examining relative effects of various drivers of species abundance and community composition through multivariate autoregressive state-space models.

By Anne Hollowed, Steve Barbeaux, Ingrid Spies, and Matt Baker
The earth’s oceans influence the fundamental processes of our planet and provide the living resources and services upon which humans depend. They play a critical role in the global carbon cycle and provide the habitats that sustain marine biodiversity. Humans are changing the world oceans to an extent that is unprecedented. Greenhouse gas emissions are warming the planet, affecting the global carbon cycle, and changing the chemical composition of the ocean. Marine ecosystems are being disrupted by overfishing and pollution. These fundamental changes can have serious consequences for oceanic productivity and species composition.

The International Council for the Exploration of the Sea (ICES), the North Pacific Marine Science Organization (PICES), and the Intergovernmental Oceanographic Commission of UNESCO (IOC) joined forces in 2008 for the first global ocean symposium in Gijön, Spain, to provide a comprehensive view of the current state of the global ocean and compare between regions. The 2008 symposium in Gijön, Spain, attracted 400 scientists from 48 countries. The 2nd International Symposium on Effects of Climate Change on the World’s Oceans covered many issues of the role of climate change on the oceans: sea level rise, changes in thermo-haline ocean circulation, acidification, oligotrophy of temperate seas, changes in species abundance, distribution and phenology, loss of biodiversity, all of which will have serious implications for marine living resources and the humans that depend on them. The symposium’s aim was to bring together experts from different disciplines to exchange observations, results, models, and ideas at a global scale and to discuss the opportunities to mitigate and protect the marine environment and its living resources.

Anne Hollowed (co-chair of the ICES/PICES Strategic Initiative on Climate Change Effects on Marine Ecosystems, SICCEME), Miguel Bernal (Spain, ICES Working Group on Integrative Physical-Biological and Ecosystem Modeling, WGIPEM) and Keith Criddle (University of Alaska Fairbanks, PICES Section on Human Dimensions, SHD) co-convener Session 4: Climate Change Effects on Living Marine Resources: From Physics to Fish, Marine Mammals, and Seabirds, to Fishermen and Fishery Dependent Communities. This session was the largest and most attended session of the symposium, with 55 oral presentations from scientists from 17 countries. The SICCEME co-chair Manuel Barange (United Kingdom) was the keynote plenary speaker, gave a presentation titled “Quantifying the Impacts of Climate Change on Marine Shelf Ecosystems and Their Resources: Feeding the World in 2050.” This talk focused on the recent findings of the Quest-Fish program. Dr. Shin-ichi Ito (Japan) was the theme session invited speaker, he gave a presentation titled “Climate-induced Fluctuation of Japanese Sardine; Its Influence on Marine Ecosystem and Human Being.”

The theme session spanned a 4 days. Day 1 started with a series of synthesis talks followed by presentations that focused on climate change impacts on high latitude and middle latitude ecosystems. The morning of Day 2 highlighted new analytical approaches to understanding how climate change and ocean acidification will impact the spatial distribution of marine species and how these shifts in distribution will impact marine ecosystems. Speakers for the afternoon session targeted social and economic impacts of climate change on fishery dependent communities. Day 3 speakers presented studies of ecosystem level impacts of climate change and results from regional assessments of climate change. Day 4 focused on studies that formally linked climate change projections to assessments of the performance of management strategies. These 4 days provided a global view of the implications of climate change on marine ecosystems.

Anne Hollowed gave an oral presentation titled “Modeling Fish and Shellfish Responses to Climate Change: Trade-offs in Model Complexity.” She recognized that the marine science community has applied numerous techniques to project the effects of climate change on marine ecosystems and the responses of fishery dependent communities to these ecosystem changes. Considerable progress has already been made in coupling nutrient, phytoplankton and zooplankton into physical models using the existing Global Climate Model and Earth System Models. There is considerable interest in extending this capability to include commercially exploited fish and shellfish. Fish and shellfish exhibit complex responses to changes in the distribution and abundance of prey, competitors, and predators. Incorporation of these complex processes will come at a high computational and operational cost. She compared the costs and benefits of different methods for modeling fish and shellfish responses to climate change on a global scale. A variety of different modeling approaches were considered including: minimally realistic trophic energy transfers, size spectrum models, single species and multispecies stock assessment models, whole ecosystem models, and spatially explicit coupled-biophysical models (e.g. NEMURO-FISH), and spatially explicit gradient tracking models.

Management strategy evaluation for Gulf of Alaska pollock (Theragra chalcogramma) fishery: how persistent are the environmental-recruitment links? Z. Teresa Amar and Martin W. Dorn

A management strategy evaluation for the Gulf of Alaska pollock fishery was performed based on data through 2005. One of the sources of error and uncertainty in the previous analysis included links between environmental indices and age-1 recruitment. The results suggested that winter precipitation and summer sea surface temperature (SST) had a positive impact and spring and autumn SST had a negative impact on recruitment when the normalized indices were included to account for some recruitment variability; these findings matched results from other studies. It is useful to reexamine these environmental recruitment relationships after new data have been collected to assess how robust they are. This study includes six additional years of stock assessment and environmental data and examines whether the environmental recruitment links, suggested previously, have persisted. This study also extends the previous operating model configuration by considering additional local- and basin-scale environmental covariates which were available for the historical period and can be obtained from downscaled IPCC models output. Environmental recruitment relationships were evaluated with cross-validation outside of the operating model, and a set of parsimonious models which explained a considerable amount of the recruitment variance were included in the operating model to generate future recruitment based on IPCC model output.

By Anne Hollowed, Teresa Amar, and Paul Spencer

Projected spatial distributions for eastern Bering Sea arrowtooth flounder under simulated climate scenarios, with implications for predation

Paul D. Spencer, Nicholas A. Bond, Anne B. Hollowed and Franz J. Mueter

Empirical relationships between the extent of the eastern Bering Sea shell summer cold pool (bottom water ≤ 2°C) and maximum sea ice extent and sea level pressure allow projections of cold pool area from global climate model simulations. The present study uses these projections to predict future spatial distributions of arrowtooth flounder in the Bering Sea, assuming these distributions are controlled primarily by the cold pool. An inverse relationship between the area occupied by arrowtooth flounder and the cold pool area has been observed from 1982 to 2010. Small cold pool areas and large arrowtooth flounder areas were observed in the warm years of 2005–07, whereas the colder years of 2006–10 have exhibited larger cold pool areas and smaller arrowtooth flounder areas. Projections of cold pool area from 2010 to 2050 based upon 15 International Panel on Climate Change (IPCC) model runs show a wide range of variability but an overall decreasing trend, resulting in the median arrowtooth flounder area across the 15 IPCC models increasing from 144,000 km2 in 2010 to 160,000 km2 in 2050. Changes in the spatial distribution of arrowtooth flounder relative to other species can affect their consumption of prey, of which age-1 and -2 walleye pollock comprise a large portion. The relationship between the area occupied within various EBS subareas and cold pool extent can be explored for arrowtooth flounder and walleye pollock in order to project future spatial distributions and assess the potential impact of arrowtooth predation on pollock.
Workshop on Strategies for Implementing Management Strategy Evaluations

During the first week of June, colleagues from the Alaska and Northwest Fisheries Science Centers, the University of Washington, and the Chilean fisheries agency INPESCA (Instituto de Investigación Pesquera) convened an informal technical workshop on methods for developing management strategy evaluations (MSEs). The workshop provided a forum for a variety of case studies including Bering Sea yellowfin sole and Chilean hake. Additional overviews on methods used for Pacific sardine and Gulf of Alaska pollock were also presented. Approaches for modifying current models within an MSE context were reviewed and developed. This included co-converting “estimation models” into “operating models” that can be tested over a broad range of alternative hypotheses and sources of estimation uncertainty. In particular, the workshop participants developed code to generically call operating models which will then provide output that can be processed and evaluated with estimation models (and by extension catch specification/control rules). A side benefit of this exercise was honing skills in simulating data from known population dynamics parameters to test assessment model estimation performance.

Activities focused on two main topics: 1) Ways to condition an operating model that reflects (to the extent practical) uncertainty in the resource dynamics with the ability to generate new data (given a future catch level) and 2) testing the robustness of control rules (quota specification processes) given new data sequences arising from the operating model. Ideally, operating models should reflect the uncertainty of processes and measurement errors for the stock in question. One method is to “grid” over different structural models (and use the point estimates obtained). This was contrasted with a separate technique in which operating model simulations are derived from Markov chain Monte Carlo (MCMC) estimates of the posterior probability densities. The group also developed and reviewed a hybrid approach which used MCMC-derived posterior distributions for different model configurations (fixed values of stock recruitment steepness). With the generous assistance and expertise from NWFSC scientists, methods for simulating data using the stock synthesis program (using the R package rks) were developed. For further details and technical documentation, contact James lanelli (Jim.lanelli@noaa.gov).

By James lanelli

De Robertis, A., and E.D. Cokelet.


Heard, W.R.


Hulsom, P.-J.F., D.H. Hanselman, and T.J. Quinn II.

Jensen, P.C., and P. Bentzen.


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

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