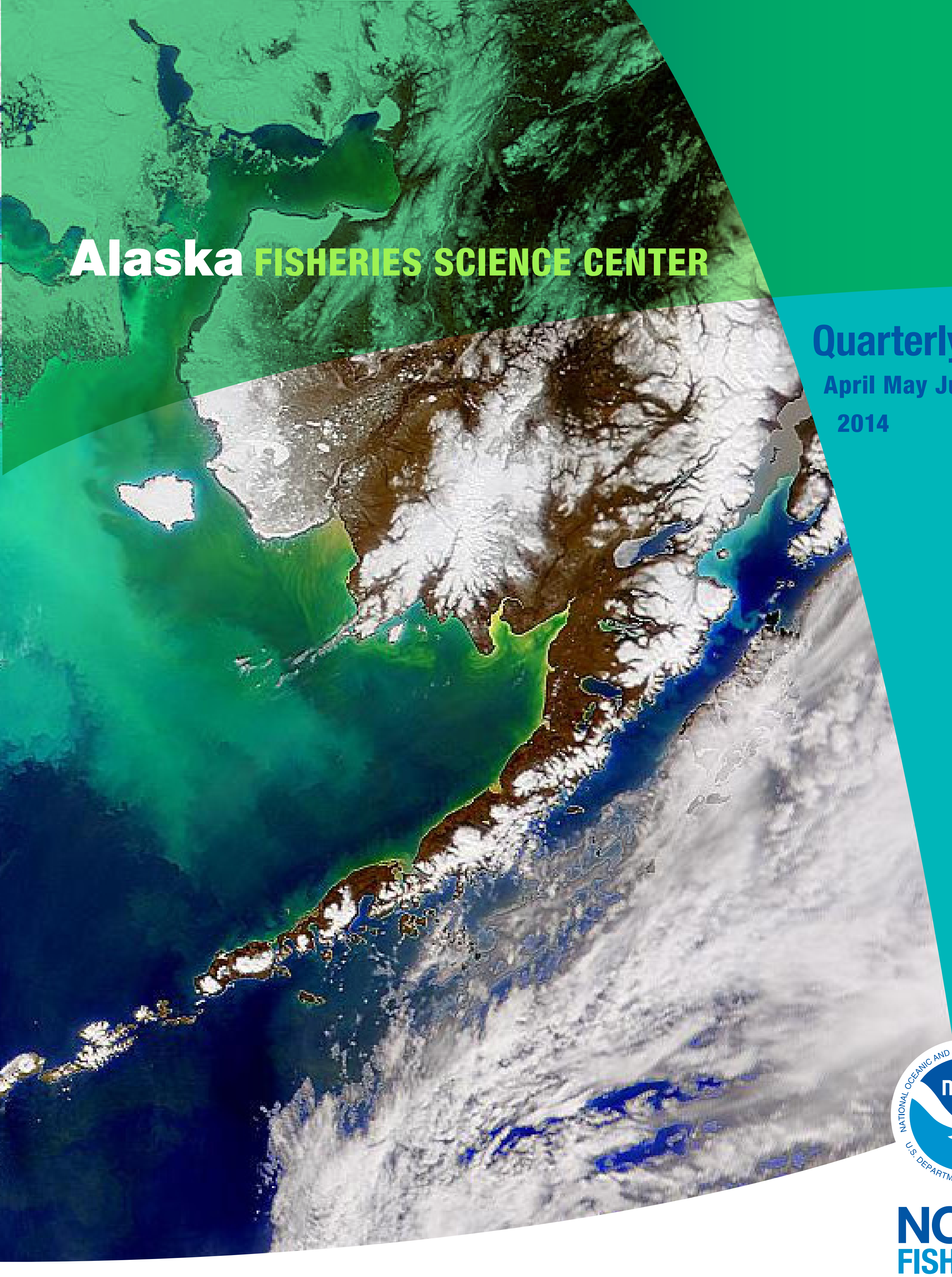

Alaska FISHERIES SCIENCE CENTER

Quarterly Report

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2014

NOAA FISHERIES

Spring and Fall Phytoplankton Blooms In the Eastern Bering Sea

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

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Cover. Image taken on April 25, 1998, showing the coccolithophore bloom in the Bering Sea. This is not a false-color image: the greenish color is caused by the high concentration of phytoplankton.
Photo NASA SeaWiFS (Broerse et al. 2003 , Continental Shelf Research, 23, 1579-1596)

NOAA FISHERIES

Spring and Fall Phytoplankton Blooms in the Eastern Bering Sea During 1995–2011

Michael F. Sigler, Phyllis J. Stabeno, Lisa B. Eisner, Jeffrey M. Napp, Franz J. Mueter

Introduction

The timing and magnitude of phytoplankton blooms in subarctic ecosystems often strongly influence the amount of energy transferred through subsequent trophic pathways. In the southeastern Bering Sea, spring bloom timing has been linked to production of large crustacean zooplankton and walleye pollock (*Gadus chalcogrammus*); if ice is present after mid-March, an early ice-associated bloom occurs there; otherwise a spring bloom usually occurs in May. Although spring bloom timing is well-characterized in the southeastern part of the shelf, less is known about the spring bloom elsewhere in the eastern Bering Sea, as well as the characteristics of the fall bloom.

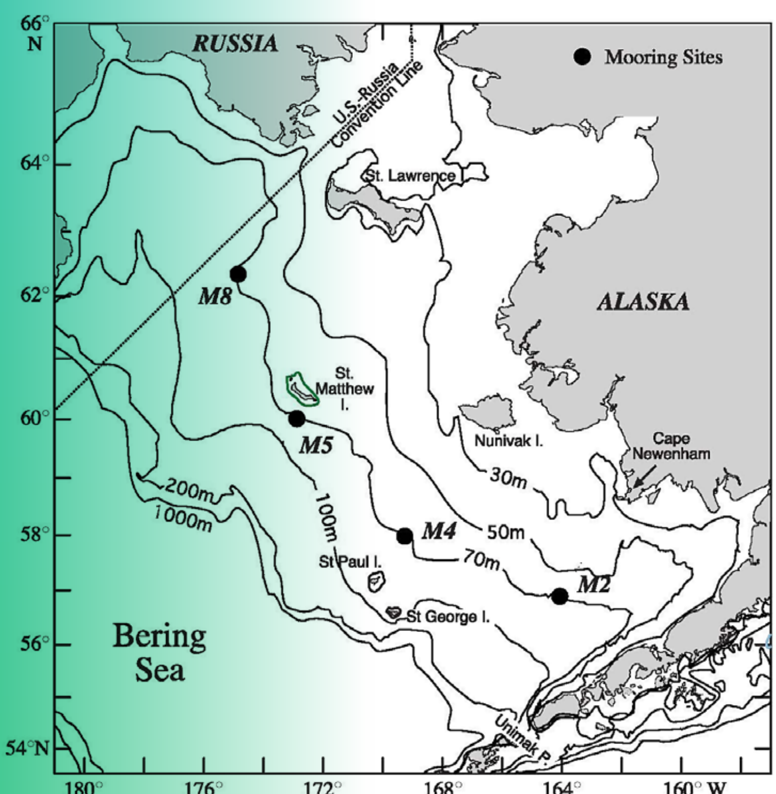

Figure 1. Study area and mooring locations.

The eastern Bering Sea is dominated by a broad continental shelf (~ 500 km wide), a large part of which is ice-covered during winter, with the maximum extent varying more than 100 km among years. In ice-covered areas, the seasonal cycle of primary production begins with ice algae (primarily large diatoms), which begin to grow in the spring when light level becomes adequate. Ice algae are adapted to lower light levels than pelagic phytoplankton and grow within the ice and at the ice–water interface depending on the amount of overlying snow cover. Ice algae begin to grow in mid-February in the Bering Sea and may provide an early concentrated food source for zooplankton.

Phytoplankton in the Bering Sea exhibit net growth in the spring once the water becomes stratified and the mixed layer is shallower than the critical depth. Prior to this, phytoplankton are considered to be light-limited, but have adequate nutrients due to the advection of nutrient-rich slope water onto the shelf during the previous winter, which is mixed throughout the water column; nutrient recycling on the shelf also is important. The phytoplankton spring bloom typically ends when the surface nutrient supply is exhausted and phytoplankton growth becomes nutrient limited (typically below 1 µM nitrate). Grazing pressure from mesozooplankton and microzooplankton also increases as the spring progresses, which can reduce the net accumulation of phytoplankton standing stocks.

In the summer, phytoplankton concentration in the surface mixed layer is typically low due to nutrient limitation and continued grazing pressure. Episodic wind events can break down stratification and mix nutrients and viable phytoplankton cells to the surface during this period. During fall, increased frequency and intensity of storms and overall cooling of the water column reduces stratification and deepens the mixed layer so that nutrients are mixed to the surface to fuel fall phytoplankton blooms. The fall bloom ends when phytoplankton become light-limited, due to decreased day length and deepening of the mixed layer.

In this article we focus on the middle domain of the eastern Bering Sea shelf where four oceanographic moorings have been located. The measurements on the moorings include temperature and chlorophyll *a* fluorescence. In summer, the middle domain is strongly stratified into two layers, with a wind-mixed upper layer and a tidally-mixed lower layer. The middle domain typically extends from the 50-m isobath to the 100-m isobath and is bounded by oceanic fronts or transition zones. In winter, the middle domain is usually well mixed and cold, with a large part (> 50%) ice-covered. These four oceanographic moorings provide the longest daily record of in situ oceanographic measurements in the eastern Bering Sea. This article describes the first examination of the chlorophyll a fluorescence data, excepting previous analyses of the spring bloom at the southern-most mooring. In this article our objectives are to characterize spring and fall blooms over the eastern Bering Sea middle shelf; relate their timing and strength to physical characteristics including spring ice retreat and fall overturn; and discuss some implications of these results for one of the large crustacean zooplankton taxa characteristic of that domain (*Calanus* spp.).

Data and methods

Four oceanographic moorings have been deployed along the 70-m depth contour of the eastern Bering Sea shelf, with two southern locations sampled almost continually since 1995 (M2) and 1999 (M4) and two northern locations since 2004 (M8) and 2005 (M5) (Fig. 1). Data collected by instruments on the moorings included temperature (miniature temperature recorders, SeaBird SBE-37 and SBE-39) and chlorophyll *a* fluorescence (WET Labs DLSB ECO Fluorometer). A transition to fluorometer sensors with wipers that sharply reduced fouling occurred during 2001–04.

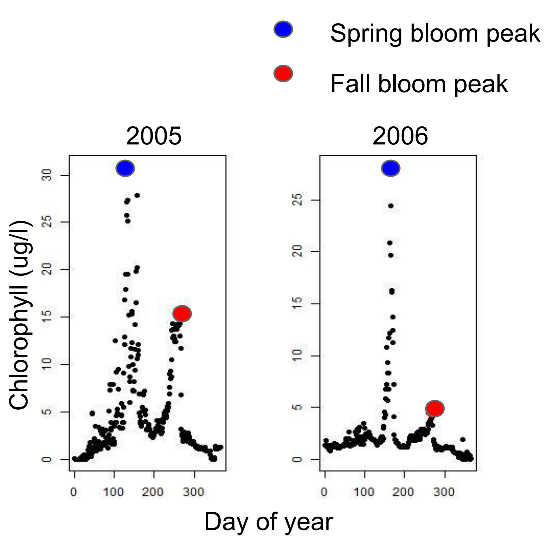

Figure 2. Example annual records of chlorophyll a values with spring (blue circle) and fall (red circle) blooms marked.

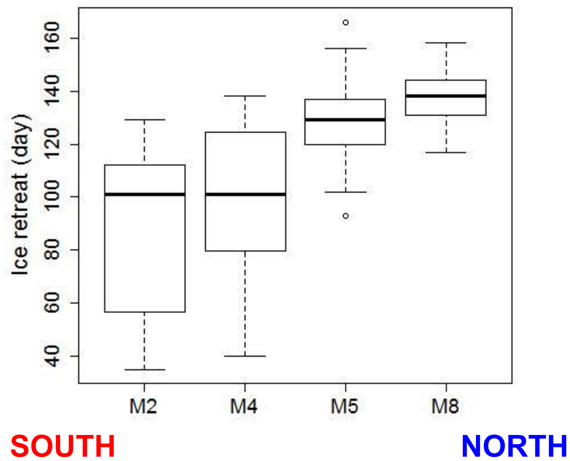

Figure 3. A boxplot of ice retreat (day) by mooring. The box extends from the first quartile to the third quartile, the heavy line dividing the box is the median and the whiskers arethe smallest and largest values. The number of years with ice present were 12 (M2), 15 (M4), 17 (M5) and 17 (M8).

Data were collected at least hourly. For consistency, our analyses focus on data recorded at 11 m (or the shallowest instrument at M5 (15 m) and M8 (20 m) during autumn, winter, and early spring).

Two sources of sea-ice data were used. The first source was the National Ice Center (NIC), with data available from 1972 to 2005; the second source was the Advanced Microwave Scanning Radiometer EOS (AMSR), with data available from 2002 to 2012. These two data sets provide data over the entire period (1972–2012) for which high-quality data on sea-ice extent and areal concentration are available. To examine how the ice cover varies along the 70-m isobath, a 100-km by 100-km box was defined around each of our biophysical moorings (M2, M4, M5, and M8) maintained by NOAA. AMSR and NIC data overlap during the 4-year period 2002-05, during which time they have very similar values. To span the period 1972–2012, we used both NIC and AMSR data, using the average value in the overlap years to derive the annual cycle of percent ice cover for each mooring location.

Winds were estimated using daily data from the National Centers for Environmental Prediction (NCEP)/National Center for Atmospheric Research (NCAR) Reanalysis; wind velocity was interpolated to the locations of the four moorings. The daily winds from the reanalysis are reliable in this region based on a comparison to independent buoy measurements from 1995 to 2000.

Data analysis

Ice cover for each mooring and year was examined to determine if ice was present at any time that winter or spring and if present, when the ice retreated for the last time. Ice retreat was considered to have occurred when ice cover fell below 15% for the last time during that spring. The temperature records for each mooring and year were examined to determine 1) when the ocean began warming following ice retreat; and 2) when fall overturn occurred. When ice was present the temperature was approximately –1.7°C. Warming was considered to have started when the near surface temperature rose above –1°C for the last time that spring. Fall overturn was considered to have occurred once temperature fell 2°C below the summer maximum.

Chlorophyll *a* values for each mooring and year were examined to determine the time and magnitude of the maximum value in spring and fall. These records were plotted and the times and magnitudes of the spring and fall blooms were assigned (Fig. 2). Each year, the spring bloom was assigned to the maximum value before day 180 (ca. June 27) and the fall bloom was assigned to the maximum value after day 210 (ca. July 27). In some years the data record was discontinuous and the maximum value could not be determined.

Results

Ice was present for about two out of three years at M2 (12 of 17), nearly all years at M4 (15 of 17), and all years at M5 and M8 (17 of 17). When ice was present, retreat was significantly (ANOVA, $p < 0.001$, df = 3, 57) earlier in the south (mean M2: day 88; M4: 99; M5: 130; M8: 138) (Fig. 3). In some years when ice was present, retreat occurred before mid-March (M2 during 1998, 2000, 2002, 2006 and M4 during 2000 and 2002). Ice was absent at M2 during 1996, 2001, and 2003–05 and at M4 during 2001 and 2005. Ice presence reduced ocean temperature below -1°C in all cases but one (ice was present at M2 in 2002, but for only 11 days, and minimum temperature was -0.1°C).

During years when ice was absent (or was present, but retreated before mid-March), the spring bloom maximum occurred in late May to early June (average day 148, SE= 3.5, n = 11) (Fig. 4). This pattern occurred for M2 and M4 but not M5 or M8 where ice always was present after mid-March (Fig. 5). There was no statistically significant difference in timing of the spring bloom maximum in years when ice was absent (average day 141) and when ice was present, but retreated before mid-March (average day 153) (two-way t-test, df= 9, p= 0.10). During years when ice was absent or retreated before mid-March, spring bloom maximum averaged 19 mg Chl l^{-1} (log-transformed, SE=1.2, n =11). There was no statistically significant difference in spring bloom maximum in years when ice was absent (average 25 mg Chl l^{-1}) and when ice retreated before mid-March (average 15 mg Chl l^{-1}) (log-transformed, two-way t-test, df=9, p =0.14).

In contrast to the late May to early June timing of the spring bloom in years when ice was absent or retreated early, if ice was present after mid-March (day 75), an ice-associated bloom occurred between early April and mid-June, and the bloom timing was related to ice retreat timing, regardless of mooring. Later blooms occurred when ice retreat was later (linear regression, y-intercept=53, slope =0.66, df =1, 24, p <0.001) (Fig. 6). This relationship implies that bloom day is 119 when ice retreat occurs on day 100, 152 when ice retreat occurs on day 150, and 172 when ice retreat occurs on day 180. There was no statistically significant difference in spring bloom magnitude when ice was present, but retreated before mid-March or ice was absent (average 19 mg Chl l^{-1}) and when ice was present after mid-March (average 17 mg Chl l^{-1}) (log-transformed, two-way t-test, df =35, p =0.70); the overall average spring bloom magnitude was 17 mg Chl l^{-1} (log-transformed, SE =1.2, n = 37).

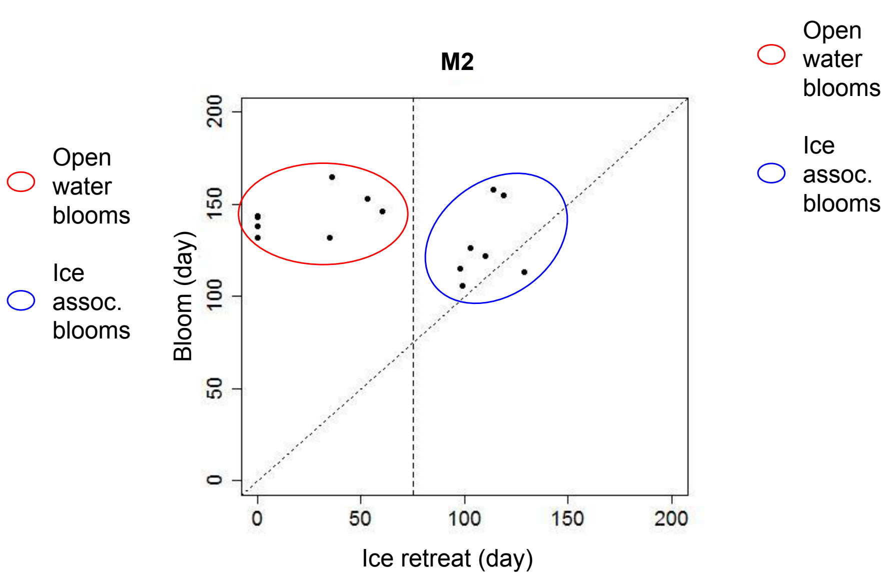

Figure 4. Scatterplot of spring bloom maximum (day) versus ice retreat (day) for mooring M2. If ice was absent that year, then the ice retreat date is zero. The diagonal dashed line is the 1:1 line to compare timings of spring bloom and ice retreat. The vertical dashed line is March 15. The red oval encloses open water blooms and the blue oval encloses ice-associated blooms.

Fall overturn timing was similar among moorings on average (M2 mean was day 259; M4: 261; M5: 259; M8: 268 (ANOVA, df = 3, 34, p = 0.49)), but was more variable at M2 and M4. Fall bloom timing was similar among moorings (M2 mean: day 276; M4: 277; M5: 258; M8: 281) (ANOVA, p = 0.32, df = 3, 29). Fall bloom magnitude also was similar among moorings (ANOVA, log-transform, p = 0.93, df = 3, 30). On average, the fall bloom occurred on day 274 (late September) (SE = 4.2, n = 33) with an average chlorophyll value of 8 mg Chl l^{-1} (SE = 1.2, n = 34).

The magnitudes of the spring and fall blooms were correlated (Pearson's r= 0.46, df = 28, p = 0.011, log-transformed values) (Fig. 7). The interval of time between the spring and fall blooms ranged from about 4–6 months, with longer intervals occurring for earlier spring blooms (linear regression, intercept=294, slope=- 1.16, df= 1, 27, p<0.001) (Fig. 8).

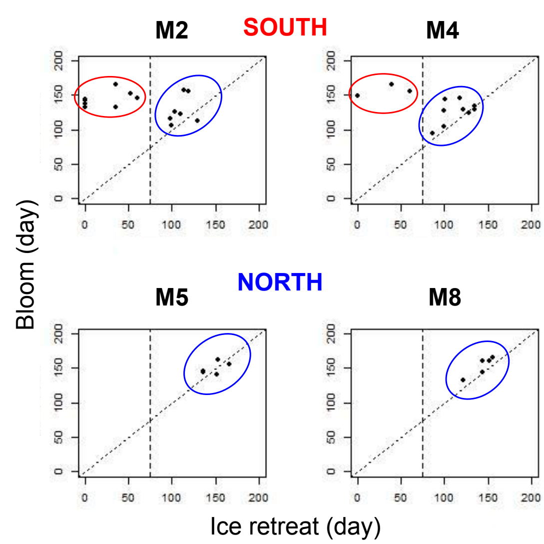

Figure 5. Scatterplot of spring bloom maximum (day) versus ice retreat (day) by mooring. If ice was absent that year, then the ice retreat date is zero. The diagonal dashed line is the 1:1 line to compare timings of spring bloom and ice retreat. The vertical dashed line is March 15. The red oval encloses open water blooms and the blue oval encloses ice-associated blooms.

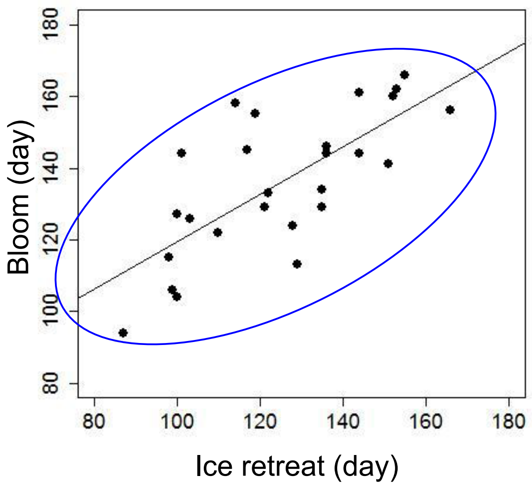

Figure 6. Scatterplot of the observed (number) and fitted (line, based on simple linear regression, y-intercept=53, slope=0.66, df=1, 24, p<0.01) values of spring bloom maximum (day) versus ice retreat (day) for all moorings when ice was present after March 15. The number indicates mooring number.

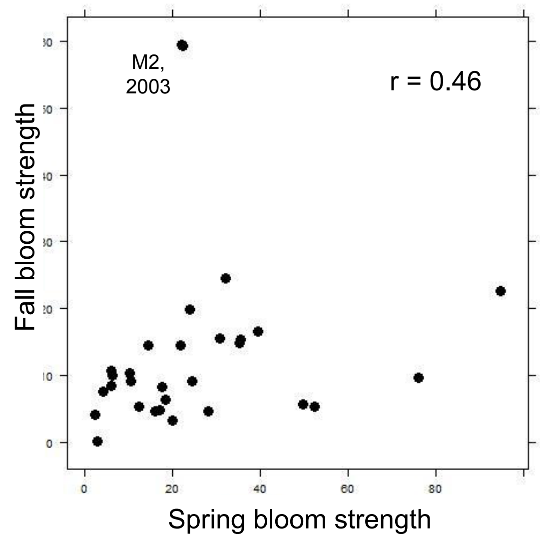

Figure 7. Scatterplot of maximum spring bloom magnitude and maximum fall bloom magnitude. The number indicates mooring number.

Discussion

Spring

We found that in the eastern Bering Sea, if ice was present after mid-March, spring bloom timing was related to ice retreat timing; if ice was absent or retreats before mid-March, a spring bloom usually occurred in May or early June. In general, ice-associated phytoplankton blooms are observed near the retreating ice edge on shipboard surveys and in ocean color data, due to melting ice increasing the stability of the water column. While the spring bloom usually moves northward as the eastern Bering Sea becomes ice free, sometimes ice melts in the north before disappearing farther south and a spring bloom occurs in the northern ice-free area before it occurs in the south if light levels are sufficient (e.g., 2010). Percent ice cover also influences whether or not ice-associated blooms occur by modulating both light and stratification. The relationship between the timing of the spring bloom and ice retreat when ice retreat occurred after mid-March was statistically significant for the eastern Bering Sea (pooled data from the north and south; Fig. 6).

We summarize these findings on spring bloom timing and ice retreat timing as follows (Fig. 9). If ice retreats after mid-March, an ice-associated bloom occurs; this pattern applies throughout the eastern Bering Sea. If the ice retreats early (before mid-March), there is no ice- associated bloom because sunlight is insufficient to initiate an ice-associated bloom. To date, early ice retreat occurs only in the southeastern Bering Sea and not in the northern Bering Sea; this pattern of persistent ice in the northern Bering Sea is expected to continue into the foreseeable future. An open-water bloom occurs if ice retreats before March 15 or ice is absent; this pattern applies only in the southeastern Bering Sea.

Fall

A fall bloom commonly occurred in both the northern and southeastern Bering Sea, on average in late September. Winds at M2, M4, M5, and M8 are significantly correlated, which will tend to synchronize fall blooms, as was observed. However, bloom timing was not significantly related to either storm or fall overturn timing. The lack of a significant effect was unexpected; however a timing effect for the fall bloom may be difficult to detect because timing is affected by several interacting factors including wind strength, stratification, fall cooling, and light level. For example, fall overturn requires strong winds, but once cooling begins in late September and early October, less wind energy is necessary to overturn the ocean. A fall bloom also depends on sufficient light, introduction of nutrients from below the pycnocline, short periods of stabilization that allow phytoplankton to remain in the sunlit waters and grow, and may be influenced by zooplankton grazing.

Our mooring data and previous middle-shelf observations indicated that the magnitudes of fall blooms were weaker than spring blooms on average. It may be that nutrient supply rates are limiting (e.g., storm mixing) and/or the accumulation of chlorophyll *a* is limited by grazing. For instance, if the lower layer has 20 µM of nitrate and the surface mixed layer is 20 m deep and depleted of nitrate, which are typical conditions during summer, then deepening the mixed layer by 5 m will result in only 4 µM of nitrate, compared to 18 µM available for consumption in the top 20 m of water column in spring. In addition, variations in chlorophyll *a* reflect the result of multiple processes including phytoplankton growth, grazing, sinking, and advection. Chlorophyll *a* will not increase until cell growth exceeds losses by grazing and other factors. While grazing impact has been measured for spring, grazing impact has not been measured for fall, so comparing grazing pressure on spring and fall blooms is not possible. Finally, phytoplankton physiological status and species composition can impact bloom intensity.

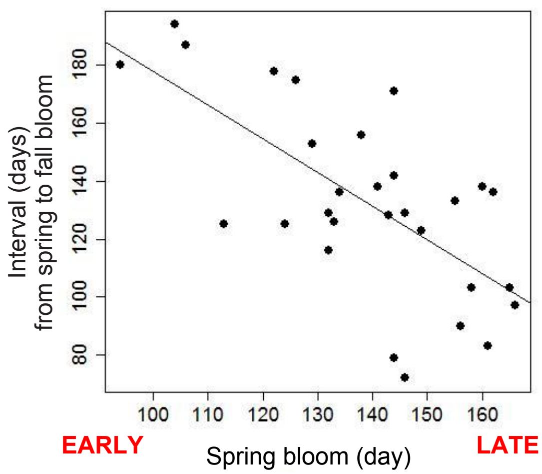

Figure 8. Scatterplot of observed (number) and fitted (line, based on linear regression, intercept=204, slope=-1.16, df=1, 27, 0<0.001) values for all moorings. The y-axis is the interval between the spring and fall bloom maximum (days). The x-axis is the spring bloom maximum (day). The number indicates mooring number.

Spring/fall comparisons

Spring and fall bloom magnitudes were related, implying that a common factor influences spring and fall primary production (e.g., overwinter replenishment of nutrients). The fall bloom may be linked to the spring bloom by the fraction of spring bloom organic matter that sinks to the benthos, is remineralized, and ultimately is reintroduced to the euphotic zone during convection in the fall. In addition, this relationship likely amplifies secondary production during good years (both spring and fall blooms tend to be strong) and vice versa during bad years (both spring and fall blooms tend to be weak). An analysis of nutrient information, comparing spring–fall differences by year, would help us to understand the mechanism for this relationship.

The fall bloom occurred in late September on average, and the timing was less variable than for the spring bloom (varies over ~ 60-day compared to ~ 120-day period) regardless of location, so the spring–fall interval largely depends on spring bloom timing. In the northern Bering Sea, where ice is present every year and on average retreats in late May (Fig. 3), the interval typically lasted 4 months (Fig. 8). The interval also typically lasted 4 months in the southeastern Bering Sea in years when ice was absent or retreated before March 15. In contrast, the interval lasted up to 6 months in the southeastern Bering Sea in years when ice was present after March 15, but retreated soon thereafter.

Biological implications

Spring bloom timing predictably varied between early April and mid-June depending on ice presence/absence and ice retreat timing. Thus the secondary community (zooplankton species) that benefits will depend on how close timing of their spring energy-intensive needs, such as reproduction and awakening from winter diapauses, matches the timing of the spring bloom. Species that require an early pulse of energy will benefit from years when ice is present but retreats in late March (conditions that tend to result in early April phytoplankton bloom). In contrast, species with a phenology timed for a late energy pulse will benefit from years with no ice (conditions that tend to result in a late May to early June bloom).

These observations also imply that climate, through its connection to the production, transport, and dissipation of sea ice, has the potential to affect the success of zooplankton populations and the strength of coupling between primary production and higher trophic levels. For example, the large crustacean zooplankton taxa *Calanus* spp. may benefit in years when ice is present after March 15 but retreats relatively early (Fig. 10). Spring *Calanus* spp. concentrations in the southeastern Bering Sea were higher in cold years with late ice retreat than in warm years with early ice retreat. Here we simplify *Calanus* spp. life history into four major steps from winter/late spring through the following winter: spawning, metamorphosis, accumulation of depot lipids, and overwintering. The timing of spawning by *Calanus* spp. in the eastern Bering Sea is protracted (from February to May), and the longer that conditions are suitable, the more total eggs each female will produce. Both early and late spawning by *Calanus* spp. females may benefit in cold years with late ice retreat, as reproduction timing then coincides with either the ice algae or the spring bloom. Individuals likely metamorphose from naupliar to copepodite stages during the early spring bloom. It has been hypothesized that metamorphosis is a recruitment bottleneck and that an early spring bloom benefits copepodite recruitment. The spring bloom occurs during April in years when ice is present, but retreats relatively early, which may promote strong recruitment of copepodites. In addition, a cold winter with ice present likely reduces metabolism and lipid utilization by *Calanus* spp. and thus may promote winter survival. Daily respiration rates are 47% higher for average winter bottom temperatures of warm (2°C) versus cold (-1.8°C) years in the southeastern Bering Sea. Overall, three conditions favor *Calanus* spp. production in cold years: the availability of ice algae or an early spring bloom to support egg production, the match of copepodites with the spring bloom for early spawners, and reduced metabolic rates during winter.

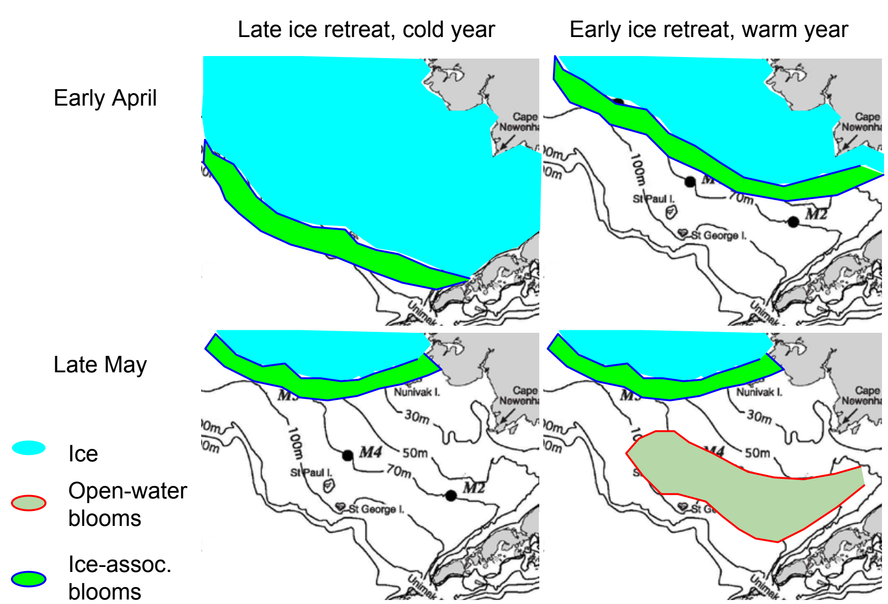

Figure 9. If ice retreats after mid-March, an ice-associated bloom occurs; this pattern applies throughout the eastern Bering Sea. If the ice retreats early (before mid-March), there is no ice-associated bloom because sunlight is insufficient to initiate an ice-associated bloom. An open-water bloom occurs if ice retreats before March 15 or ice is absent; this pattern applies only in the southeastern Bering Sea. This open-water bloom occurs in late May.

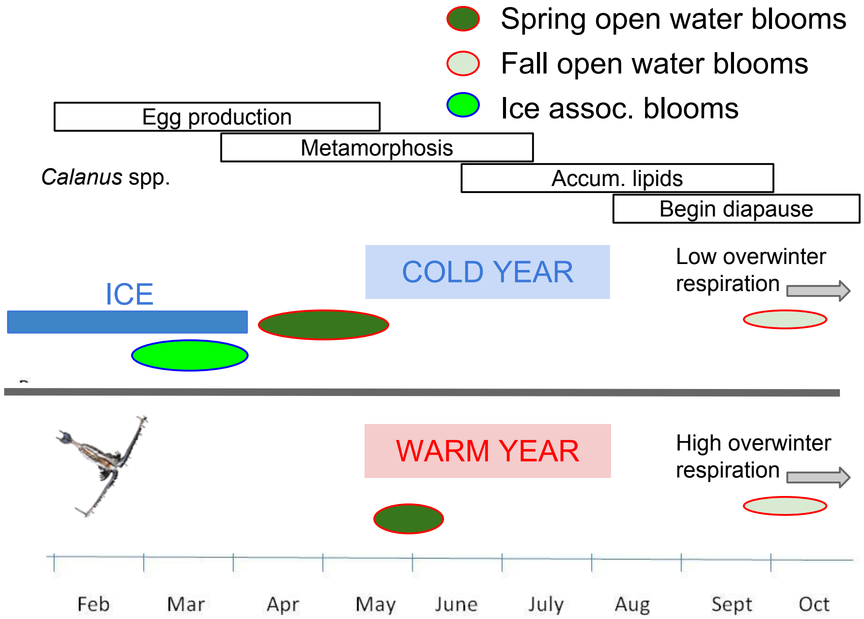

Figure 10. Timing of *Calanus* spp. reproduction relative to the presence of ice and ice algae, and the spring and fall blooms. The *Calanus* spp. life history is simplified and the timings are approximate. The blue rectangle is the period of ice cover. The dark green oval is the period for the spring bloom and the light green oval is the period for the fall bloom. Ice algae blooms occur during ice cover and ice retreat (bright green oval) and begin as early as mid-February.

Summary

The timing and magnitude of phytoplankton blooms in subarctic ecosystems often strongly influence the amount of energy that is transferred through subsequent trophic pathways. In the eastern Bering Sea, spring bloom timing has been linked to ice retreat timing and production of zooplankton and fish. A large part of the eastern Bering Sea shelf (~ 500 km wide) is ice-covered during winter and spring. Four oceanographic moorings have been deployed along the 70-m depth contour of the eastern Bering Sea shelf with the southern location occupied annually since 1995, the two northern locations since 2004, and the remaining location since 2001. Chlorophyll *a* fluorescence data from the four moorings provide 37 realizations of a spring bloom and 33 realizations of a fall bloom. We found that in the eastern Bering Sea, if ice was present after mid-March, spring bloom timing was related to ice retreat timing ($p < 0.001$, df = 1, 24); if ice was absent or retreated before mid-March, a spring bloom usually occurred in May or early June (average day 148, SE = 3.5, $n = 11$). A fall bloom also commonly occurred, usually in late September (average day 274, SE = 4.2, $n = 33$), and its timing was not significantly related to the timing of storms ($p = 0.88$, df = 1, 27) or fall water column overturn ($p = 0.49$, df = 1, 27). The magnitudes of the spring and fall blooms were correlated ($p = 0.011$, df = 28). The interval between the spring and fall blooms varied between 4 to 6 months depending on year and location. We present a hypothesis to explain how the large crustacean zooplankton taxa *Calanus* spp. likely respond to variation in the interval between blooms (spring to fall and fall to spring).

Conclusions

- In the eastern Bering Sea, if ice is present after mid-March, spring bloom timing is related to ice retreat timing; if ice is absent or retreats before mid-March, a spring bloom usually occurs in May or early June.
- Spring and fall bloom magnitudes are related, implying that a common factor influences spring and fall primary production.
- We hypothesize that large crustacean zooplankton such as *Calanus* spp. benefit from cold, icy winters in the southeastern Bering Sea because ice algae or ice-associated phytoplankton blooms provide an early spring food source, and respiration rates are lower during cold winters.

Additional Reading

Baier, C.T., Napp, J.M., 2003. Climate-induced variability in *Calanus marshallae* populations. J. Plankton Res. 25, 771–782.

Coyle, K.O., Eisner, L.B., Mueter, F.J., Pinchuk, A.I., Janout, M.A., Cieciel, K.D., Farley, E.V., Andrews, A.G., 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the Oscillating Control Hypothesis. Fish. Oceanogr. 20, 139–156.

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Sigler, M.F., Stabeno, P.J., Eisner, L.B., Napp, J.M., Mueter, F.J. 2014. Spring and fall phytoplankton blooms in a productive subarctic ecosystem, the eastern Bering Sea, during 1995-2011. Deep-Sea Res. II

Stabeno, P.J., Kachel, N.B., Moore, S.E., Napp, J.M., Sigler, M.F., Yamaguchi, A., Zerbini, A.N. 2012. Comparison of warm and cold years on the southeastern Bering Sea shelf and some implications for the ecosystem. Deep-Sea Res. 65-70, 31-45. Ecosystem Monitoring and Assessment Program

Ecosystem Monitoring & Assessment Program

Southeast Coastal Monitoring Survey Data as Indicators for the Recruitment of Gulf of Alaska Sablefish

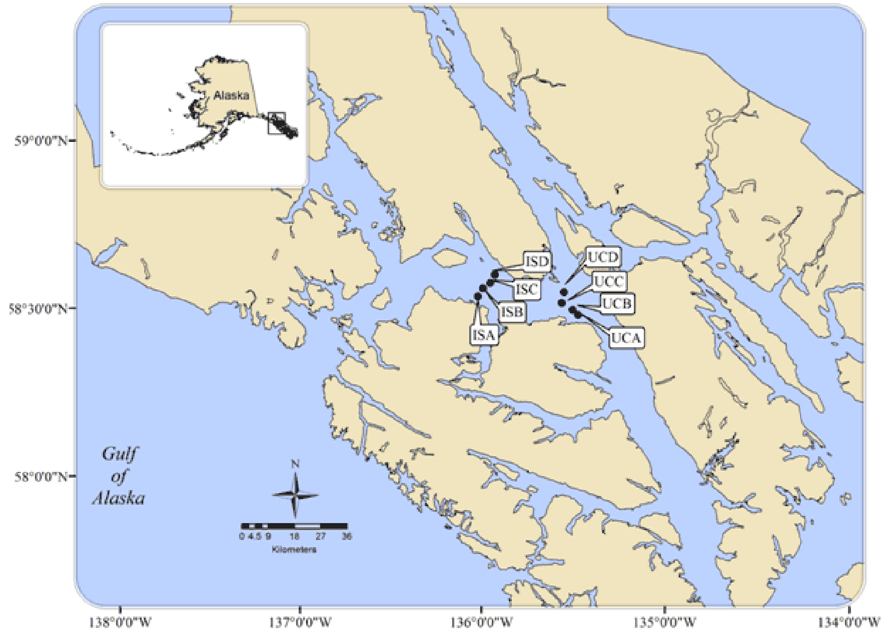


Figure 1. Southeast Alaska Coastal Monitoring survey station locations. Data from ISB was used in our analysis.

Scientists within the AFSC's Ecosystem Monitoring and Assessment and Marine Ecology Stock Assessment programs are exploring the application of fish and oceanographic survey data to understand variability in the recruitment of sablefish (Anoplopoma fimbria). The data come from the Southeast Alaska Coastal Monitoring project, which is conducted annually (1999 to present) within inside waters of northern Southeast Alaska (Fig. 1), an important pelagic rearing habitat shared by juvenile (age-0) salmon and young sablefish (age-0 to age-2).

In a linear regression model, the stock assessment estimates of age-2 sablefish abundance were described as a function of sea temperature and chlorophyll during the age-0 stage of sablefish (Fig. 2). Chlorophyll was the strongest predictor of sablefish recruitment ($R^2 = 0.77$; p-value = 0.00009). High chlorophyll values in 2000 and 2008 were associated with high recruitment of age-2 sablefish in 2002 and 2010. Sea temperature explained an additional 9% (R2 = 0.86; p-value = 0.0003) of the variation in age-2 sablefish recruitment.

Residuals of the model had a strong alternating year pattern that may be due to an interaction with pink salmon, which have a 2 year life cycle and are present as juveniles in large numbers in even years along with sablefish.

The addition of a juvenile pink salmon abundance index and a time series predictor in the model helped explain an additional 9% of the variability in sablefish recruitment ($R^2 = 0.97$; p-value = 0.00001) (Fig. 3). Juvenile pink salmon survival served as a proxy for sablefish survival. In addition, higher primary productivity during late summer may index supplementary food supply prior to winter and increased probability for over-wintering survival.

Proxies are being developed for these early life history conditions (late summer bloom and juvenile salmon survival) in order to lengthen the time series of predictor variables and to conduct model validation.

These findings highlight the application of fisheries oceanography survey data of non-target species to represent conditions experienced by a more elusive species in the region, such as sablefish.

By Ellen Yasumiishi

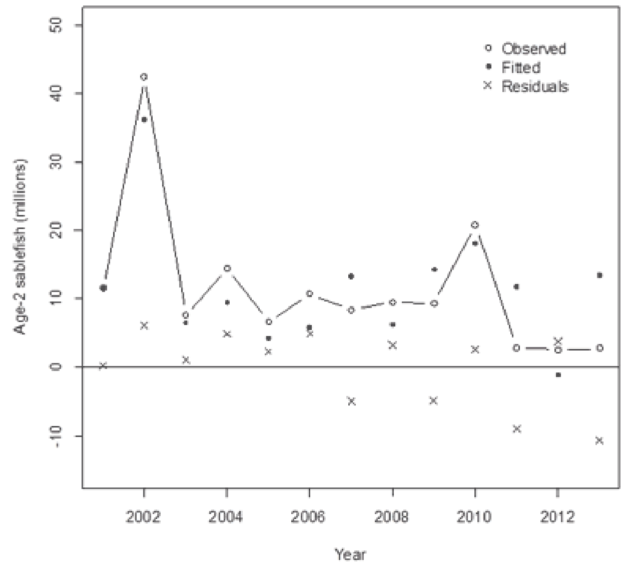


Figure 2. Observed, fitted, and residuals of the joint linear regression model describing age-2 sablefish abundance as a function of chlorophyll a and sea temperature (R2 = 0.77; p-value = 0.00009).

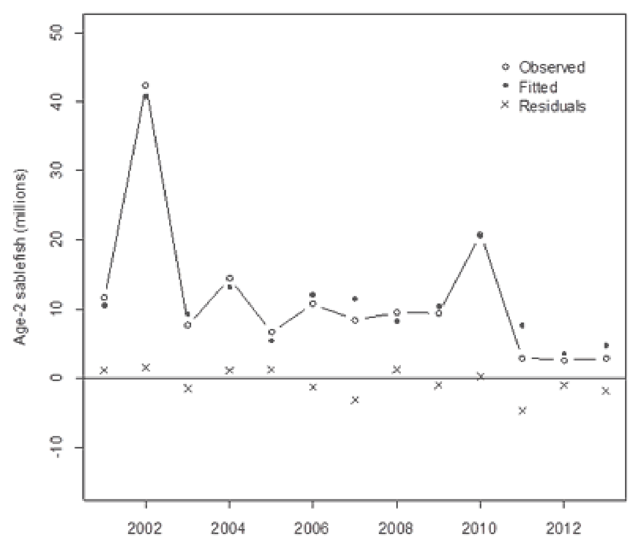


Figure 3. Observed, fitted, and residuals of the joint linear regression and time series error model describing age-2 sablefish abundance as a function of chlorophyll a, sea temperature, juvenile pink salmon abundance index during the age-0 life stage of sablefish, and a 2nd order autoregression process (R2 = 0.97; p-value = 0.00001).


Northern sea nettle, Chrysaora melanaster, caught in surface trawl.

The Jellyfish Monitoring Program at Auke Bay Laboratories

For the last decade, jellyfish have captured the interest of researchers. Because of their ability to quickly increase in numbers and size, jellyfish have the potential to alter food webs through competition and predation and thus, influence the abundance of commercially important species. Jellyfish monitoring work has been incorporated into the fisheries oceanographic project BASIS (Bering Arctic Subarctic Integrated Surveys) in the eastern Bering Sea since 2004; the Chukchi Sea in 2007 and 2011-12; and in 2012 was expanded to the eastern Gulf of Alaska (GOA) after notable jellyfish catches during summer surveys.

The objectives of the jellyfish monitoring program are 1) to identify species composition, 2) to establish yearly relative abundance and biomass indices for those commonly encountered genus/species by area, and 3) to determine potential effects on target fish species as a result of jellyfish interactions. These objectives are designed to be met through quantifying all jellyfish from BASIS net tows and conducting diet and digestion studies for the most dominant species.

The GOA project coordinates annual fisheries and oceanographic studies using a series of surface trawls, oceanographic instrumentation, and zooplankton net tows to investigate ecological conditions and juvenile forage fish in the eastern Gulf of Alaska. It specifically targets commercially important young-of-the-year groundfish and juvenile salmonid species during July-August in federal waters up to 100 miles offshore from the south end of Baranof Island to Kayak Island, Alaska. After jellyfish were observed in notable numbers in the surface trawl catches, protocols were modified in 2011to include detailing speciation, individual weights, and bell diameters.

The five most commonly occurring jellyfish in the GOA project in order of highest biomass are *Chrysaora melanaster*, *Aequorea* spp., *Cyanea capillata*, *Aurelia* spp., and *Staurophora mertensii*. This is similar to the eastern Bering Sea project in terms of composition with both areas recording C. melanaster as the most dominant species in 2013.

The next phase of the jellyfish monitoring program will include collection of individual specimens for digestion and diet work starting in fall 2014, use of a more complete identification guide for trawled jellyfish which will be completed in winter 2014, and expansion of monitoring in the eastern Gulf of Alaska to include additional data collection from the Southeast Coastal Monitoring Project in 2015.

By Kristin Cieciel

Resource Ecology and Ecosystem Modeling Program

Fish Stomach Collection and Lab Analysis

During the second quarter of 2014, Resource Ecology and Ecosystem Modeling (REEM) staff analyzed the contents of 4,589 groundfish stomachs. Laboratory analysis was completed and the resulting data error-checked and loaded into the AFSC's Groundfish Food Habits database, resulting in 9,172 added records. The majority of the samples analyzed during the quarter were walleye pollock from the eastern Bering Sea and arrowtooth flounder from the Gulf of Alaska. Other program highlights include:

- Russel Crandall, a University of Washington School of Aquatic and Fisheries Sciences (SAFS) undergraduate, began working on his Capstone student project.
- A scientist visiting from SAFS, Joseph Bizzarro, is currently working in the REEM stomach lab to identify prey items of Pacific skate species.
- Stomach sampling was performed by fisheries observers on 147 walleye pollock, 44 arrowtooth flounder and 5 Pacific cod from the eastern Bering Sea and Aleutian Islands region.
- Twenty stomach sampling kits for fisheries observers were assembled in Dutch Harbor, Alaska.
- Program outreach activities included presentations and lab tours for the Western Washington University's Multicultural Initiative in the Marine Sciences: Undergraduate Participation (MIMSUP) program. Program staff also gave presentations and led educational activities to groups visiting the NOAA campus during the NOAA Open House on 15-16 May. The REEM educational display and the fish food habits hands-on activities were presented during a visit from the Pacific Science Center's Marine Science Student Camp on 24 June.

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

Congressional Briefing

The Senate Commerce Committee sponsored a Congressional Staff Briefing on 24 June at the Capitol building in Washington DC, organized by Dr. Richard Merrick, entitled *Closing the Data Gaps: Challenges in Stock Assessment Science*. AFSC scientist Kerim Aydin attended and presented results of the Bering Sea Integrated Research Program on integrating climate effects (especially ice) into the stock assessment for walleye pollock.

By Kerim Aydin

BSIERP FEAST 6-Year Project Wrap-Up and Future Work

Delivery of the final report for the Forage Euphausiid Abundance in Space and Time (FEAST) model - part of the Bering Sea Integrated Ecosystem Research Project (BSIERP)- concluded a 6-year multi-disciplinary project which produced 12 peer-reviewed publications (several currently in review) and 31 presentations at international meetings. FEAST has been used to focus some of the fieldwork and started a collaborative framework between field researchers and modelers, a process that has now been implemented at the AFSC across several Divisions and teams as well as NOAA's Pacific Marine Environmental Laboratory (PMEL). FEAST will also be a centerpiece of its strategy developing an Integrated Ecosystem Assessment (IEA) for the Alaska region. This effort, part of NOAA's national IEA program, will not only include regular updates to FEAST but will also use the model as a focus for collaborative fieldwork from disciplines from physics through biology, economics, and social sciences. As IEAs focus on delivering management results, this will serve as a direct conduit for bringing process-oriented fieldwork into the management arena via management strategy analyses, ecosystem indicator development, and improved prediction capabilities both in the short and long term.

By Ivonne Ortiz

The Norway-United States Climate Change and Marine Ecosystems (NUCCME) Workshop

Kirstin Holsman (Joint Institute for the Study of the Atmosphere and Ocean, University of Washington/AFSC) and Mike Sigler (AFSC) attended the Norway-United States Climate Change and Marine Ecosystems (NUCCME) meeting in Norway on 5-9 May. The international workshop is the third in a series of Marine Ecosystems of Norway and the United States (MENU) workshops and was aimed at comparative evaluation of climate effects on arctic and sub-arctic marine ecosystems. Meeting participants split into three working groups loosely centered around: 1) climate projections of primary and secondary productivity and species recruitment; 2) multi-species model projections of climate effects on fisheries; and 3) potential economic and societal consequences of climate change in the two regions. The first two objectives are those of NUCCME/ MENU III while the last fits within the CLIFFIMA-net objectives. Each working-group identified and began writing a subset of paper topics that will compose a special issue of *Climate Change* in 2015. In particular, AFSC researchers Holsman and Sigler are leads on two papers, respectively 1) "A Comparative Approach for Methods of Including Climate Features in Future Projections and Setting of Harvest Control Rules" and 2) "Projected Rcruitment of Bering, Barents, and Norwegian Sea Fish Species Under Climate Change Using ROMS/NPZ Predictions of Future Conditions."

By Kirstin Holsman

Arctic Ecosystem Integrated Survey PI Meeting

Kerim Aydin and Andy Whitehouse participated in the Arctic Ecosystem Integrated Survey (EIS) principal investigator's meeting, 17-19 June in Juneau, Alaska. The goal of the Arctic EIS is to contribute to a comprehensive assessment of oceanography, lower trophic levels, and fish of the northeastern Bering Sea and eastern Chukchi Sea shelf. At this meeting, Kerim and Andy presented results of diet analyses of several fish species collected during various fisheries research surveys.

By Kerim Aydin

Economics & Social Sciences Research Program

Examining the Flow of Revenues from North Pacific Fisheries

The North Pacific fisheries generate close to $2 billion dollars in first-wholesale revenue each year, yet there is no systematic accounting or analysis of the states or cities to where this money flows. In this project we are identifying the main fleets exploiting the North Pacific fisheries and summarizing the revenues earned by the location of residence and hailing port for fleet participants over several years. We hypothesize that the location of residence data for vessel owners is an indicator of where fishing profits are likely to be spent. The hailing port data may be representative of where the vessel obtains a significant portion of its supplies and, potentially, crew members. We are also attempting to identify spatial trends and structural breaks in the distribution of revenues in response to recent management actions. Finally, we hope to examine whether the revenue distribution has consolidated over time. We believe this information will be interesting to the public at large and fishery managers seeking more information on how fleet-level decisions map into the distribution of earnings to different cities and states.

By Ron Felthoven, Chris Anderson and Jenefer Meredith

Assessing the Economic Impacts of 2011 Steller Sea Lion Protective Measures in the Aleutian Islands

One of the primary challenges to fisheries management in Alaska continues to be protecting the endangered Western stock of Steller sea lions. For more than 20 years regulations have restricted fishing effort in the Aleutian Islands (AI), Bering Sea, and Gulf of Alaska. In 2011, additional measures were implemented that further restricted fishing in the AI because of concerns that fishing there is harming the Steller sea lion population. NOAA Fisheries is beginning a new research project that will analyze the costs of the recent 2011 measures implemented in the AI on fishery participants. As part of the analysis, the impact on three fleets will be considered: the Amendment 80 non-pollock multi-species trawl fishery, the non-trawl Pacific cod fishery, and the catcher vessel trawl and non-trawl fisheries. Because regulations have been sequentially implemented over most of the last two decades, the reference point is not the native state of the fishery, but rather a more recent period which will be determined at the start of this research in consultation with NMFS analysts.

By Alan Haynie

Status of Stocks & Multispecies Assessment Program

Successful Atka Mackerel Tagging Cruise in the Western Aleutian Islands

Fisheries Interaction Team (FIT) staff in the Status of Stocks and Multispecies Assessment (SSMA) program participated in a cooperative Atka mackerel (Pleurogrammus monopterygius) tagging research cruise in the central, and western Aleutian Islands (Fig.1) aboard the chartered fishing vessel Morning Star from 17 May to 11 June. The goal of the ongoing tag release-recovery studies is to determine the efficacy of Atka mackerel trawl exclusion zones. The trawl exclusion zones are areas established around Steller sea lion rookeries to protect critical Steller sea lion habitat and prey resources. During the cruise over 20,000 Atka mackerel were tagged and released at four areas in the western Aleutian Islands (Buldir Island, western Aleutian Island Seamounts, Agattu Island, and Ingenstrem Rock) as well as Seguam Pass in the central Aleutian Islands. This tagging study will help to improve our understanding of the rate of exchange of Atka mackerel between open and closed fishing grounds as well as establish baseline data after a 4-year fishing closure in the western Aleutian Islands. The results from the western Aleutian Islands will be compared to Seguam Pass, which has an established time series of Atka mackerel tagging beginning in 2000.

In addition to tagging, secondary objectives of the cruise included conducting a tag-mortality study and collecting biological samples from Atka mackerel. Atka mackerel habitat was also characterized with oceanographic samples and underwater camera tows at each tagging location. Finally, three projects were conducted at the request of other researchers: 1) attempted recovery of moored hydrophones for a killer whale acoustic predation project at National Marine Mammal Laboratory, 2) collection of Atka mackerel and Pacific cod samples for stable isotope and mercury analysis by Lori Rhea at the University of Alaska Fairbanks, and 3) collection of incidental marine mammal and seabird observations.

By Libby Logerwell

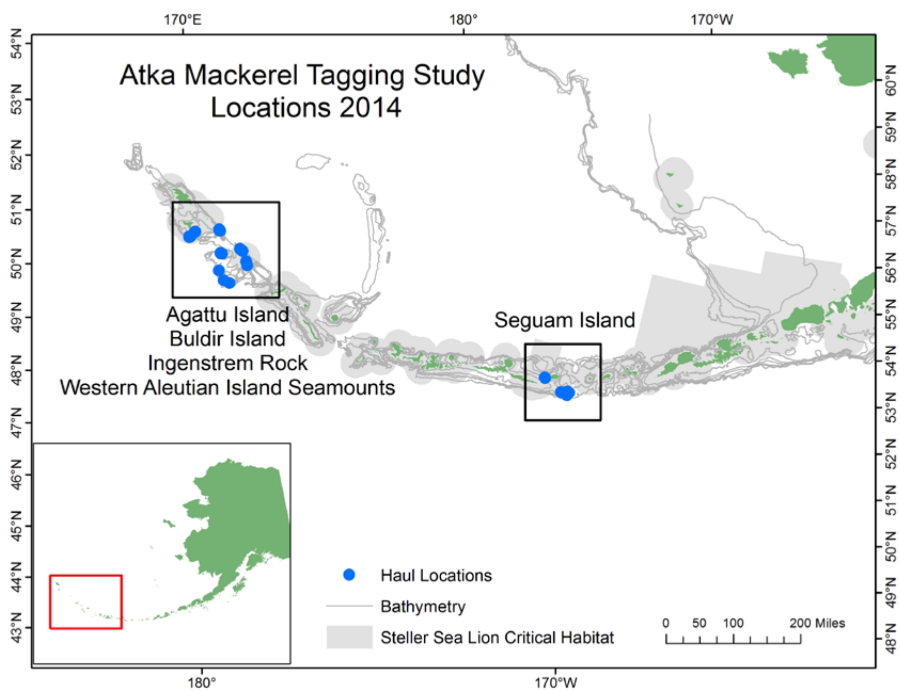


Figure 1. Atka mackerel 2014 tagging study locations in the western Aleutian Islands and at Seguam Pass in the central Aleutian Islands. Haul locations are where Atka mackerel were caught, tagged, and released.

Annual Meeting of the NMFS-Sea Grant Graduate Fellows in Population Dynamics and Economics and Group Tour of the Elwha Dam Removal Project

The NMFS-Sea Grant Graduate Fellows in Population Dynamics and Economics held their annual meeting at the AFSC on 16-18 June 2014. The fellows are Ph.D. students in fisheries population dynamics and economics who have been awarded 2-3 years of funding from NMFS and Sea Grant for their graduate studies. The fellows gather once a year at a NMFS science center to present their most recent research findings. This year, AFSC scientists Ben Fissel and Carey McGilliard helped to organize the annual meeting, and three Center scientists gave presentations in addition to the presentations by the current fellows; Martin Dorn presented the talk "Implementing OFLs and ABCs for data-poor stocks managed by the Pacific Fishery Management Council"; Alan Haynie presented "The Easy Job of Staying Busy as a NOAA Fisheries Economist"; and Steve Ignell gave a welcome speech. Sandra Lowe, Ron Felthoven, and Carey McGilliard participated in a panel discussion held for the fellows to discuss careers in government and academia.

As part of the meeting, NMFS scientists and economists joined the graduate fellows on a tour to learn about the recent removal of two dams from the Elwha River on the Olympic Peninsula of Washington State. The dam removal project is the largest ever undertaken in the United States. The group spoke with four biologists involved in river and plant ecology and restoration. The group visited the river mouth, where a large amount of sediment was deposited following dam removal, creating a new and dynamic beach. Biologists have observed a large increase in the number of Dungeness crab occupying nearshore waters close to the river mouth. The group toured both previous reservoirs, where many native plants are now growing, including cottonwood and Oregon sunshine. Dam removal is complete, but remnants of the dam can be seen from what was previously the Mills Reservoir and will be marked with interpretive signs. A time-lapse video of the dam removal can be viewed online: https://www.youtube.com/watch?v=bUZE7kgXKJc.

By Carey McGilliard

Remnants of the upper Elwha Dam taken from what was previously Mills Reservoir. The dam removal is complete, but remnants of the infrastructure will remain

A meadow that was previously the reservoir associated with the lower dam on the Elwha River. This meadow is being restored by seeding native plants such as cottonwood and Oregon sunshine.

The new beach created by sediment washed out to the mouth of the Elwha River in Washington State as a result of the removal of two dams, the biggest dam removal project in the United States.

The 2014 ICES ECOKNOWS Symposium

The International Council for the Exploration of the Sea (ICES) held the symposium "The Ecological Basis of Risk Analysis for Marine Ecosystems" on 2 – 4 June 2014 in Porvoo, Finland. Other sponsors of the symposium included the North Pacific Marine Science Organization (PICES) and the European Commission's Community Research and Development Information Service (CORDIS) Seventh Framework Programme (FP7). The symposium was organized in close collaboration with the FP7 ECOKNOWS project (http://www.ecoknows.eu/) for improving fisheries science and management by integrating new sources of biological and environmental knowledge with respect to implementing an ecosystem approach to fisheries management.

The goal of the symposium was to review, discuss, and assess methodological approaches, case studies, and outcomes relevant to effective and efficient interdisciplinary marine ecosystems risk analysis, particularly in relation to resource use and risks of overexploitation. By comparing the different scientific fields focusing on marine risks, the symposium explored how science can identify and quantify uncertainty and develop processes that allow better interpretation of uncertainty estimates, leading to management that more effectively and efficiently meets objectives. The themes of the symposium included fisheries management under uncertainty, decision modeling in fisheries management, probabilistic fish stock assessment, oil spill and eutrophication risk analysis, environmental risk assessment for marine areas, and risk analysis in aquaculture. The keynote speakers included Samu Mäntyniemi (FI), Robert Stephenson (CA), and Tony Smith (AU).

There were several talks which mentioned Bayesian approaches, "data poor" methods, and how to communicate risk and uncertainty to stakeholders. Samu Mäntyniemi (FI) talked about the development of a general population dynamics model and case studies were presented in other talks. Anna Kuparinen (FI) has several recent papers in *The ICES Journal of Marine Science* on Allee effects and environmental influences on recruitment. There were comments about model averaging and data weighting; Ian Stewart (US) suggested decreasing the importance of model weighting, as picking the "best" model out of a set of models puts all of the weight on one model implicitly. There were also comments about asking stakeholder groups and decision makers about which tables and figures they find useful. John Mumford's (UK) talk dealt specifically with risk, visualization, and communication; he raised the issues of risk assessment vs. risk perception, how risk changes over time (spatial, temporal, cumulative), and how to express and incorporate uncertainty in the management goals and objectives. Diedre Duggan (UK) talked about developing indicators with stakeholders, and combining indicators and signal detection theory into a tool for decision making. Andrew Edwards (CA) talked about Awatea (software developed by Allan Hicks and Ray Hilborn) and its associated R package, PBSawatea. Javier Ruiz (ES) described a model with finer time scales for environmental influences on early life history stages and coarser time scales for the fishery. Finlay Scott (IT) presented a framework, a4a (assessment for all), for "data moderate" stocks which can run several thousand versions of simple stock assessment models incorporating model and biological uncertainty and alternate hypotheses, and referenced Millar et al. 2014 ICES J Mar Sci for model averaging techniques. Sakari Kuikka (FI) commented that there were few papers on Bayesian economic or bio-economic models and that this may be a deficit when moving towards ecosystem-based fisheries management or integrative modeling and management.

AFSC scientist Teresa A'mar attended the symposium, along with Wesley Patrick (NOAA Fisheries, Office of Sustainable Fisheries), Ian Stewart (International Pacific Halibut Commission), and more than 70 other researchers, primarily from Europe and Canada. In the "Fisheries management under uncertainty" session, Teresa presented the results of the study "The impact of changes in natural mortality on the performance of management strategies for the Gulf of Alaska walleye pollock (*Gadus chalcogrammus*) fishery", which she co-authored with the stock assessment author Martin Dorn. Management strategy evaluation was used to examine the impact of changes over time in natural mortality on the performance of the current management strategy for the Gulf of Alaska walleye pollock fishery. Changes and trends in natural mortality-at-age are a proxy for changes in predation impacts. While the biomass of several walleye pollock predators has been stable or decreasing since the 1970s, arrowtooth flounder biomass has increased significantly. Arrowtooth flounder predation on walleye pollock is predominantly on smaller fish, thus impacting recruitment. The current management strategy was evaluated under several scenarios of changes over time in natural mortality-at-age for young fish. The results suggest that stock size and the associated acceptable biological catch (ABC) may be positively biased (i.e., overestimated) if the true natural mortality-at-age for young fish differs appreciably from the values assumed in the current management strategy.

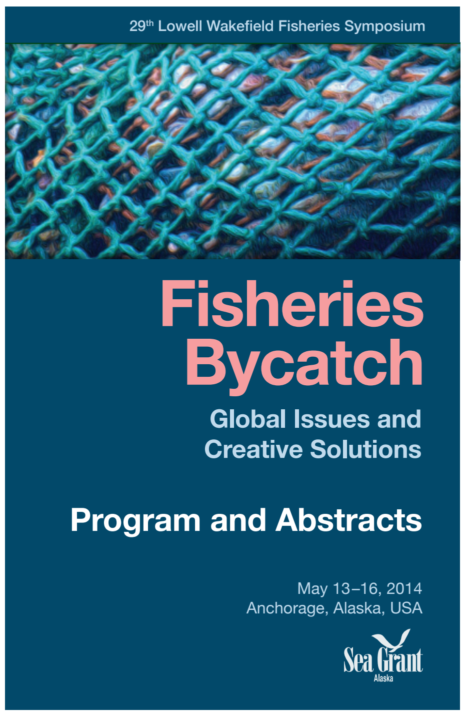
Select symposium papers will be published in The ICES Journal of Marine Science within approximately 18 months after the symposium.

By Teresa A'mar

Fisheries Bycatch: Global Issues and Creative Solution

The 29th Lowell Wakefield Fisheries Symposium was held in Anchorage, Alaska, from 13 to 16 May 2014, with a number of contributions by AFSC scientists. The symposium comprised seven sessions, which were broadly divided into topics on biological, ecological, and socio-economic issues on one side and gear technology, regulations, monitoring, and industry cooperative programs on the other.

Alan Haynie (AFSC) led the session "Fishery regulatory approaches and solutions" as an invited speaker and discussed "The Right Bycatch Management Tool for the Right Problem: How Catch Shares and Incentive Programs Are Being Utilized and How We Can Do Better." In his talk Haynie covered how multispecies catch share programs, halibut bycatch reduction efforts, and measures to reduce Chinook and chum salmon bycatch in the Bering Sea and Gulf of Alaska pollock fisheries illustrate the variety of new bycatch management programs implemented over the last decade. He contrasted how management objectives vary and made the point that a "one size fits all" system is inappropriate. Biological, economic, and other institutional factors such as industry organization and observer coverage all impact how bycatch management programs function. These factors determine which mechanisms appear to be most effective at addressing different problems.



Jim Ianelli (AFSC) provided perspective on the current measures of salmon bycatch in the eastern Bering Sea pollock fishery. In particular, based on the extensive sampling by observers and genetic stock ID work (conducted by the AFSC's Auke Bay Lab), he showed how trade-offs for the current constraints on pollock fishing may impact pollock catches and subsequent stock conditions. For example, starting in 2012, the abundant 2008 year class of pollock appears to be much smaller than average in the fishery. The extent that this is due to population-level density dependent effects is contrasted with the possibility that the pollock fleet has moved from traditional fishing grounds (which may have higher Chinook salmon bycatch rates) to areas where smaller and younger pollock are available.

Chuck Guthrie (ABL) presented his research titled "Genetic Stock Composition Estimates of Chinook Salmon Incidentally Taken as Bycatch in the 2012 Bering Sea and Gulf of Alaska Trawl Fisheries" and Chris Kondzela (also from ABL) presented "Chum Salmon Bycatch in the Bering Sea Pollock Fishery." In these studies, determining the geographic origin and stock composition of salmon caught incidentally is essential to understanding the nature of the fisheries and how management measures could be effective at minimizing the impacts. Chinook salmon samples collected in 2012 in the Bering Sea were predominately of coastal western Alaska origin (63%) based on 1,111 samples. Bycatch samples of this species taken in the Gulf of Alaska pollock fisheries indicate that the stock composition the was about 49% of British Columbia origins with the U.S. west coast comprising 28% and coastal Southeast Alaska about 20%. Chum salmon bycatch samples collected from the 2012 Bering Sea pollock fishery showed, as in previous years, that the largest contribution was from Asia (59%), followed by the eastern Gulf of Alaska–Pacific Northwest (18%), western Alaska (14%), upper-middle Yukon (7%), and southwest Alaska (2%) regions.

Carwyn Hammond (RACE) presented the talk "Reducing Unobserved Crab Mortality from Bering Sea Bottom Trawling Through Cooperative Research." In this study they showed how cooperative research projects can be very effective at reducing the negative impacts of commercial fisheries. In particular, they deployed special auxiliary nets fished behind the trawl gear (the sweeps and the footropes) which showed that crab survival improved by about 75%.

The FMA Division was extensively represented with Dr. Craig Faunce presenting: "The Risk-Matrix Approach to Evaluating Fisheries Bycatch," Jennifer Cahalan showing her "Evaluation of Design-Based Estimators in Federal Groundfish Fisheries off Alaska," and Farron Wallace giving a talk on "Innovative Camera Applications for Electronic Monitoring." Faunce's research offers a way to prioritize activities among multiple projects and potential outcomes. He constructed a risk matrix for 60 fisheries around the nation as an example which provided simple visualizations of how bycatch issues arise for a wide variety of gear types and geographic regions. These can be used to focus cooperative research and monitoring efforts to reduce and improve fishery bycatch estimates. Cahalan presented some results based on a regulations change governing the North Pacific Observer Program. The change means that NMFS controls the deployment of observers. Her findings indicate that design-based estimators are robust to highly variable sample data for rarer species. This was further illustrated comparing estimates of total discards (and precision) relative to species rarity. Farron Wallace discussed the development of a new camera system developed at the AFSC which provides the ability to monitor fisheries with cameras and automatically collect fish length measurements. Innovative time-stamping and linkage to GPS information allows precise location of species-specific catch, which may enable mapping of high bycatch rate areas. Other cost-effective savings makes this system a more broadly deployable way of collecting better information from fishing activities.

For more information please visit http://seagrant.uaf.edu/conferences/2014/wakefield-bycatch/.

By Jim Ianelli

SSMA Staff at the PICES FUTURE Open Science Meeting

Four Center scientists participated in the PICES FUTURE Open Science Meeting held 13-18 April 2014 on the Kohala Coast, Big Island, Hawaii. It was a well-attended international meeting with participants from Australia, Canada, China, France, Germany, Japan, Korea, New Zealand, Philippines, Russia, the United States and United Kingdom. The goal of the meeting was to give PICES a chance to review progress on its integrated science program FUTURE (Forecasting and Understanding Trends, Uncertainty and Responses of North Pacific Marine Ecosystems) and to identify gaps and mechanisms to fill them. The overarching question addressed by FUTURE is "What is the future of the North Pacific given current and expected pressures?"

Anne Hollowed co-convened two workshops at the FUTURE meeting. One was on "Climate change and ecosystem-based management of living marine resources: Appraising and advancing key modelling tools," which she convened with Tim Essington (University of Washington) and Myron Peck (University of Hamburg). The workshop was convened to discuss state-of-the-art tools for 1) calculating biological reference points under changing climate conditions that recognize that equilibrium states no longer apply; 2) assessing the relative ecological and economic costs and tradeoffs of different ecosystem-based management scenarios; and 3) estimating the vulnerability and stability of ecosystems (and their key components) required to make informed, ecosystem-based fisheries management decisions. The workshop provided a critical review of modelling tools available for fisheries management needs and an understanding of what advancements are required to address climate-driven changes in ecosystem dynamics.

The second workshop that Anne convened was "An international workshop for ecosystem projection model inter-comparison and assessment of climate change impacts on global fish and fisheries," with AFSC scientists Kerim Aydin and Kirstin Holsman. This workshop brought together earth system modelers, oceanographers, fisheries stock assessment scientists, and ecosystem modelers to discuss the current and near-term future status of Earth System Models and their potential contributions to projecting climate change impacts on living marine resources. This workshop provided much-needed information needed for sustainable fisheries management in the future. The group plans to hold two more workshops in March of 2015 and 2016 and submit results on model projections for selected species groups in a scientific journal in 2019.

Steve Barbeaux presented a talk in the Theme Session "Challenges in communicating science and engaging the public". The title of his talk, co-authored with Jae Bong Lee was "Broadening stakeholder involvement in fisheries research through the development of cooperative research initiatives in Korean (and Alaskan) fisheries." The talk was about the results of a 2013 exchange of experts from the Republic of Korea and the United States to evaluate possible cooperative research projects involving Korean and Alaskan fisheries. Steve described five possible cooperative research projects identified by the Korean and U.S.experts for implementation in Korea and five projects either currently implemented or planned for 2015. He also discussed the cultural and technological aides and barriers to the possible success of these projects. The Theme Session was well attended with approximately 30 participants and generated discussion on the projects during the working group discussion session afterwards on how to confront challenges in communicating science and engaging the public.

Paul Spencer presented a talk in the Theme Session "Strategies for ecosystem management in a changing climate." The title of his talk was "How might environmentally-driven changes in the distribution of arrowtooth flounder affect predation upon eastern Bering Sea walleye pollock?" His co-authors were Nicholas A. Bond (PMEL), Anne B. Hollowed, Stephani Zador, Kirstin Holsman, and Franz J. Mueter (University of Alaska Fairbanks). Paul and his colleagues found that information on the spatial distributions of predator and prey populations allows for spatially-resolved estimates of predation mortality within age-structured stock assessment models. They also found that the impact of future climate conditions upon arrowtooth flounder and walleye pollock spatial distributions are expected to have a relatively minor effect on the predation of walleye pollock by arrowtooth flounder. However, higher levels of predation could occur if the spatial distribution of arrowtooth flounder moves northward into the northwest middle eastern Bering Sea shelf.

Libby Logerwell is chair of the PICES Fishery Sciences Committee and a member of the FUTURE Scientific Steering Committee. She did not give a presentation at the FUTURE Open Science Meeting but did participate in the PICES Intersession Science Board meeting where a review of the FUTURE program was discussed.

By Libby Logerwell

International Affairs & Research Collaboration

Cooperative Research with Korea

The REFM Division has the lead for cooperative research with the Korean Ministry of Oceans and Fisheries (MOF) under a Joint Project Agreement with NOAA. The Fisheries Panel met in Pusan (ROK) in June to review the results of research conducted on 15 research tasks. The proposed budget for funding of these projects by MOF in FY2015 is $190k plus $50k for three new tasks. NOAA provides in-kind funding to the projects through personnel involvement that generally matches monetary funding from Korea. Fifteen research tasks are grouped under three projects, lead by REFM personnel for the U.S. side and Korean scientists from MOF. The table below shows the budget allocation for facilitating travel and other research activities for both sides.

Project Title and Tasks	Funding	NOAA	Korea
Fisheries Panel	**$240k**	**$110k**	**S130k**
1. Observer Training	22	8	14
2. Vessel Monitoring Network	20	10	10
3. Survey Gear Technology	15	8	7
4. Habitat Research (new)	5	5	0
A. Surveys and Monitoring	**62**	**31**	**31**
5. “Nowcast” Model Extension	13	10	3
6. Snowcrab Stock Assessment	5	0	5
7. IFRAME Extension	6	3	3
8. Management Strategy Evaluation	5	0	5
9. CPUE Standardization	6	3	3
10. Otolith & Ageing Research	20	13	7
11. Korean Pollock Stock Status (new)	15	7	8
B. Climate, Assmt, & Ecosystem	**70**	**36**	**34**
12. Vulnerable Marine Ecosystems	30	15	15
13. MOF Officials Training	30	15	15
14. Fisheries Panel Meeting	18	3	15
15. Arctic Research (new)	30	10	20
C. Applications of JPA Research	**108**	**43**	**65**

By Loh-Lee Low

Age & Growth Program

Age and Growth Program Production Numbers

Estimated production figures for 1 January – 30 June 2014. Total production figures were 11,543 with 3,170 test ages and 309 examined and determined to be unageable.

Species	Specimens Aged
Alaska plaice	539
Arctic cod	1,571
Atka mackerel	230
Dusky rockfish	73
Flathead sole	873
Greenland turbot	493
Harlequin rockfish	255
Northern rock sole	354
Northern rockfish	303
Saffron cod	848
Walleye pollock	5,194
Yellowfin sole	810

By Jon Short

Alaska Ecosystems Program

An aerial image of a Steller sea lion rookery in Alaska with the Twin Otter airplane reflected from below. Note the three sea lions in photo. (Image taken under MMPA/ESA scientific research permit 782-1889 to the National Marine Mammal Laboratory.)

Below the Fog: Monitoring Endangered Steller Sea Lions in the Western Aleutian Islands

From the window of the airplane you see only the tips of the snowcapped volcanoes of the Aleutian Island archipelago. The islands are skirted with a thick fog created by the warm air off the Pacific mixing with the cooler air off the Bering Sea. This is summer in the Aleutians. Gone are the hurricane force winds and rough seas of winter. The balmy weather signals the breeding season for many marine mammals in Alaska, and a new field season for wildlife biologists from NOAA's Alaska Fisheries Science Center (AFSC). Their mission is to find clues that explain the continued decline of the westernmost portion of the Western stock of the endangered Steller sea lions.

Aerial surveys, using a NOAA Twin Otter airplane, are the best way to annually monitor the abundance and productivity of these animals. But for the last six years the weather has not cooperated.

"During the 2012 survey, we were in Shemya for 18 days and we only flew one of the days," says Lowell Fritz, a wildlife biologist from the AFSC. "Luckily, we were able to survey most of the sites near the airstrip, but nowhere else because of the fog and wind."

To get population counts below the fog, scientists have been forced to think innovatively. The answer may be in using an unmanned aircraft like a hexacopter.

A hexacopter looks like an insect from a science fiction novel, a mutant flying spider. The abdomen, or center of the hexacopter, is a circular dome about a half-foot in diameter. Six arms extend a foot from the abdomen and end with a ten-inch rotor blade. Two legs form the landing gear. Each leg is encircled with brightly colored foam tubes, like those found near a pool, for a soft landing. The total diameter across the hexacopter, blade tip to blade tip, is about three feet. The hexacopter is piloted from the ground or a vessel's deck using a console with joysticks, a small monitor, and various switches and knobs.

"We don't like to call it a drone…we call ours Stella." says Katie Sweeney, one of a handful of U.S. Federal Aviation Administration (FAA) certified hexacopter pilots in NOAA.

This summer Fritz and Sweeney will be heading to the Aleutians aboard the USFWS Tiĝlâx, a U.S. Fish and Wildlife Service vessel, with a crew of other scientists to conduct Stella's first scientific mission. The goal is to fly over 16 high priority sites in the Western Aleutians and photograph newborn pups, juveniles, and adults. Eight sites are between Kiska and Amchitka Islands (177°E-180°) and have not been surveyed since 2008. Another eight sites are in the Delarof Islands (180°-178°W) and have not been surveyed since 2010.

Before Stella could fly there were many hoops the scientists had to go through. To fly an unmanned aircraft for government research, Sweeney and colleague LTJG Van Helker, from the NOAA Corps, had to satisfy multiple criteria required by the FAA.

"We had to go to ground school, pass the airman's knowledge test, and have a Class II Medical exam, which is typically mandated for commercial airline pilots," explains Sweeney. "And we are not even going up in the air!"

Unlike the Twin Otter airplane, Stella can fly as low as 150 ft (the Twin Otter remains at about 750 ft) over survey sites in remote areas far from an airfield and near tall cliffs. Another virtue of the hexacopter is that it is much quieter than a Twin Otter. Fewer animals will get spooked and dive into the water, allowing scientists to get more accurate estimates of population abundance and images of permanently marked animals to gather life history information.

The hexacopter may sound like a better option than the Twin Otter, but it is expensive and less efficient. It needs a vessel, like the USFWS Tiĝlâx, to bring it close to the islands for successful deployment, and it can cover only about two sites per day. A Twin Otter, on the other hand, can survey dozens of sites in a couple of hours when conditions are favorable.

The skies over the Aleutian Islands won't likely see an air force of hexacopters flying around in the name of science. But, this summer, one lone hexacopter named Stella will be flying below the fog in the western Aleutian Islands to help solve the mystery behind the decline of Steller sea lions.

By Rebecca Reuter, with contributions from Dr. Tom Gelatt, Lowell Fritz, Katherine Sweeny, and Van Helker.

Learn how the hexacopter was successfully used by scientists at the NOAA Southwest Fisheries Science Center to study penguins, leopard seals, and Antarctic fur seals in the Antarctic.

Stella, the hexacopter, awaiting test flight.

Preparing and setup for hexacopter test flight operations.

Katie Sweeney piloting hexacopter during test flight with Van Helker assisting.

A remote camera system is positioned on a makeshift ledge made from reclaimed lumber.

Remote Observations: Studying Steller Sea Lions Year Round

The plane descends into Anchorage on a typical summer day, blue skies, hot, and sunlight for almost twenty hours a day. The 3 1/2-half hour flight from Seattle, Washington, is only the first leg of the journey for Dr. Tom Gelatt and his team of Steller sea lion scientists from NOAA Fisheries Alaska Fisheries Science Center (AFSC) to participate in an annual survey of the endangered Steller sea lion.

Their destination is Adak Island in the Western Aleutian Islands – a 1,000-mile stretch of volcanic islands across the North Pacific from the Alaska Peninsula to the Russian border. After another 3-hour flight the team arrives on Adak, where the U.S. Fish and Wildlife Service research vessel *Tiĝlâx* is waiting to take them further westward to rookeries where Steller sea lions congregate to breed and give birth. Scientists can safely visit this area only once or twice a year due to weather and resource restrictions—not often enough, they are finding, to learn why the western portion of the western stock of the endangered Steller sea lion continues to decline.

To add to the scientists' challenge, sea lions marked in the United States were recently observed on the Commander Islands and the Kamchatka Peninsula in Russia. Conducting research in Russian waters on a foreign vessel requires permissions that may or may not be obtained for each survey. This means the Tiĝlâx won't travel west across the Russian border to survey rookeries on the Commander Islands only a couple hundred miles away. Instead the AFSC scientists work with colleagues at the Far East Branch of the Russian Academy of Sciences (RAS) to conduct separate surveys in Russia using Russian vessels. This requires Seattle-based scientists to fly eastward, due to lack of commercial air service from the west coast of the United States to Russia, on an 11,000-mile journey to Petropavlovsk on the Kamchatka Peninsula.

"And that is before getting on a vessel to get to the islands where the animals are." exclaims Dr. Vladamir Burkanov, a Russian scientist who has worked with the AFSC on Steller sea lions for over 25 years.

Every day of the two week survey is a flurry of activity while scientists collect as much data as possible at each rookery site. Arriving on shore aboard a rigid inflatable boat, scientists carefully capture a sea lion to get blood samples for genetic research or to place a satellite tag to learn about their migratory behaviors. Other scientists are on the lookout for fresh sea lion scat for later analysis to learn what the sea lions are eating.

Scientists hike to the highest point above the rookeries to search, using binoculars, for permanently marked animals to document movement patterns and survival rates. They also count the number of pups for birth rates, and juveniles and adults for abundance estimates. But these data are only a snapshot of what is happening at each rookery. What about the rest of the year?

Dangerous weather, limited resources, and international boundaries, led the AFSC and RAS scientists to develop a system of time-lapse cameras to observe sea lions year round. To withstand the harsh Arctic winter conditions, each system begins with a top loader PelicanTM case - a watertight, crushproof, hard plastic case used by professional photographers and scientists to carry sensitive equipment, which is then customized for the fieldwork. A window is cut into one side of the case securing a pane of glass salvaged from an old scanner. On the opposite side a round hole, about the size of a nickel, is cutout to feed electrical wires to an external solar panel. These areas are sealed with a waterproof epoxy resin.

Behind the window a single-lens reflex (SLR) digital camera is secured and powered by a rechargeable 12-volt battery connected to the solar panels. Photos are taken at a set time interval (e.g. every 30 minutes) from dawn until dusk using a timer connected to the camera. The final ingredient is a can of desiccant, added to absorb any humidity.

In the last 2 years, 78 cameras have been deployed at 18 sea lion rookeries throughout the western Aleutians of the United States and the Russian Far East. The number of cameras at each site is dependent on the size and shape of the rookery. Larger sites, sites that curve or have rocky outcroppings, have more cameras. The placement of the camera is dependent on the availability of rock outcrops to shelter the equipment from the environment and provide a wide-angle perspective of the rookery. Once those locations are determined, the camera systems are secured to salvaged lumber then bolted or secured to rocks or in some cases a modified tripod to improve the camera view of the rookery. When the scientists return each summer they collect and replace the 128 gigabyte memory cards in each camera.

"A scientist can use these photos to simulate a year-long survey at monitored Steller sea lion sites without leaving the office." remarks Burkanov.

These camera systems have remotely capture thousands of photos without maintenance or researcher presence. In the first 2 years of the study, a third of the cameras malfunctioned due to corrosion, rats, snow fall, or operator error. One camera was lost to a 30-foot monster wave.

Remote observations using time-lapse camera systems provide a new way to collect year-round information about animal abundance, behavior, and sightings of marked individuals. This vast amount of information may help solve the mystery of why Steller sea lions in the far western Aleutians continue to decline.

By Rebecca Reuter

Camera system batteries recharge using solar energy.

Big GOALS Accomplished: Surveying for Cetaceans in the Gulf of Alaska

The Gulf of Alaska (GOA) is a highly productive ecosystem and home to a number of diverse marine mammal species. Although cetaceans are present year-round, the greatest numbers occur between spring and fall, when migratory species such as humpback whales (*Megaptera novaeangliae*), blue whales (*Balaenoptera musculus*), and gray whales (*Eschrichtius robustus*) return to this area for foraging. During the era of historical whaling, many species of whales were heavily hunted in the GOA. Although today some species are recovering, such as fin whales (*B. physalus*) off western Alaska and the central Aleutian Islands (Zerbini et al. 2006) and humpback whales throughout the North Pacific (Barlow et al. 2011), not all share a similar success. North Pacific right whales (*Eubalaena japonica*), for example, were nearly decimated by illegal Russian whaling during the 1960s (Ivashchenko and Clapham 2012) and are only sighted on rare occasions today (Wade et al. 2011). Although blue whales are regularly sighted in concentrations off the west coast (Calambokidis and Barlow 2004), sightings within the GOA remain infrequent (Calambokidis et al. 2009).

The GOA is also home to three known species of beaked whales, Baird's (*Berardius bairdii*), Cuvier's (*Ziphius cavirostris*), and Stejneger's (*Mesoplodon stejnegeri*). Beaked whales are some of the most poorly understood of cetaceans with only limited sightings within the GOA. They spend a majority of their time subsurface, regularly diving to depths of hundreds to thousands of meters. They often occur in small groups and can behave inconspicuously at the surface. These factors make them difficult to detect and study using visual survey methods alone.

The Navy periodically uses a Temporary Maritime Activities Area (TMAA; 144,560 km2) in the central GOA, east of Kodiak Island (Fig. 1), for training purposes. The TMAA encompasses diverse habitat consisting of the continental shelf, slope, and offshore pelagic waters with numerous seamounts in the offshore region. In order for the Navy to conduct exercises within the TMAA, analyses of the potential impacts on biological and environmental resources are required. In 2009, the Navy funded a line-transect survey (Gulf of Alaska Line-Transect Survey, GOALS) that provided density and abundance estimates for fin whales and humpback whales, as well as limited distribution information for several other species (Rone et al. 2010). The survey was successful in gathering important data on the cetaceans present in this largely unexplored area. However, additional data on species' densities in regional areas was necessary for the Navy to meet their environmental stewardship obligations. In the summer of 2013, the Navy funded an additional survey (GOALS II) to fill knowledge gaps on the distribution, movements, and densities of marine mammals within the TMAA.

Eleven scientists from four organizations (National Marine Mammal Laboratory, Cascadia Research Collective, Bio-Waves, and HDR, Inc.) participated in the GOALS II survey conducted from 23 June to 18 July 2013. Four survey strata were designed to account for the four distinct habitats within the GOA TMAA (Fig. 1). Tracklines were designed to provide uniform sampling coverage within each stratum using an equal-spaced zigzag sampler configuration (Strindberg et al. 2004; Fig. 1). Utilization of both visual and passive acoustic methods allowed for 24-hour operations and increased the likelihood of detecting elusive beaked whales. Additionally, photographs were collected for comparison to existing catalogs and satellite tags were deployed on an opportunistic basis.

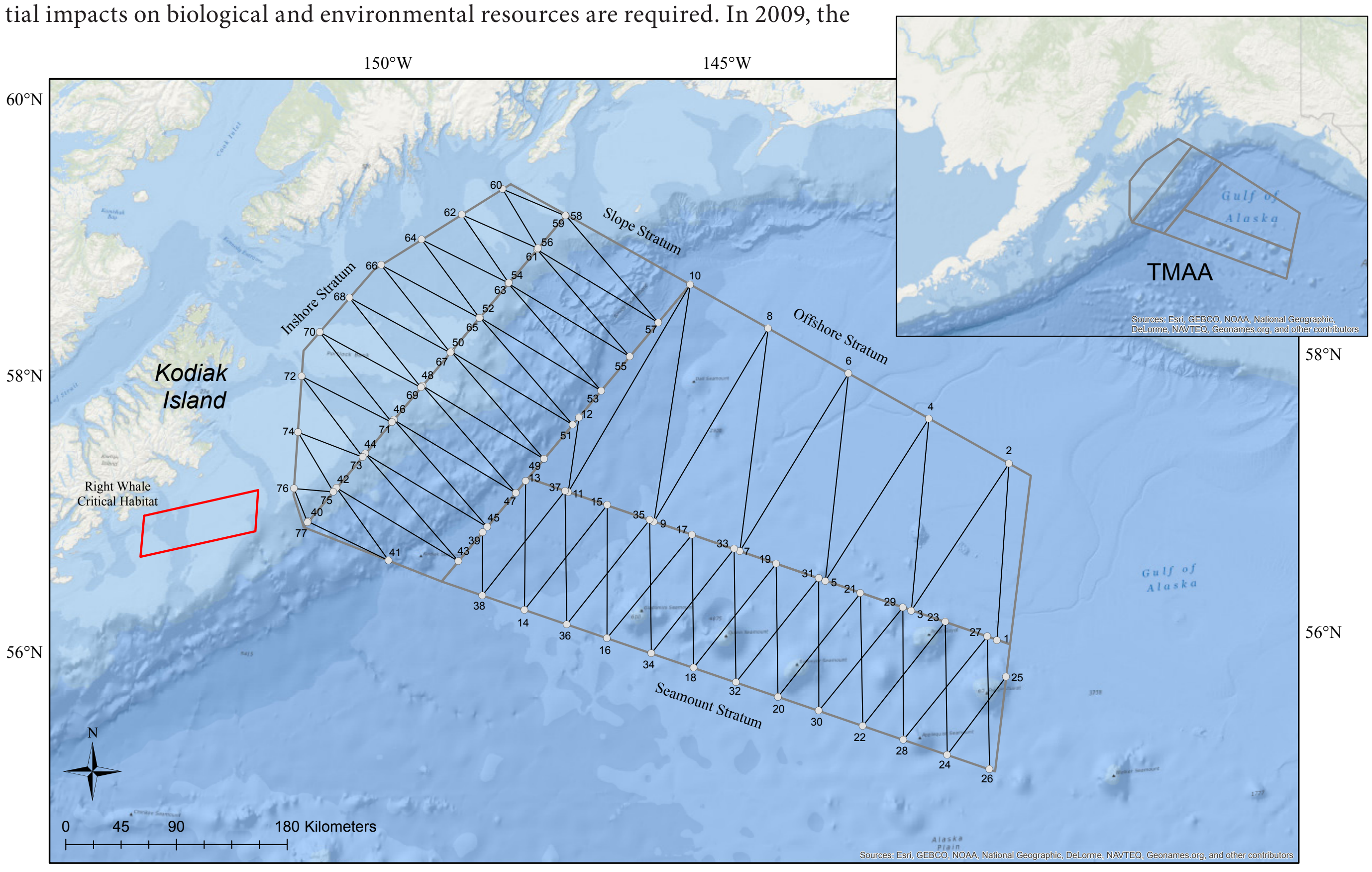


Figure 1. The Navy Temporary Maritime Activities Area (TMAA) with survey strata and tracklines for the GOALS II research cruise.

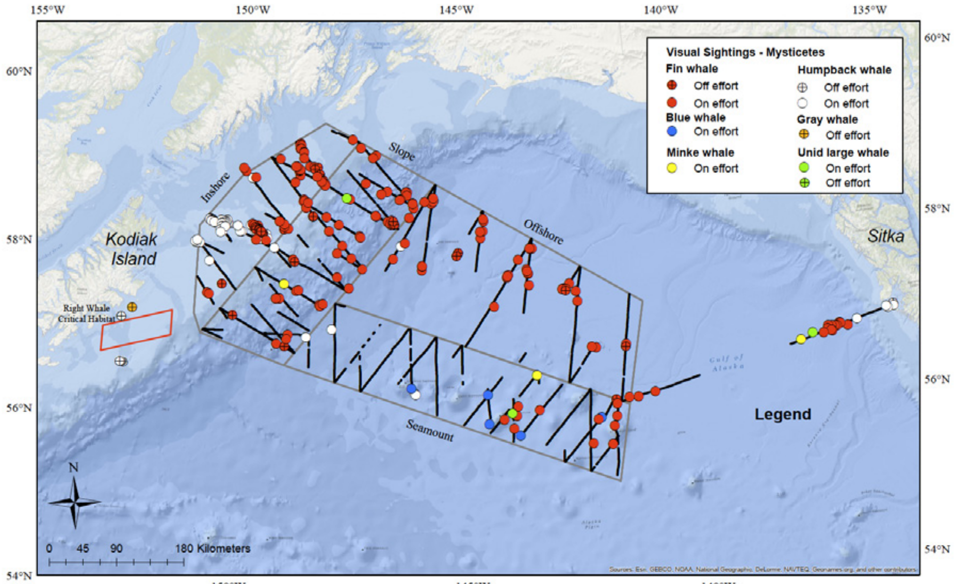


Figure 2. Mysticete sightings and visual survey effort for the GOALS II research cruise.

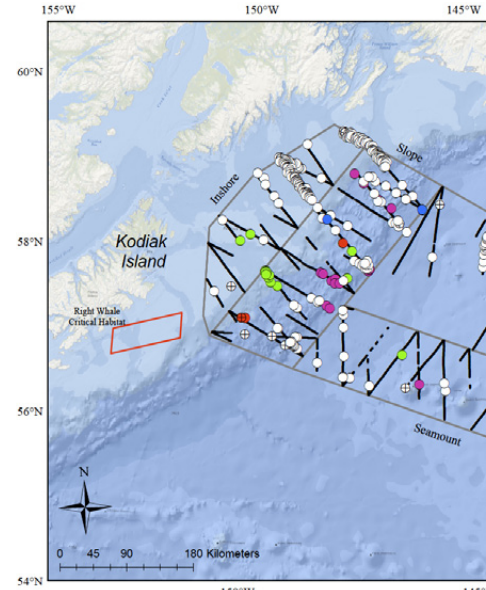


Figure 3. Odontocete sightings and visual survey

During GOALS II, the visual team completed 4,155 km of transect, with an additional 349 km of transit (Figs. 2, 3). There were 646 sightings (1,705 individuals) of 11 confirmed cetacean species (Figs. 2, 3). The acoustic team conducted round-the-clock monitoring with a towed-hydrophone array for 6,304 km of transect effort. There were 379 acoustic detections of six confirmed cetacean species: Baird's, Cuvier's, and Stejneger's beaked whales; killer whales (*Orcinus orca*); sperm whales; and Dall's porpoise (*Phocoenoides dalli*) (Fig. 4). Additionally, 186 sonobuoys were deployed and analyzed for presence/absence of calls. Calls were detected from seven confirmed species on 140 sonobuoys: blue whales, fin whales, humpback whales, killer whales, sei whales (B. borealis), North Pacific right whales, and sperm whales (Fig. 5). Photographs of five cetacean species were collected for photo-identification purposes: fin whales, humpback whales, blue whales, killer whales, and Baird's beaked whales. One blue whale, one killer whale, and eight humpback whales were matched to historical catalogs.

Two satellite-transmitter tags were attached to monitor movements of cetaceans. One was deployed on a blue whale and transmitted for 9 days, and the other was deployed on a Baird's beaked whale and transmitted for 15 days. Both whales were tagged near the Surveyor Seamount (Fig. 6) within 6 km of each other. The blue whale traveled about 250 km south of the survey area, headed west near the Patton Seamount chain, and then began moving north; its final transmission was about 100 km southwest of the survey area on 9 July. Maximum distance from the deployment location was 317 km on 5 July. Based on photo-identification matches, this blue whale had been previously identified off Baja California, Mexico, in 2005. The Baird's beaked whale stayed within the seamount stratum for 9 days, spending 6 days in the vicinity of

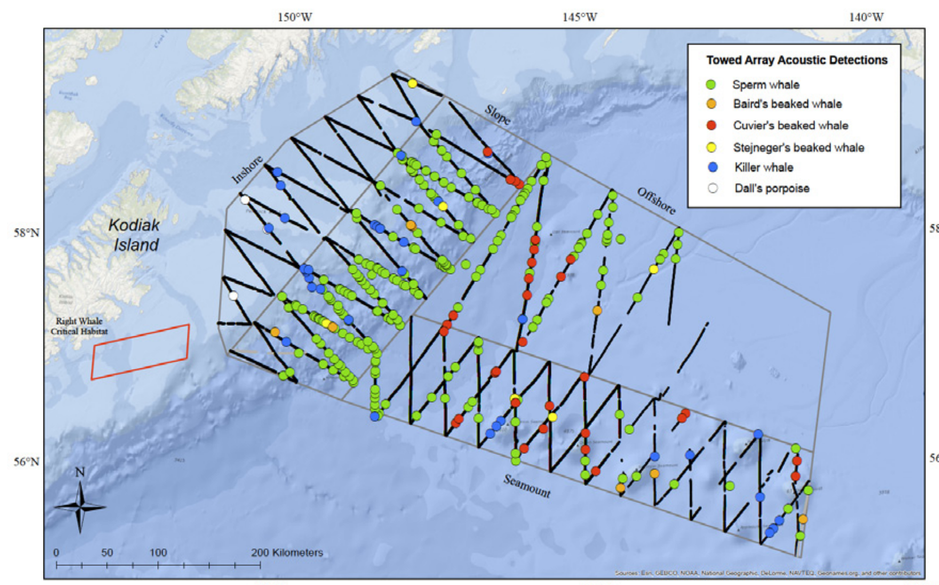
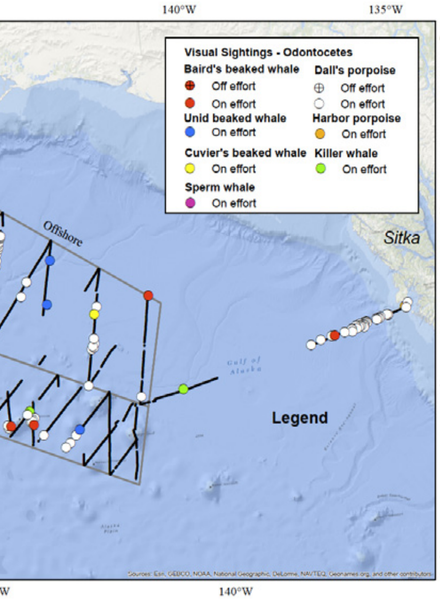


Figure 4. Towed-hydrophone array acoustic detections and effort for the GOALS II research cruise.

Table 1. Estimates of density (individuals/km2) and CV (in parenthesis) for blue, fin, and humpback whales after pro-rating the abundance of unidentified large whales. Estimates were not corrected for the proportion of animals missed on the trackline.

	Stratum				
Species	**Inshore**	**Offshore**	**Seamount**	**Slope**	**Total**
Blue whale			0.002 (1.22)		0.001 (1.22)
Fin whale	0.071 (0.49)	0.021 (0.27)	0.005 (0.39)	0.014 (0.21)	0.022 (0.28)
Humpback whale	0.129 (0.74)	0.001 (0.76)	0.001 (0.64)	0.000 (1.03)	0.019 (0.71)
Sperm whale - visual			0.001 (1.09)	0.007 (0.58)	0.002 (0.57)
Sperm whale - acoustic		0.001 (0.36)	0.000 (0.55)	0.003 (0.18)	0.001 (0.18)
Killer whale	0.005 (0.60)		0.002 (0.77)	0.020 (1.93)	0.006 (0.73)
Dall's porpoise1	0.214 (0.50)	0.028 (0.52)	0.011 (0.41)	0.133 (0.36)	0.072 (0.28)

[1] Dall's porpoise estimates assume no responsive movement occurred prior to detection, an assumption often violated as this species tends to approach the vessel for bow riding.



effort for the GOALS II research cruise.

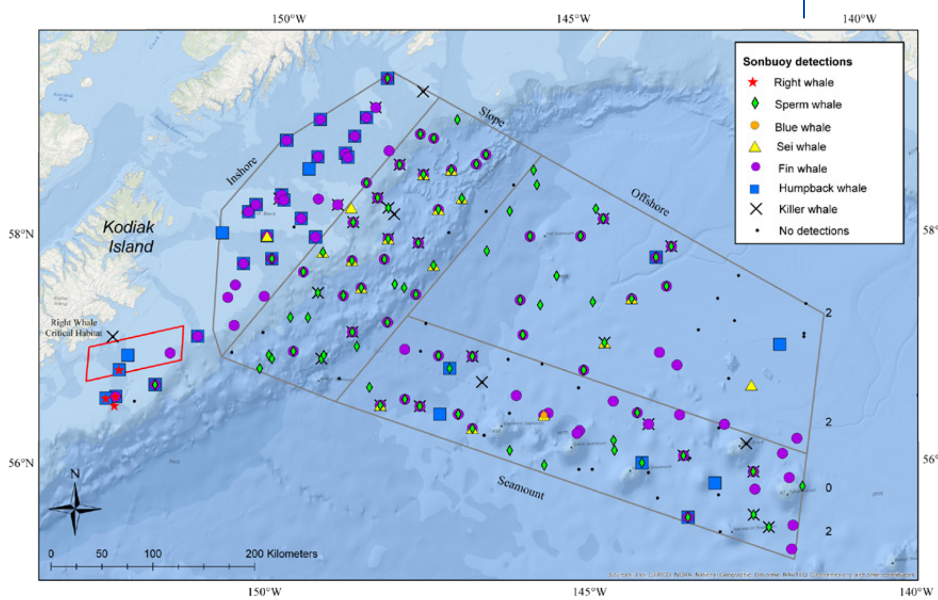


Figure 5. Sonobuoy deployments and detections for the GOALS II research cruise.

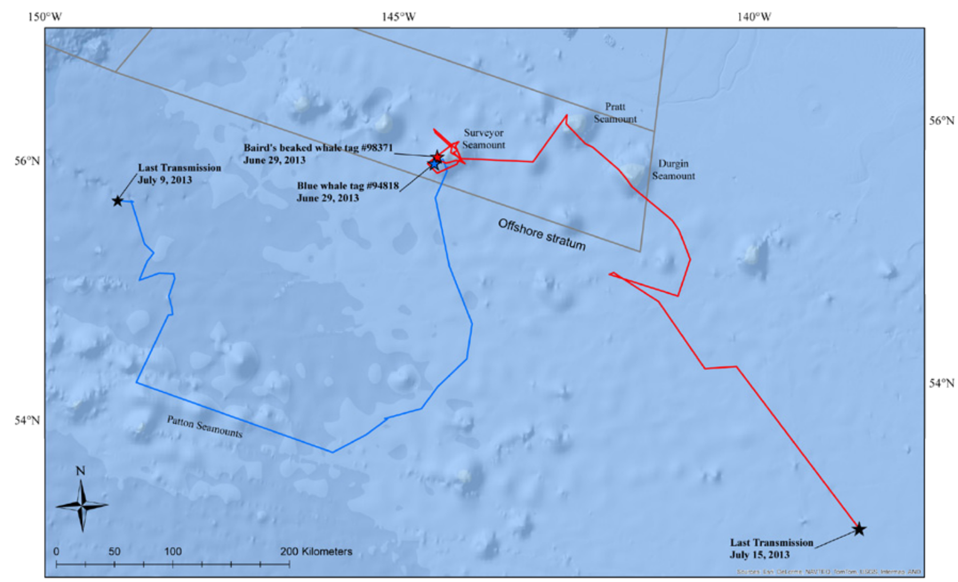


Figure 6. Satellite telemetry locations of two tagged whales during the GOALS II research cruise (blue = blue whale, red = Baird's beaked whale).

Table 2. Estimates of abundance (individuals) and CV (in parenthesis) for blue, fin, and humpback whales after pro-rating the abundance of unidentified large whales. Estimates were not corrected for the proportion of animals missed on the trackline.

	Stratum				
Species	**Inshore**	**Offshore**	**Seamount**	**Slope**	**Total**
Blue whale			78 (1.22)		78 (1.22)
Fin whale	1,610 (0.49)	1,265 (0.27)	207 (0.39)	499 (0.21)	3,581 (0.28)
Humpback whale	2,927(0.74)	65 (0.76)	53 (0.64)	9 (1.03)	3,054 (0.71)
Sperm whale - visual			31 (1.09)	265 (0.58)	296 (0.57)
Sperm whale - acoustic		78 (0.36)	16 (0.55)	121 (0.18)	215 (0.18)
Killer whale	117 (0.60)		107 (0.77)	726 (1.93)	950 (0.73)
Dall's porpoise1	4,873 (0.50)	1,658 (0.52)	486 (0.41)	4,907 (0.36)	11,924 (0.28)

[1] Dall's porpoise estimates assume no responsive movement occurred prior to detection, an assumption often violated as this species tends to approach the vessel for bow riding.

the Surveyor Seamount before heading northeast to the Pratt Seamount and then southeast to the Durgin Seamount. The animal then headed southeast until its last transmission on 15 July, at its maximum distance of 482 km from the deployment location (300 km from the survey area).

Density (Table 1) and abundance (Table 2) (uncorrected for the proportion of animals missed on the transect line) were estimated from line-transect data for six cetacean species. The abundance of large whales not identified to species for visual detections was computed and allocated to blue whales, fin whales, and humpback whales proportionally within each stratum. Pooled density (D) and abundance (N) estimates for the survey area were calculated for blue whales (N = 78; D = 0.001; CV = 1.22), fin whales (N = 3,581; D = 0.022; CV = 0.28), humpback whales (N = 3,054; D = 0.019; CV = 0.71), killer whales (N = 950; D = 0.0058; CV = 0.73), sperm whales (N = 296; D = 0.0018; CV(N) = 0.57), and Dall's porpoise (N = 11,924; D = 0.072; CV = 0.28). A second density and abundance estimate was obtained for sperm whales using acoustic localizations from the towed-hydrophone array (N = 215; D = 0.0013; CV = 0.18).

Results from this survey provide one of the most comprehensive data sets on cetacean occurrence and distribution within the central GOA. Visual and acoustic detections were sufficient to calculate density and abundance estimates for six cetacean species. New information on movements and habitat use within the GOA were documented through the first satellite-tag deployments on blue and Baird's beaked whales within this region. Photographic data contributed to knowledge on seasonal presence of identified individuals. Overall, GOALS II was overwhelmingly successful and provided valuable new data on cetaceans within an area of the GOA that is rarely surveyed.

By Brenda K. Rone

Polar Ecosystems Program

A Research Cruise to Study the Ecology of Ice-Associated Seals in the Central Bering Sea Aboard the NOAA Ship *Oscar Dyson* in April 2014

Figure 1. Photo of NMML researchers releasing a tagged ribbon seal and her pup on an ice floe. The NOAA Ship *Oscar Dyson* is in the background. Photo by Brett McClintock.

The National Marine Mammal Laboratory's (NMML) Polar Ecosystems Program (PEP) conducted an ice-seal research cruise in the central Bering Sea this spring, from 4 April to 1 May 2014, aboard the NOAA Ship Oscar Dyson. One of the primary objectives for the cruise was to deploy satellite-linked tags on ribbon and spotted seals, which are closely associated with sea ice during this time of year (Fig 1). The data collected by the satellite-linked tags will, together with information collected during similar cruises since 2005, provide information on the timing of hauling out (critical for calculating abundance estimates from aerial surveys) and dive behavior and seasonal movements (useful in identifying important habitat).

The Oscar Dyson departed Kodiak, Alaska, on the afternoon of 4 April and arrived at the southern edge of the marginal ice zone of the Bering Sea on 8 April. Our field crew consisted of eight PEP biologists and one veterinarian. A typical day consisted of survey watches from 9 am to 6 pm Hawaii-Aleutian Time (HAST: UTC-10:00), while transiting along the edge of and within the marginal pack ice. Once the numbers of seals observed and the characteristics of the sea ice warranted it, small boats were launched for seal tagging and sampling operations. Small boats were launched on 13 of 20 days in the operations area, with the remainder lost to unsuitable weather or ice characteristics; much of the marginal ice zone consisted of young, thin ice formed late in the winter that was easily moved and broken by the swell and not of the type preferred by seals. The majority of the operations were concentrated in the area west of St. Matthew Island, Alaska (Fig. 2).

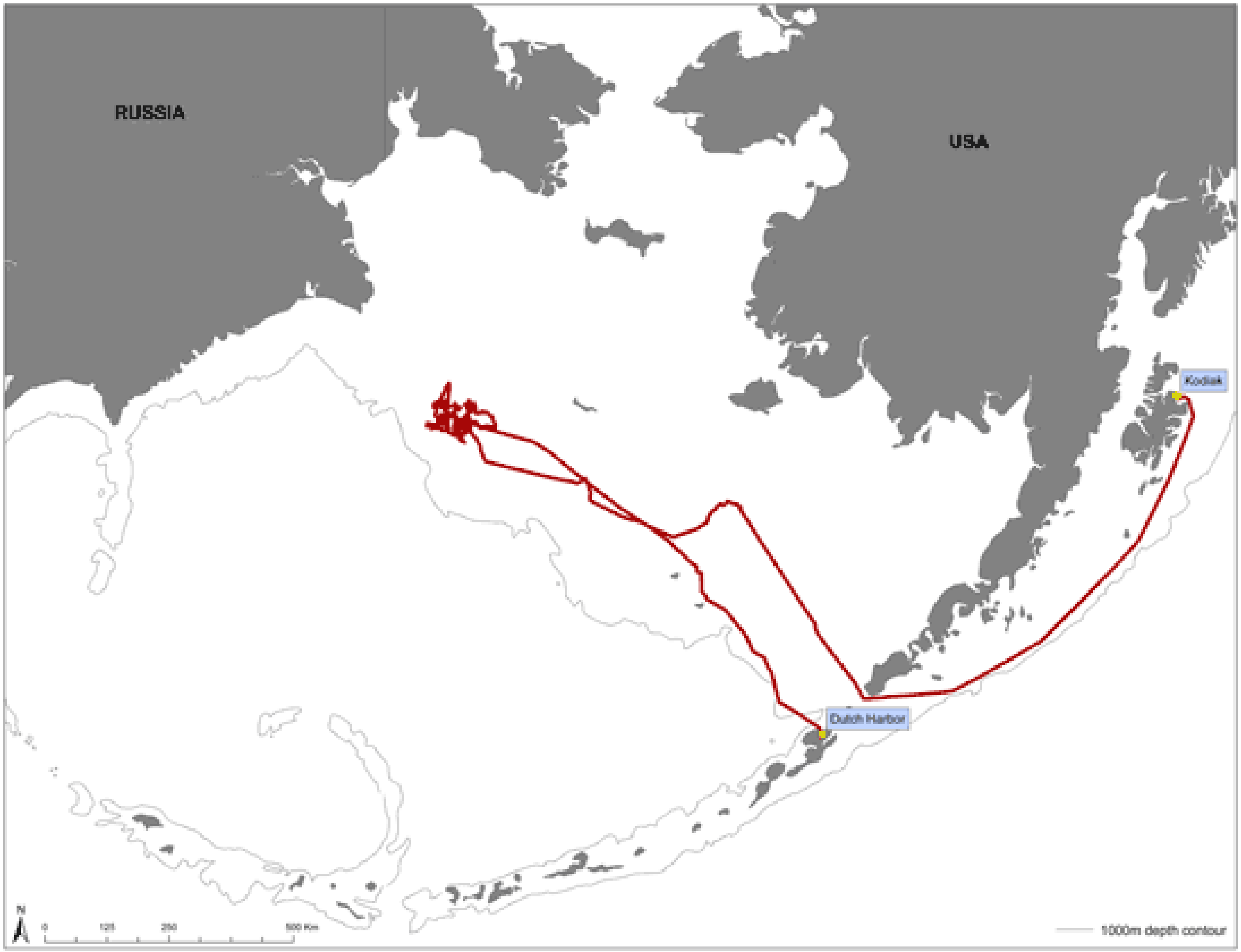


Figure 2. Cruise track of the NOAA Ship Oscar Dyson from Kodiak, Alaska, on 4 April to Dutch Harbor, Alaska, on 1 May 2014.

We captured, handled, and released 19 ribbon, 8 spotted, and 2 bearded seals, for a total of 29 individuals. Seals were captured on ice floes with hand-held landing nets. We attached satellite transmitters to 14 ribbon and 5 spotted seals. Most of the transmitters were SPOT tags (Wildlife Computers, Redmond, WA), attached to the seals' hind-flippers, that provide long-term movement data and haul-out timelines but only when the seals are hauled out with their flippers exposed. The remaining transmitters were SPLASH tags (Wildlife Computers, Redmond, WA) that provide more detailed information about locations at sea and diving behavior. SPLASH tags must be glued to the hair on the seals' back or head (Fig. 1).

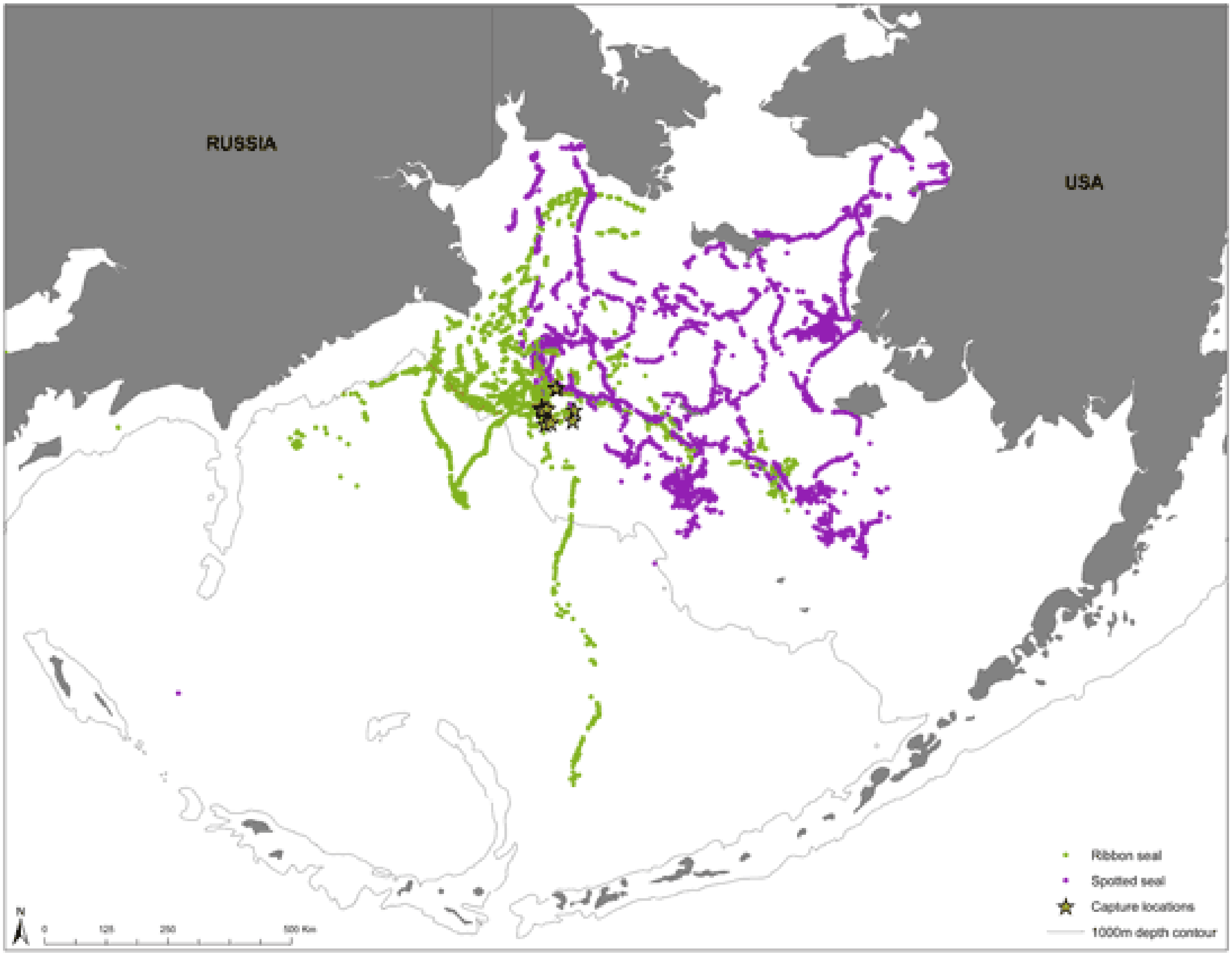


Figure 3. Preliminary map of ribbon (green) and spotted (purple) seal movements from ARGOS satellite tags from April to July 2014. Tagging locations are shown as yellow stars.

Adult spotted and ribbon seals undergo an annual molt in May and June, so the SPLASH tags are expected to provide data for only a few weeks or months before being shed. Data from the deployed tags are already providing information (Fig. 3). As observed from tags deployed in previous years, both ribbon and spotted seals have a strong association with the sea ice. As the sea ice retreated in early summer, the spotted seals tended to head towards more coastal habitats along Alaska or Russia while ribbon seals remained in the ice-free waters near the shelf break and over the Aleutian Basin.

In addition to location estimates, the SPLASH tags deployed on this cruise provide important behavioral data. Diving is an indicator of foraging activity and long periods at the surface indicate haul-out and resting behaviors. Figure 4 provides a graphic representation of dives for one adult and four young-of-the-year spotted seals. The adult seal exhibits reduced dive activity and more surface behavior leading up to the annual molt. The young animals show increased dive activity as they learn to dive and survive on their own. These spotted seals are likely focused on demersal fish species and, thus, variation in the maximum dive depth values over time is largely an indicator of the Bering Sea shelf bathymetry.

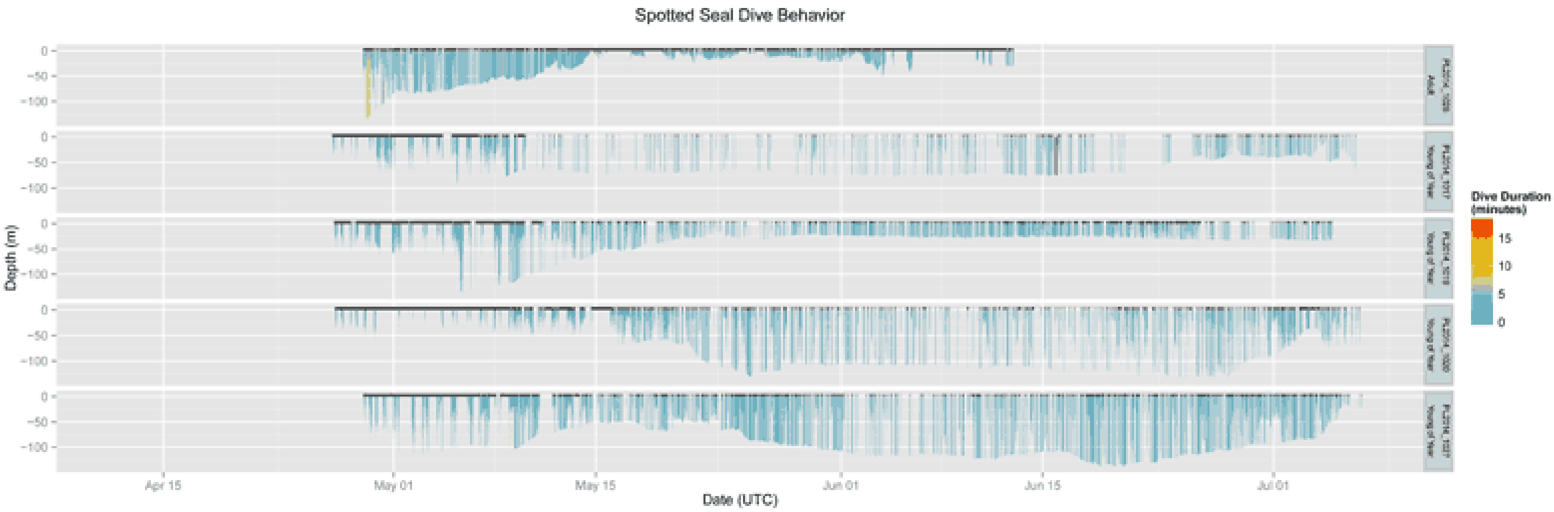


Figure 4. Plot of diving behavior for one adult and four young-of-the-year spotted seals from late April to early July 2014. The length of each bar indicates the maximum depth of each dive and the color indicates the dive's duration, with warmer colors indicating dives up to 15 minutes long.

The sampling for each seal typically included morphometrics (i.e., length, girth, and mass measurements) and the collection of numerous tissue and fecal samples for studies of pathology, genetic population structure, blood chemistry, diet, contaminants, health, and condition. Data from two ribbon seals were submitted for consideration as cases in the Northern Pinniped Unusual Mortality Event. Many of the seals we sampled were mother-pup pairs, dependent pups, or recently weaned pups—a primary focus of this cruise, which was timed to coincide with the whelping, nursing, and maturation of pups. These samples will begin to form a reference database that can be used to assess the future impacts of climate disruption and loss of sea ice.

This project's success was made possible by outstanding support from the command and crew of the Oscar Dyson, the Alaska Fisheries Science Center, Pacific Islands Fisheries Science Center, Marine Mammal Health and Stranding Response Program, and The Marine Mammal Center.

By Michael Cameron, Peter Boveng,
and Josh London

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Authors citing affiliation with the AFSC are denoted in **boldface**.

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