

ARCTIC WHALE ECOLOGY STUDY  
(ARCWEST):  
USE OF THE CHUKCHI SEA BY  
ENDANGERED BALEEN AND  
OTHER WHALES  
(WESTWARD EXTENSION OF THE BOWFEST)

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## Executive Summary

Through an Inter-Agency agreement (IAA) between the National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), National Marine Mammal Laboratory (NMML) and the Bureau of Ocean Energy Management (BOEM), NMML is conducting a dedicated multi-year study to determine relationships between dominant currents passing from the Bering Sea into and through the Chukchi Sea and prey resources delivered to the Barrow Arch area (an area of high bowhead whale and prey concentrations between Wainwright and Smith Bay), and to provide information about the dynamic nature of those relationships relative to whale distribution and habitat utilization in the eastern Chukchi and extreme western Beaufort Seas. This study will also provide important baseline data on the occurrence, distribution, and habitat use of large whales in an area that is subject to rapid change in climate and human industrial development. This quarterly report covers the period of this study from July through September 2015.

The major activities during the third quarter of 2015 consisted of planning and executing the 2015 Arctic Whale Ecology Study (ARCWEST)/Chukchi Acoustics, Oceanography, and Zooplankton Study: Hanna Shoal (Extension of CHAOZ, abbreviated CHAOZ-X) cruise, the processing and analysis of data collected during the 2013 and 2014 cruises. The cruise took place on the chartered research vessel F/V Aquila, left Nome, AK on 8 September, and returned to Dutch Harbor, AK on 28 September. Eleven scientists, technicians, and observers from six different laboratories and institutions participated on the ARCWEST cruise. Highlights of progress and results to date are listed below by objective, with additional details in the main body of the report.

1. Assess patterns of spatial and temporal use of the Chukchi Sea by endangered bowhead, fin and humpback whales, and beluga and gray whales.
  - A third and final year of visual and acoustic observations were collected.
  - The acoustics team continues to process the long-term time series in the Chukchi Sea. Analyses continue on three new moorings: Point Hope (PH1), Nome (NM1), and Peard Bay (PB1). The first two of these locations are crucial as they link the Chukchi and Bering Seas within a migratory corridor and will provide further information on migration paths of large whales within the region. The Peard Bay mooring is the first to provide data in that near shore, up-canyon location.
  - As part of her work on North Pacific Right Whales, Dana Wright is analyzing data from the Bering Sea moorings (M8, BS1, KZ1, NM1) for bowhead whales among other mid-frequency species (*i.e.*, right, humpback, minke, and gray whales; walrus and other pinnipeds; and vessel and airgun noise), which will provide essential information on movements on the wintering grounds and migratory timing of this important Chukchi species.
  - State-space models applied to telemetry data revealed potentially important foraging habitats.

2. Assess the population structure and origin of whales in the region.
  - Timing of seasonal peaks in beluga whale calling correlates with satellite tag and genetic data which suggests passive acoustics can be used to monitor movements of the individual populations (Garland *et al*, 2015a). A paper on beluga whale vocalizations and call classification from the eastern Beaufort Sea population is in press (Garland *et al.*, 2015b).
  - Photographs of gray, humpback, and killer whales are being compared to existing catalogs.
3. Evaluate ecological relationships for the species, including physical and biological oceanography that affect critical habitat for these species.
  - The Chukchi Acoustics, Oceanography, and Zooplankton Study (CHAOZ) found that bowhead whales remain in the Chukchi Sea until the sea ice is about 0.5-1 meter thick. Sea ice thickness and bowhead acoustic data from the ARCWEST moorings will be used to validate this finding, wince they are more spread out than the CHAOZ moorings.
  - ADCP data from the 2011-2012 deployment showed intermittent diel vertical migration of zooplankton.
4. Conduct physical and biological oceanographic sampling to further understand the transport and advection of krill and nutrients from the northern Bering Sea through the Bering Strait and to the Barrow Arch area.
  - The monthly mean transport at Icy Cape has been explored using CHAOZ (2010–2011), ARCWEST (2012–2013), and CHAOZ-X (2012–2013) data. More than a third of the transport remains on the shelf, heading toward the Barrow Arch area.
  - The monthly mean transports during winter and fall were highly variable, but transport was northeastward with less variability in April through July.
  - August 2014 – August 2015 mooring and hydrographic data should be available early 2016.
  - 2014 samples have been processed by the Polish Plankton Sorting and Identification Center in Szczecin, Poland and data analysis should begin soon after QA efforts are completed.

### **Introduction and objectives**

The western Arctic physical climate is rapidly changing. The summer Arctic minimum sea ice extent in September 2012 reached a new record of 3.61 million square kilometers, a further 16% reduction from a record set in 2007 (4.30 million square kilometers). This area was more than 50% less than that of two decades ago (Parkinson and Comiso, 2013). The speed of this ice loss was unexpected, as the consensus of the climate research community was that this level of ice reduction would not be seen for another thirty years (Wang and Overland, 2009). As sea temperature, oceanographic currents, and prey availability are altered by climate change, parallel changes in baleen whale species composition, abundance and distribution are expected (and evidenced already by local knowledge and opportunistic sightings). In addition, the observed northward retreat of the minimum extent of summer sea ice has

the potential to create opportunities for the expansion of oil and gas-related exploration and development into previously closed seasons and localities in the Alaskan Arctic. It will also open maritime transportation lanes across the Arctic adding (to a potentially dramatic degree) to the ambient noise in the environment. This combination of increasing anthropogenic impacts, coupled with the steadily increasing abundance and related seasonal range expansion by bowhead (*Balaena mysticetus*), gray (*Eschrichtius robustus*), humpback (*Megaptera novaeangliae*) and fin whales (*Balaenoptera physalus*), mandates that more complete information on the year-round presence of large whales is needed in the Chukchi Sea planning area. Timing and location of whale migrations may play an important role in assessing where, when, or how exploration or access to petroleum reserves may be conducted, to mitigate or minimize the impact on protected species. Moreover, several species are used, or potentially used, for subsistence by native communities in both Russia and the US. Whales form an important part of the diet and cultural traditions of most people in villages along the coasts of the Chukchi Sea. Detailed knowledge of large whale migration and movement patterns is essential for effective population monitoring. Because all marine mammal species are subjected to changes in environmental variables such as oceanographic currents, sea temperature, sea ice cover, prey availability, and anthropogenic impacts, more complete information on the year-round presence of these species in the Chukchi Sea, how presence relates to these variables, and the transport of nutrient and prey through the Chukchi Sea is needed.

The ARCWEST study has five component projects: visual observation, satellite tagging, passive acoustics, lower trophic level sampling, and physical oceanographic sampling. Each component project is coordinated by a Project Leader with extensive experience in that discipline. Visual surveys, along with sonobuoy deployments, will provide distributional data on baleen whales and other marine mammals. Satellite tagging will provide valuable information on both large- and fine-scale movements and habitat use of baleen whales. Passive acoustic moorings will provide year-round assessments of the seasonal occurrence of baleen whales. Concurrently deployed bio-physical moorings offer the potential of correlating whale distribution with biological and physical oceanographic conditions and indices of potential prey density. Satellite-tracked ocean current drifters will examine potential pathways to the areas of high biological importance. Our goal is to use these tools to understand the mechanisms responsible for the high biological activity so that we can predict, in a qualitative way, the effects of climate change on these preferred habitats.

The overall goal of this multi-year IAA is to use passive acoustic recorder deployments, visual and passive acoustic surveys, and satellite tagging to explore the distribution and movements of baleen whales in the Bering and Chukchi Seas, particularly in the Chukchi Sea lease areas. In addition, oceanographic and lower trophic level sampling and moorings will be used to explore the relationships between currents passing through the Bering Strait and resources delivered to the Barrow Arch area (an area of high bowhead whale and prey concentrations between Wainwright and Smith Bay), and the dynamic nature of those relationships relative to whale distribution and habitat utilization in the eastern Chukchi and extreme western Beaufort Seas.

The specific objectives are:

1. Assess patterns of spatial and temporal use of the Chukchi Sea by endangered bowhead, fin and humpback whales, and beluga and gray whales.
2. Assess the population structure and origin of whales in the region.
3. Evaluate ecological relationships for the species, including physical and biological oceanography that affect critical habitat for these species.
4. Conduct physical and biological oceanographic sampling to further understand the transport and advection of krill and nutrients from the northern Bering Sea through the Bering Strait and to the Barrow Arch area.

### Cruise activities and summary

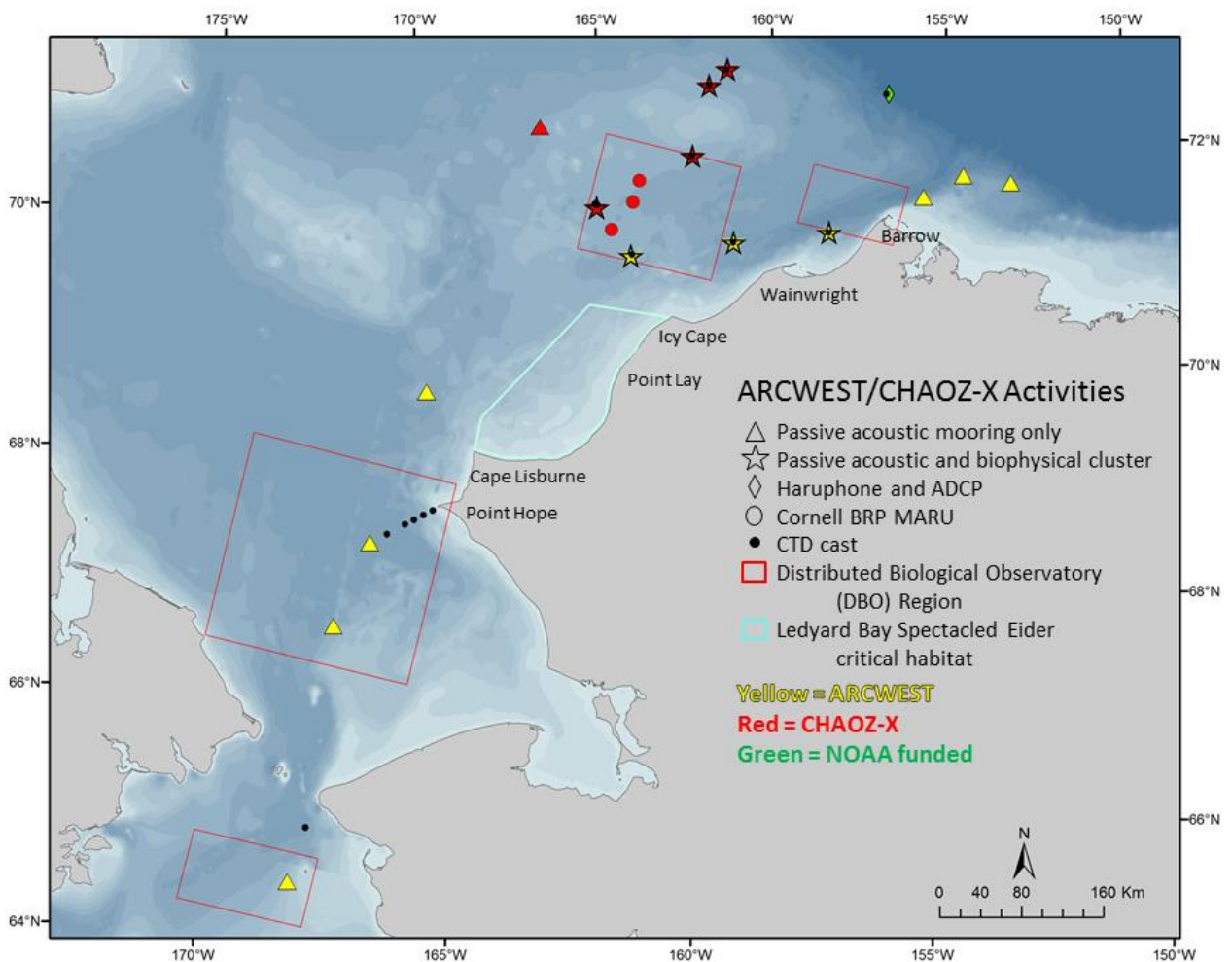


Figure 1. Overview of activities undertaken in the study area during the 2015 ARCWEST/CHAOZ-X cruise.

ARCWEST conducted vessel sharing with NOAA funded oceanographic work again this year. As part of that cost sharing effort, lower trophic level and physical/chemical oceanographic sampling was conducted on the NOAA Ship *Ronald H. Brown* from 6 August to 4 September and passive acoustic and biophysical mooring retrieval/deployment, marine mammal visual survey, and passive acoustic monitoring (sonobuoys) were conducted on the F/V *Aquila* from 8 to 28 September (Figure 1). Please see the cruise reports (available at <http://www.afsc.noaa.gov/nmml/cetacean/arcwest.php>) for full summaries of activities and progress made during these cruises: the ARCWEST/CHAOZ-X 2015 Cruise Report and Eco-FOCI's 2015 Arctic Cruise Report. In addition to work conducted under ARCWEST, moorings were deployed under the CHAOZ-X project (see the October CHAOZ-X Quarterly Report, available at <http://www.afsc.noaa.gov/nmml/cetacean/choaz-x.php>). Analysis of the data collected during the 2013 and 2014 vessel cruises has continued.

Planning has begun for the final data analysis and synthesis work which will begin in the fall 2015 to produce the final report in 2017. The ARCWEST team plans to use framework which was developed for the CHAOZ draft final report. Therefore, we have already begun to plan how the ARCWEST data will be integrated to enable multi-disciplinary, synthesis analyses, and the programs to run these analyses have been written. The CHAOZ final report will provide important baseline data to which ARCWEST can compare.

### **Preliminary data analysis results and planning**

#### Marine Mammal Component:

##### *Long-term passive acoustic recorders:*

[Note: All recorders used by NMML in this study are Autonomous Underwater Recorders for Acoustic Listening (AURALS, Multi-Électronique, Rimouski, QC, Canada), sampling at a rate of 16 kHz on a duty cycle of 80 minutes of recordings made every 5 hours, for an entire year].

Fourteen ARCWEST passive acoustic moorings were retrieved in 2015. As this was the final field season, none were redeployed using ARCWEST funds. However, a small grant from NOAA/S&T was obtained to redeploy all fourteen of these moorings (see ARCWEST-CHAOZ-X 2015 Cruise Report for additional details and maps). In addition, these funds were used to redeploy five recorders on the four PMEL oceanographic moorings in the Bering Sea; one mooring site (M2) is turned around twice a year and so two recorders are used). These redeployments will provide the sixth year in the long-term data record (begun during the CHAOZ study) at the IC1 site, the third year at the PB1 site, and the fourth year at the rest of the sites. Furthermore, several of these recorders (IC1, WT1, PB1) have been collocated with a cluster of biophysical moorings, and one (PH1) was redeployed with a microcat on the mooring. Locations for the 2014 and 2015 ARCWEST moorings were determined in coordination with the oceanographic and lower trophic level components of ARCWEST.

In addition to these long-term mooring sites, funds were also provided by a NMML grant from the NOAA Science and Technology (S&T)/Ocean Acoustics Program to retrieve and redeploy one AURAL mooring in Norton Sound (NS1). This redeployment will provide the third and final year of data collection at that site.

We are analyzing the ARCWEST long-term passive acoustic dataset using an in-house MATLAB- based analysis program (SoundChecker). SoundChecker operates on image files of a fixed time interval that can

be generated ahead of time, saving valuable time during analysis. The image files are manually scanned by an analyst and those with calling are flagged. The program allows for multiple species/signals to be analyzed at the same time. These include a variety of marine mammal (i.e. right, bowhead, humpback, gray, sei, fin, beluga, and killer whales; walrus; bearded, ribbon, and ringed seals) and noise sources (i.e., airguns, vessels, ice). NMML is still trying to implement a new auto-detector/classifier (Baumgartner and Mussoline 2011); however, results are discouraging. This analysis will add to the results obtained from the CHAOZ study; continuing one of the longest full-year record of baleen and odontocete whales, ice seals, walrus, vessels and airguns, and ice noise in the Chukchi Sea. An example of the two-year time record for bowhead whales on the Icy Cape line (40,70, and 120 is shown in Figure 2). These data are the only of their kind in the Chukchi lease area as they are concurrently collected with collocated oceanographic moorings; allowing for examination of the effects of oceanographic conditions on marine mammal distribution (e.g., see Figure 3). Results from these ARCWEST recorders will add a new long-term spatial component to the existing CHAOZ data which was limited to the Icy Cape line.

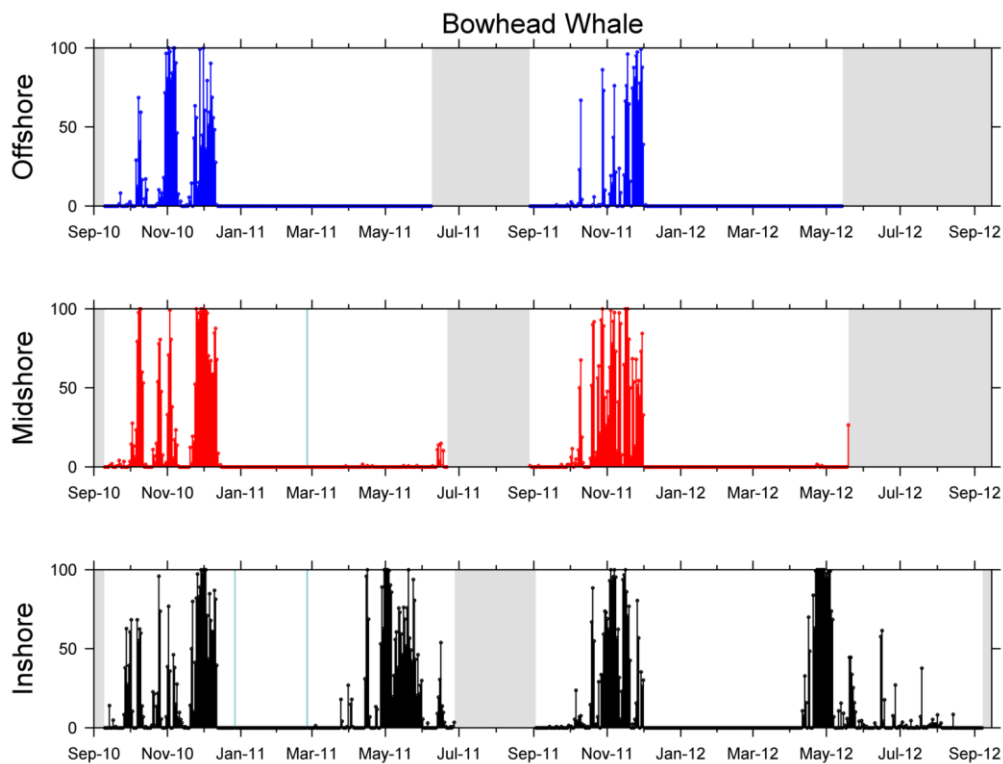


Figure 2. Bowhead whale calling activity (presented as the percentage of time intervals with calls) for inshore (IC1; lower panel), midshore (IC2; middle panel), and offshore (IC3; upper panel) locations, 2010-2012. Dark gray shading indicates no data, and teal shading indicates days where detections were masked by noise.

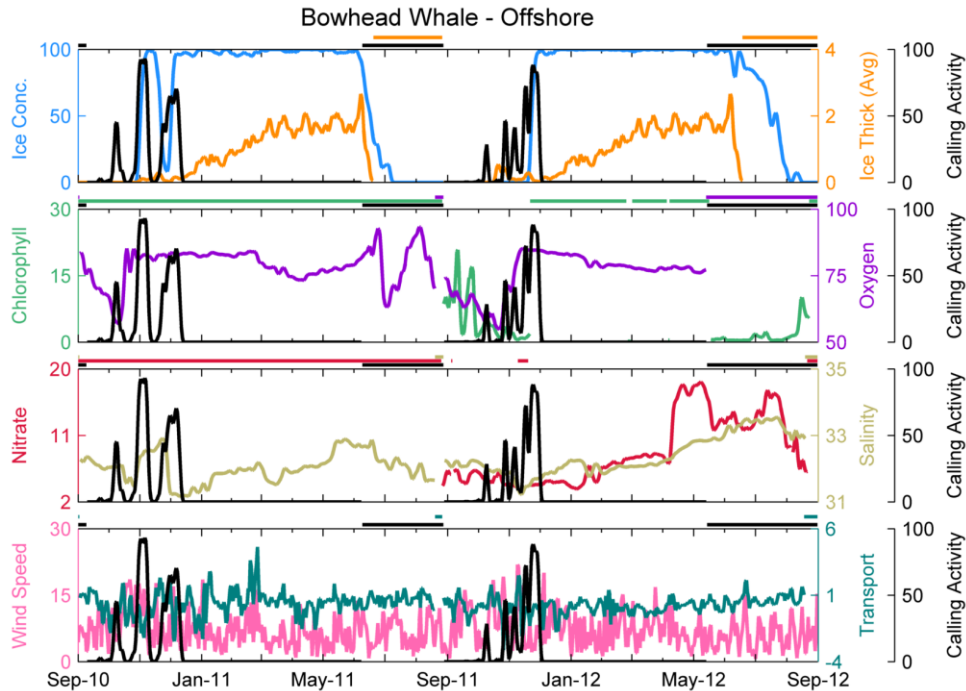


Figure 3. Bowhead whale calling activity as it relates to oceanographic variables at the offshore (IC3) location, 2010-2012. Black line = percent of time intervals with calls. Top row: percent ice concentration (blue line) and ice thickness (m; orange line). Second row: chlorophyll ( $\mu\text{g}/\text{l}$ ; green line) and oxygen ( $\text{m} \times 10$ ; purple line). Third row: nitrate ( $\mu\text{m}$ ; red line) and salinity (psu; tan line). Bottom row: wind speed ( $\text{m}/\text{s}$ ; pink line) and transport (sv; teal line). Horizontal bars above each row indicate times with no data. All data except wind speed are presented as a 3-day moving average.

Ellen Garland, our NRC postdoctoral fellow, left at the beginning of the year for a postdoctoral fellowship at the University of St. Andrews. She continues to lead, and run analysis for, her beluga study on population differences in beluga vocal behavior for the Alaskan region. The main goal of this study is to provide baseline information on the migration timing and call characteristics of the three migratory beluga populations (eastern Beaufort, eastern Chukchi, and eastern Bering; O’Corry-Crowe et al. 1997) that reside in, and traverse, the Bering, Chukchi and Beaufort Seas. The IC1 mooring (formerly CHAOZ and now ARCWEST) is a big part of this study. To date, her results suggest that migratory timing of Arctic beluga whales can be identified by peaks in seasonal call detections and that the eastern Beaufort and eastern Chukchi populations migrate through the eastern Chukchi (inshore (IC1) and offshore (IC3)) at distinct times (Garland et al. 2015a). She has also developed a preliminary repertoire for the eastern Beaufort Sea beluga population providing a proof of concept in the measuring and statistical analysis of call types (Garland et al. 2015b), and has almost completed for the eastern Chukchi Sea repertoire.



*Sonobuoys:*

We deployed 133 sonobuoys during the 2015 ARCWEST/CHAOZ-X cruise on the F/V Aquila. Extremely noticeable was the fact that few marine mammals were detected (Figure 4). In the ARCWEST main study area a very small number of sonobuoys detected walrus, bearded seal, and bowhead (with a few fin and humpback detections in the southern Chukchi). For more details see the ARCWEST/CHAOZ-X 2015 Cruise Report. No sonobuoys were deployed from the NOAA Ship *Ronald H. Brown*.

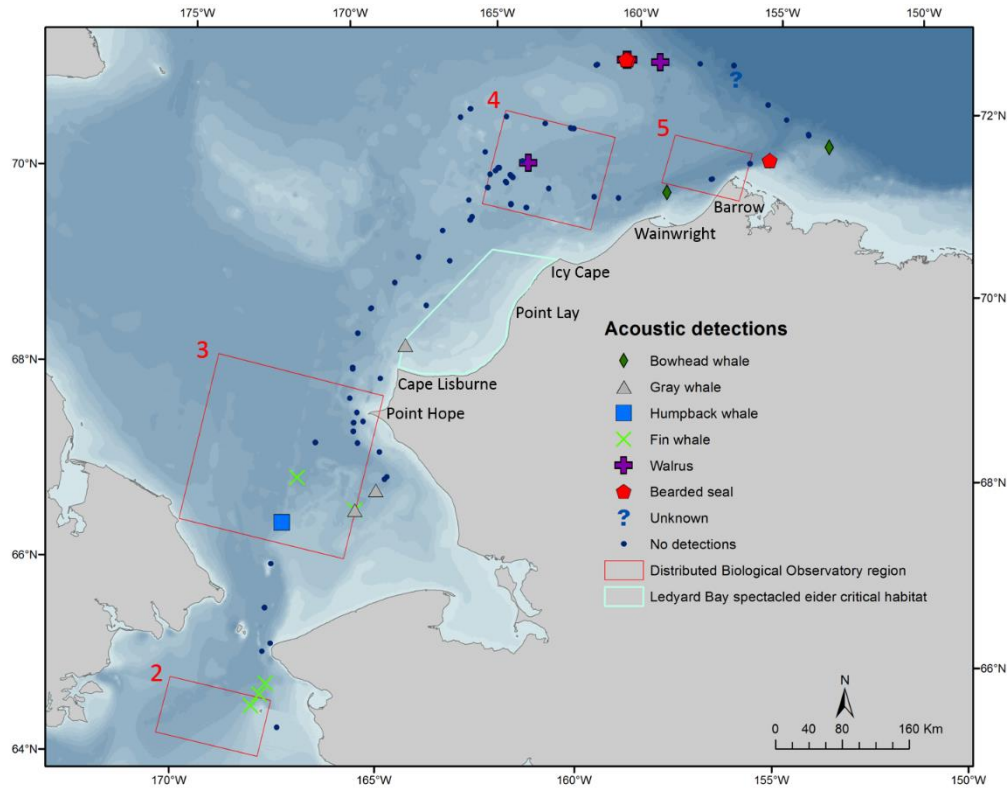


Figure 4. Sonobuoy deployment and acoustic detections from the ARCWEST/CHAOZ-X 2015 research cruise in the Chukchi Sea.

*Visual Observations Component:*

During the 2015 cruise, a total of 629 nm of on-effort trackline were surveyed in the Beaufort and Chukchi Seas (Figure 5) and the Bering Sea (Figure 6). Twenty eight sightings (41 individuals) of 8 confirmed marine mammal species were recorded (Table 1, Figures 5 and 6). The 2015 data will be integrated with previous years for an overall assessment of the distribution pattern of cetaceans in the study area.

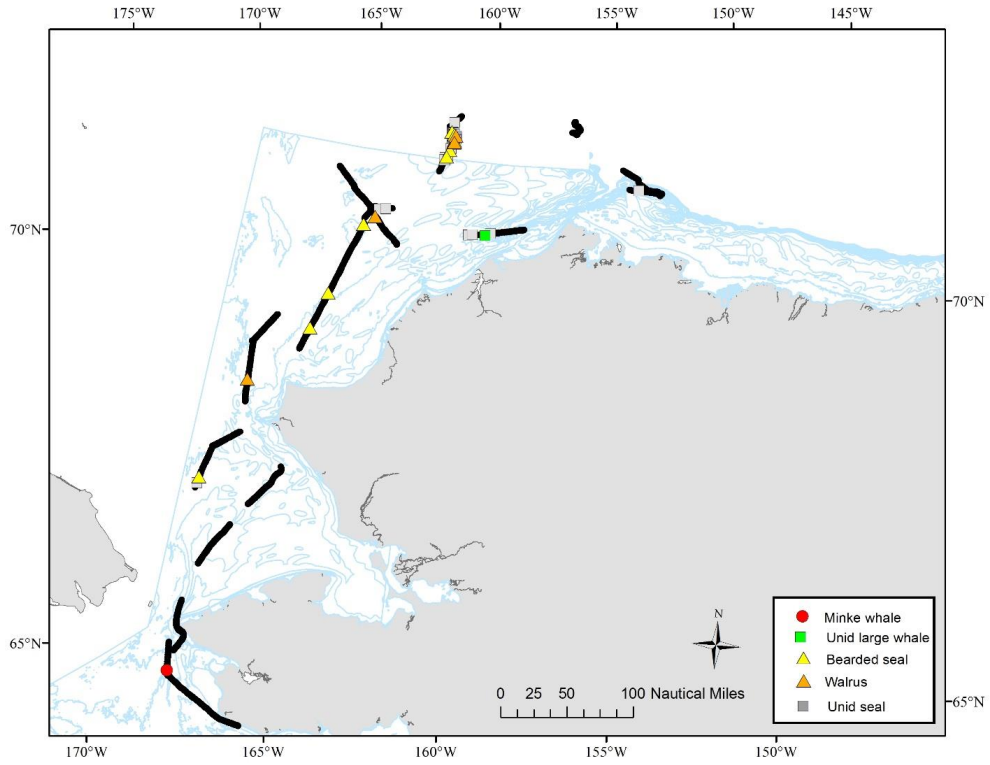


Figure 5. Marine mammal sightings and effort data from the ARCWEST/CHAOZ-X 2015 research cruise, Beaufort Sea to Bering Strait.

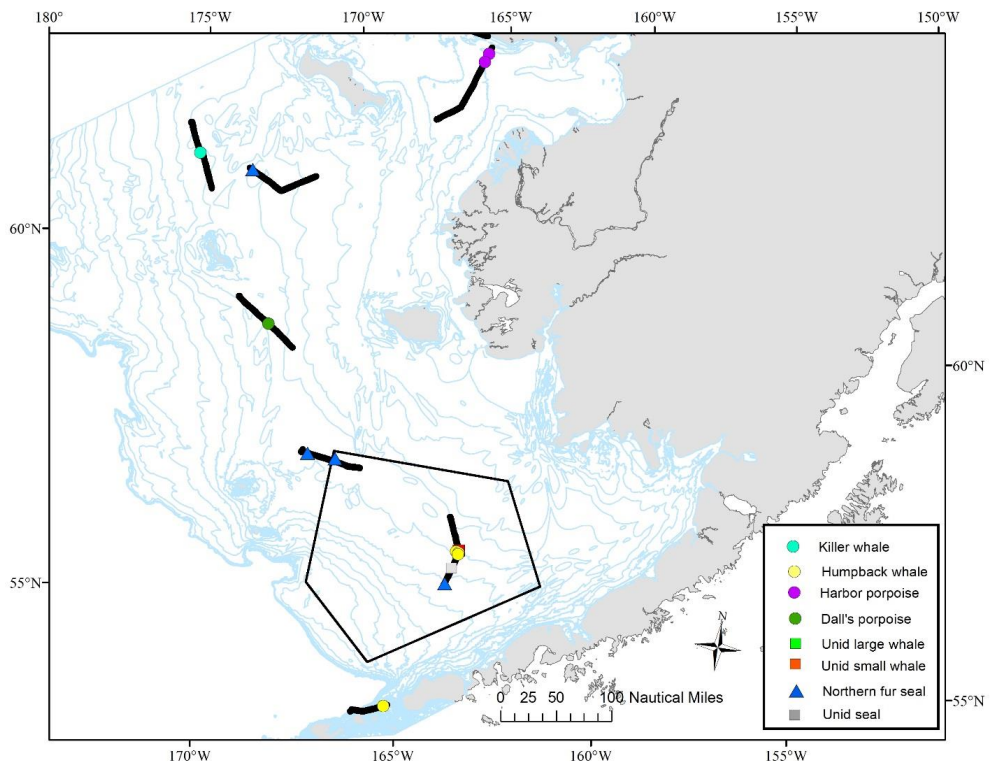


Figure 6. Marine mammal sightings and effort data from the ARCWEST/CHAOZ-X 2015 research cruise, Bering Sea.

Table 1. Marine mammal sightings (individuals) from the ARCWEST 2015 research cruise.

<b>Species</b>	<b>On-Effort</b>	<b>Off-Effort</b>	<b>Total</b>
<b>Cetaceans</b>			
Humpback Whale	2(6)	3(4)	5(10)
Minke Whale	1(1)	0	1(1)
Harbor Porpoise	2(2)	0	2(2)
Dall's Porpoise	1(3)	0	1(3)
Killer Whale	1(2)	0	1(2)
Unid Large Whale	1(1)	1(1)	2(2)
Unid Small Whale	0	1(1)	1(1)
Unid Porpoise	1(1)	0	1(1)
<i>Total Cetacean</i>	<i>9(16)</i>	<i>5(6)</i>	<i>14(22)</i>
<b>Other</b>			
Fur Seal	1(2)	3(5)	4(7)
Walrus	4(6)	0	4(6)
Bearded Seal	10(10)	0	10(10)
Unid Seal	34(34)	1(1)	35(35)
<i>Total Other</i>	<i>49(52)</i>	<i>4(6)</i>	<i>53(58)</i>
<b>Total</b>	<b>58(68)</b>	<b>9(12)</b>	<b>67(80)</b>

*Photo-ID:*

During the 2015 cruise, photo-identification data from two killer whales were obtained and will be matched to existing catalogs or archived for future photo-identification projects. Additional details are available in the ARCWEST/CHAOZ-X cruise reports.

*Satellite Tagging Component:*

Analysis of the telemetry data collected in 2012 and 2013 is ongoing. An abstract with results from satellite tag data obtained during ARCWEST was submitted to the Society for Marine Mammalogy's Biennial Conference and was accepted as an oral presentation (Appendix). In addition, a manuscript is in preparation for publication of these results. We expect submission will occur within the next 6 months.

Oceanographic and Lower Trophic Level Component:

We engaged in two cruises this past summer, a biophysical sampling cruise and a biophysical mooring cruise (see the ARCWEST/CHAOZ-X 2015 Cruise Report and Eco-FOCI's 2015 Arctic Cruise Report for additional details). The first cruise was aboard the NOAA Ship *Ronald H. Brown* occupied lower trophic level and physical/chemical oceanographic sampling onshore and offshore, with the inshore portions of many of the transects being ARCWEST stations. This cruise was part of a cost sharing effort on the NOAA Ship *Ronald H. Brown* since ship time was fully funded by NOAA/OAR. The research on board was a collaborative effort of BOEM and NOAA funded scientists. A map of these stations (Figure 1) shows both the ARCWEST and CHAOZ-X stations. See the Eco-FOCI's 2015 Arctic Cruise Report for a complete listing of CTD stations. Oceanographic mooring work was conducted on a second cruise on the F/V *Aquila*.

### Moorings:

Locations for the oceanographic and active acoustic moorings which were retrieved in 2015 are shown in Figure 1 (stars). See the PMEL mooring website ([http://www.pmel.noaa.gov/foci/operations/mooring\\_plans/2015/aug2015\\_aq1501\\_moorings.html](http://www.pmel.noaa.gov/foci/operations/mooring_plans/2015/aug2015_aq1501_moorings.html)<sup>1</sup>) for information on the instruments placed on each mooring. Seven of the ARCWEST biophysical moorings were redeployed at C1, C2, C4 and C9. In addition, an upward looking passive acoustic TAPS-6NG (Tracor Acoustic Profiling System, Next Generation) instrument was deployed at C2 (Figure 1) to measure zooplankton bio-volume and size distribution.

The monthly mean transport at Icy Cape during 2010-2014 was strongly variable during winter and fall (Figure 7). During spring and summer (April – July), however, transport was consistently northeastward and less variable among years. Using the measurements of transport through Bering Strait (Woodgate et al., 2005) indicates that the monthly mean transport on the Icy Cape line ranges from 25-50% of the transport through Bering Strait.

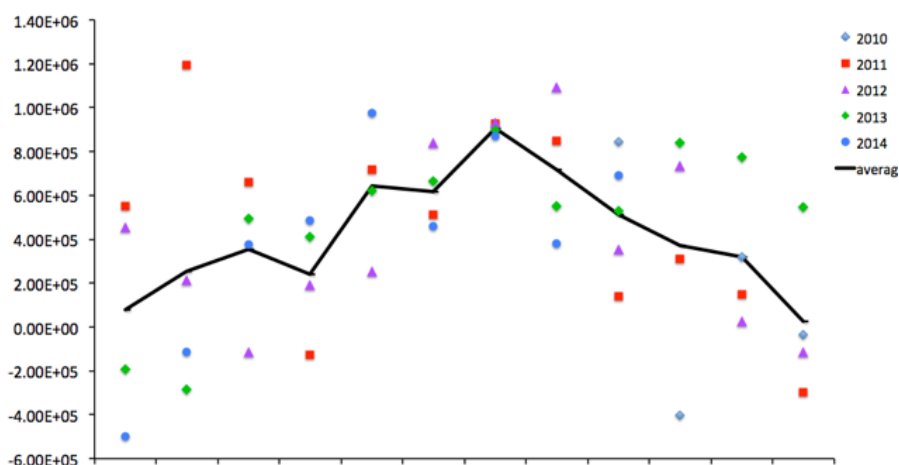


Figure 7. Mean transport per month for five years during 2010–2014 at Icy Cape, Alaska. Means combine the CHAOZ (2010–2011) and ARCWEST/CHAOZ-X (2012–2014) data.

### Hydrography & Plankton Sampling:

In 2015, the sampling effort was conducted off the NOAA Ship *Ronald H. Brown* from 6 August to 4 September (Figure 8a). The line off Point Hope (Figure 8b, yellow dots in DBO3) was partially sampled by the F/V *Aquila* (see the 2015 ARCWEST/CHAOZ-X Cruise Report for details).

Nutrient samples will be processed this fall and incorporated into the hydrographic files. Data will be uploaded to the database in the winter. Chlorophyll samples (N > 400) were collected and are stored in a freezer in Seattle. Chlorophyll samples will be analyzed in January/February and uploaded into the database.

As in previous years, biological sampling included samples for extracted chlorophyll a and zooplankton samples collected with the Tucker Sled. Chlorophyll a samples were frozen and returned to Seattle for

<sup>1</sup>On this webpage subsurface moorings relevant to this project are titled 15CK (i.e., Chukchi Sea 2015) and 15BS (i.e., Bering Sea 2015). The number on the end corresponds to the mooring clusters: e.g., 15CKT-2A corresponds to C2 and 15BS-2C corresponds to M2.

extraction and analysis. The zooplankton samples were returned to Seattle and will be shipped to the Polish Plankton Sorting and Identification Center in November. We expect the digital data to be returned in late spring or early summer.

In addition to the ARCWEST and CHAOZ-X sampling described above, the NOAA Program on Innovative Technology for Arctic Exploration (PITAE) program conducted field work in the Chukchi Sea in 2015. In July, the USCGC *Healy* deployed two wave gliders and an oceanographic mooring in the vicinity of biophysical mooring C2. These technologies were retrieved in late August and mid-September, respectively. Data from the PITAE field work will be incorporated into the ARCWEST synthesis analyses.

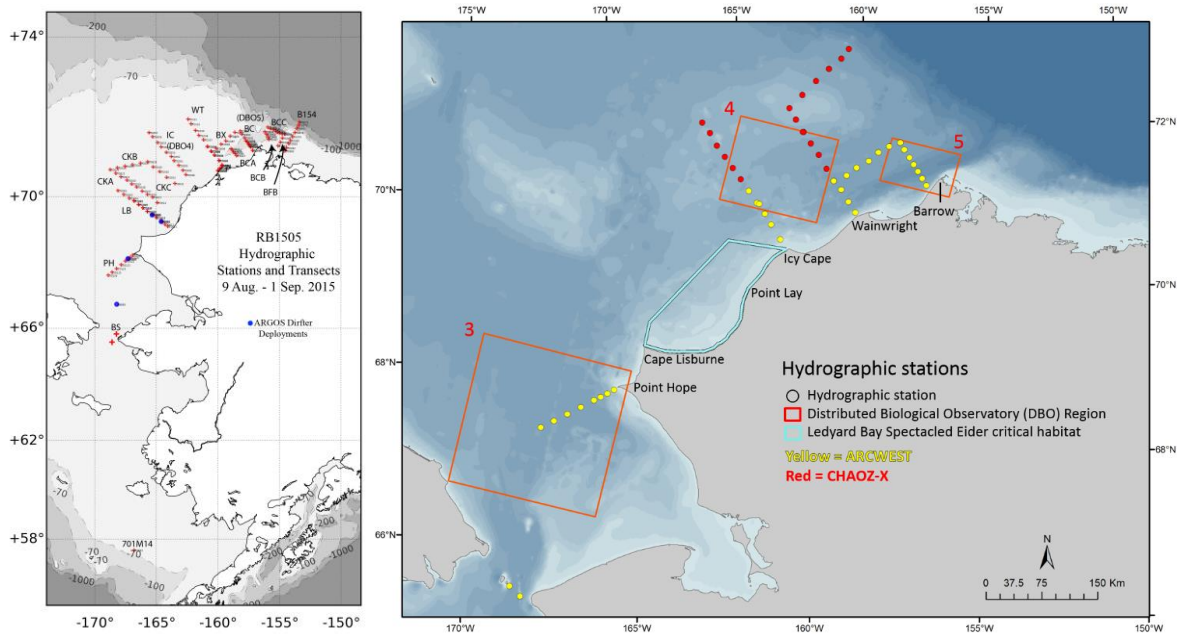


Figure 8a. Biophysical stations sampled by the NOAA Ship *Ronald H. Brown* with ARGOD Drifter Deployment locations. Figure 8b. Biophysical stations in regards to CHAOZ-X, ARCWEST, and the DBO. Yellow dots indicate ARCWEST stations. Red dots indicate CHAOZ-X stations. Red lined boxes indicate DBO regions.

### Satellite Tracked Drifters:

Satellite-tacked drifters were deployed (Figure 9) from the USCGC *Healy* (eight in July) and NOAA Ship *Ronald H. Brown* (four in August). Previous movies showing drifter tracks since 2011 can be viewed at the following website under the heading *Drifter Movies/Chukchi Sea/2015*: [http://www.ecofoci.noaa.gov/efoci\\_drifters.shtml](http://www.ecofoci.noaa.gov/efoci_drifters.shtml). Also at this site, movies showing drifter tracks with ice extent in 2011, 2012-2013, and 2013-2014 can be downloaded under the heading *Chukchi Sea Drifters with Ice Movies (M4V)*.

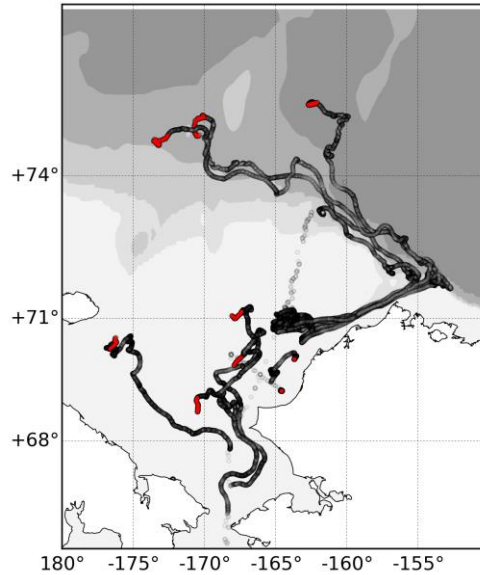


Figure 9. 2015 US Arctic Drifter Composite. Red indicates most recent data over a five-day period beginning 17 September 2015. Black shows the trajectories since the start of the deployment or start of the year for multiyear deployments. 2015 deployment locations can be found in Figure 8a.

#### *Active Acoustics:*

All TAPS-6NG instruments were retrieved and a single TAPS-6NG instrument was deployed at site C2 on the Icy Cape line by the *F/V Aquila* (see the ARCWEST/CHAOZ-X 2015 Cruise Report for additional details). This instrument contains the newly designed controller board and the full set of calibrated transducers.

A new, simpler, control board was designed, built and preliminarily tested for the TAPS-6NG. Tests were accomplished on the bench and on a short deployment in Lake Washington. Based on those tests we decided to attempt a redeployment of the instrument in the Chukchi. The instrument was deployed at site C2 as the ship made it way eastward. The *F/V Aquila* returned to the site 6 days later, retrieved the instrument, downloaded data, and then redeployed the instrument for the winter. It appears that the instrument collected data during the entire 6 day deployment. We will examine the data to determine if it is what was expected.

#### *Lower Trophic Level Sample and Data Analyses:*

Chlorophyll samples from 2014 were processed. Greater than 225 zooplankton samples were collected and preserved on the 2014 cruise. All samples were sent to the Polish Plankton Sorting and Identification Center in Szczecin, Poland, and counts of organisms were returned to us in June of 2015. Our standard QC/QA procedures will be applied where every handwritten form will be compared to what was entered into the computer in Poland and corrected as needed. After QC/QA, the data will then be uploaded to the database. We have finished the transition of our new database. However, we only have data available up until 2012. The 2013 data are awaiting QA/QC and the 2014 data are awaiting verification and QA/QC.

### **Contribution of data to the Distributed Biological Observatory (DBO)**

The ARCWEST program contributes data to the DBO Workspace, supported by AOOS/AXIOM. ARCWEST principal investigators were invited to join the password-protected workspace in December 2013, and are in the process of contributing data and data products (maps and figures) as are other DBO contributors. The development of the Workspace is an activity of the DBO Implementation Team (<http://www.arctic.noaa.gov/dbo>) and is in its early stages. The contribution of information from the ARCWEST program is considered foundational to the development of the workspace, especially for the visual and acoustic data provided on marine mammals. To date, the 2013 and 2014 sonobuoy data have been uploaded, as well as a map detailing the location of the currently deployed passive acoustic moorings. Long-term biophysical mooring data is being uploaded to the website upon completion.

### **Significant technical, schedule, or cost problems encountered**

Challenges for the 2015 field season included: paying for increases in fuel and vessel costs that have occurred since the ARCWEST proposal was written and approved, as well as mooring costs that have more than doubled. Costs for a vessel charter are higher than anticipated in 2011 when the ARCWEST budget was submitted. To save funds, we have conducted vessel sharing with PMEL each year. In 2015, we exercised the option year on our 2014 vessel charter contract with KB Fisheries, Inc. to conduct mooring retrieval and deployment, drifter deployment, and marine mammal acoustics and visual observations. As part of that cost sharing effort, lower trophic level and physical/chemical oceanographic sampling was conducted off the NOAA Ship *Ronald H. Brown*. Ship time on the NOAA Ship *Ronald H. Brown* was fully funded by NOAA/OAR with the research on board being a collaborative effort of BOEM and NOAA funded scientists.

Due to the 8 September 2013 incident in which the satellite tagging team was flipped overboard during satellite tagging operations involving gray whales (see Appendix 7 of the ARCWEST 2013 Cruise Report available at <http://www.afsc.noaa.gov/nmml/cetacean/arcwest.php>), additional expenses have been incurred due to lost gear and skiff repairs.

To address budget shortfalls and funds needed to successfully complete the 2015 ARCWEST/CHAOZ-X cruise, a supplemental funding request was submitted to Carol Fairfield on 21 November 2014. After the costs of the 2015 field season have been fully invoiced, a revised supplemental funding request will be submitted to document funds needed to complete the analysis and synthesis of the ARCWEST project in the best manner possible.

### **Significant meetings held or other contacts made**

7 July 2015: N. Friday emailed cruise information to the Alaska Eskimo Whaling Commission (AEWC), Chukchi and North Slope whaling captain associations, village liaisons, communications centers, and the North Slope Borough. Hard copies for the community outreach fliers were also mailed to the AEWC and village liaisons.

12 August 2015: N. Friday emailed updated cruise information to the AEWC, Chukchi and North Slope whaling captain associations, village liaisons, communications centers, and the North Slope Borough. Updated hard copies for the community outreach fliers were also mailed to the AEWC and village liaisons. Following this outreach, N. Friday and C. Berchok conducted email correspondence with A. Brower, Executive Director of AEWC, to refine our cruise plan to avoid fall whaling activities.



9 to 29 September 2015: C. Berchok emailed the AEWG, Chukchi and North Slope whaling captain associations, village liaisons, communications centers, and the North Slope Borough with daily updates on the progress of the cruise.

### Presentations and Publications

Garland, E.G., Berchok, C.L. and Castellote, M. 2015. Temporal peaks in beluga whale (*Delphinapterus leucas*) acoustic detections in the northern Bering, northeastern Chukchi, and western Beaufort Seas: 2010-2011. *Polar Biology*. DOI: 10.1007/s00300-014-1636-1.

Garland, E.C., Castellote, M. and Berchok, C.L. 2015. Beluga whale (*Delphinapterus leucas*) vocalizations and call classification from the eastern Beaufort Sea population. *Journal of the Acoustical Society of America*.

Martini, K.I., P.J. Stabeno, C. Ladd, P. Winsor, T. Weingartner, C.W. Mordy, and L. Eisner. 2015. Dependence of subsurface chlorophyll on seasonal water masses in the Chukchi Sea. *J. Geophys. Res.* [submitted]

Stabeno, P., Ladd, C. and Salo, S. in prep. Four years of current measurements in the Chukchi Sea. *Continental Shelf Research*.

Stabeno, P. 2014. US Arctic Present and Future. Pacific Marine Environmental Laboratory. Seattle, WA. 12 August 2014. Presentation to the NOAA Senior Research Council.

### Literature Cited

Garland, E.G., Berchok, C.L. and Castellote, M. 2015a. Temporal peaks in beluga whale (*Delphinapterus leucas*) acoustic detections in the northern Bering, northeastern Chukchi, and western Beaufort Seas: 2010-2011. *Polar Biology*. DOI: 10.1007/s00300-014-1636-1.

Garland, E.C., Castellote, M. and Berchok, C.L. 2015b. Beluga whale (*Delphinapterus leucas*) vocalizations and call classification from the eastern Beaufort Sea population. *Journal of the Acoustical Society of America*.

Woodgate, R.A., Aagaard, K. and Weingartner, T.J. 2005. Monthly temperature, salinity, and transport variability of the Bering Strait through flow. *Geophys. Res. Lett.*, 32(4): L04601. DOI: 10.1029/2004GL021880.



## APPENDIX

An abstract with results from satellite tag data obtained during ARCWEST which was submitted to the Society for Marine Mammalogy's Biennial Conference and was accepted as an oral presentation.

### **Fine-scale movement and dive behavior of gray whales satellite-tracked in the northern Bering and Chukchi Seas**

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- 3) Cascadia Research Collective

North Pacific gray whales routinely aggregate in large numbers to feed on benthic organisms in the northern Bering and Chukchi Seas each summer. In August and September of 2012 and 2013, five gray whales were tracked with satellite tags deployed in the Chukchi Sea for an average of 44 days (range = 12-67d). One gray whale, tagged near Wainwright, Alaska, in 2012, stayed within a 140km radius of the deployment location for the 57-days it was monitored. Four whales tagged 85km southwest of Pt. Hope, Alaska, in 2013, showed varying movement patterns: one animal travelled west toward the Chukotka Peninsula immediately after tagging, two individuals spent more than a month near the tagging location before moving south to or toward St. Lawrence Island, and one spent the entire 42 days of tag duration within a 130km radius of the deployment location. Results from switching state-space models reveal area-restricted search behavior in well-known gray whale foraging habitats. One tag was equipped with dive-depth sensors and recorded regular dives of 55-60m during periods of area-restricted search off Pt. Hope and St. Lawrence Island, further underscoring the significance of these habitats for gray whale foraging. While these results emphasize the importance of well-known foraging areas, they also highlight occasional long-distance travel between periods of area-restricted search, likely in response to changing prey availability. Additionally, this study provides new information from dive-depth recordings of foraging gray whales, allowing for further insight into their fine-scale habitat use.