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

Nancy A. Friday[1], Ph.D.
Phillip J. Clapham[1], Ph.D.
Catherine L. Berchok[1], Ph.D.
Jessica L. Crance[1], M.S.
Alexandre N. Zerbini[1,5], Ph.D.
Brenda K. Rone[1], M.S
Amy S. Kennedy[1,4], Ph.D.
Phyllis J. Stabeno[2], Ph.D.
Jeffrey M. Napp[3], Ph.D.
Adam Spear[3], M.S.

[1] National Marine Mammal Laboratory
Alaska Fisheries Science Center

[2] Pacific Marine Environmental Laboratory

[3] Resource Assessment and Conservation Engineering Division
Alaska Fisheries Science Center
7600 Sand Point Way NE
Seattle, WA 98115

[4] Joint Institute for the Study of the Atmosphere and Ocean
University of Washington
Box 355672
3737 Brooklyn Ave NE
Seattle, WA 98105

[5] Cascadia Research Collective
218 ½ W 4th Ave.
Olympia, WA 98501

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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 annual report covers work conducted in 2015, the third year of the study.

The major activities during 2015 consisted of planning for and executing the 2015 Arctic Whale Ecology Study (ARCWEST)/Chukchi Acoustics, Oceanography, and Zooplankton Study-extension (CHAOZ-X) cruise, after-season maintenance and testing of the passive acoustic recorders, the processing and analysis of data collected during the 2013 and 2014 cruises, and planning for the final report. 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. As a result of the work conducted to complete the final report for the Chukchi Acoustics, Oceanography, and Zooplankton Study (CHAOZ), the ARCWEST team has developed the framework of 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. The acoustics group is also mid-way through implementing a passive acoustics database (Tethys, Roch *et al*., 2013), as part of a pilot project with NGDC to archive the data and make it publically accessible. 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 season of visual and acoustic observations were collected. There were very few acoustic detections during the field season compared to previous years. Only 18% of sonobuoys deployed in the Chukchi Sea (14 of 78) had acoustic detections, compared with 46% (69 of 149) in 2014.

    - The acoustics team continues to process the long-term time series in the Chukchi Sea. Analyses are on-going for four mooring locations: Cape Lisburne (CL1), Point Hope (PH1), Nome (NM1), and Peard Bay (PB1/C5). 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 from any research group to provide data in that near shore, up-canyon location.

    - Two years of recordings 2010-2012 on the Cape Lisburne (CL1) and Point Hope (PH1) moorings have each been analyzed for fin whales. These data will further improve the fin whale call library for use in the Low-Frequency Detection and Classification System.

- 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; as well as walrus and other pinnipeds), which will provide essential information on movements on the wintering grounds and migratory timing of these 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 has been published (Garland *et al*., 2015b). Alex Ulmke is continuing the work begun by Ellen Garland in analyzing beluga whale vocalizations, with her current focus on the Norton Sound mooring (NS1).

    - 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 meter thick. Sea ice thickness and bowhead acoustic data from the ARCWEST moorings will be used to validate this finding, since 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 (2012–2014), and CHAOZ-X (2012–2014) data. More than a third of the transport entering the Arctic through Bering Strait remains on the shelf, heading toward the Barrow Arch area.

    - The monthly mean transports during winter and fall were highly variable with large standard deviations each month. In addition, the year to year variability is also large. During April – August, year-to-year variability is much reduced.

    - The August 2014 to August 2015 mooring and hydrographic data should be available by March 2016, except for the ice thickness data, which is taking longer to process and will not be available to June.

- The 2014 plankton samples from the large mesh net have been processed by the Polish Plankton Sorting and Identification Center in Szczecin, Poland and the paper forms have been reconciled with the digital files. Uploading of the data into the database will occur in the first quarter of 2016. The 2014 chlorophyll samples were processed. Paperwork to bring an analysis contractor onboard for the first two quarters of 2016 was submitted to Acquisitions and Grants. The contract begins in early February.

**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**

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 Annual Report, available at http://www.afsc.noaa.gov/nmml/cetacean/chaoz-x.php). Analysis of the data collected during the 2013 and 2014 vessel cruises has continued.

To reduce costs and provide additional resources for non-Federal staff, passive acoustic staff and a telemetry analyst have been hired through the Joint Institute for the Study of the Atmosphere and Ocean (JISAO). NMML is currently in the process on hiring additional, temporary passive acoustic staff to assist with processing the acoustic data collected on the acoustic recorders.

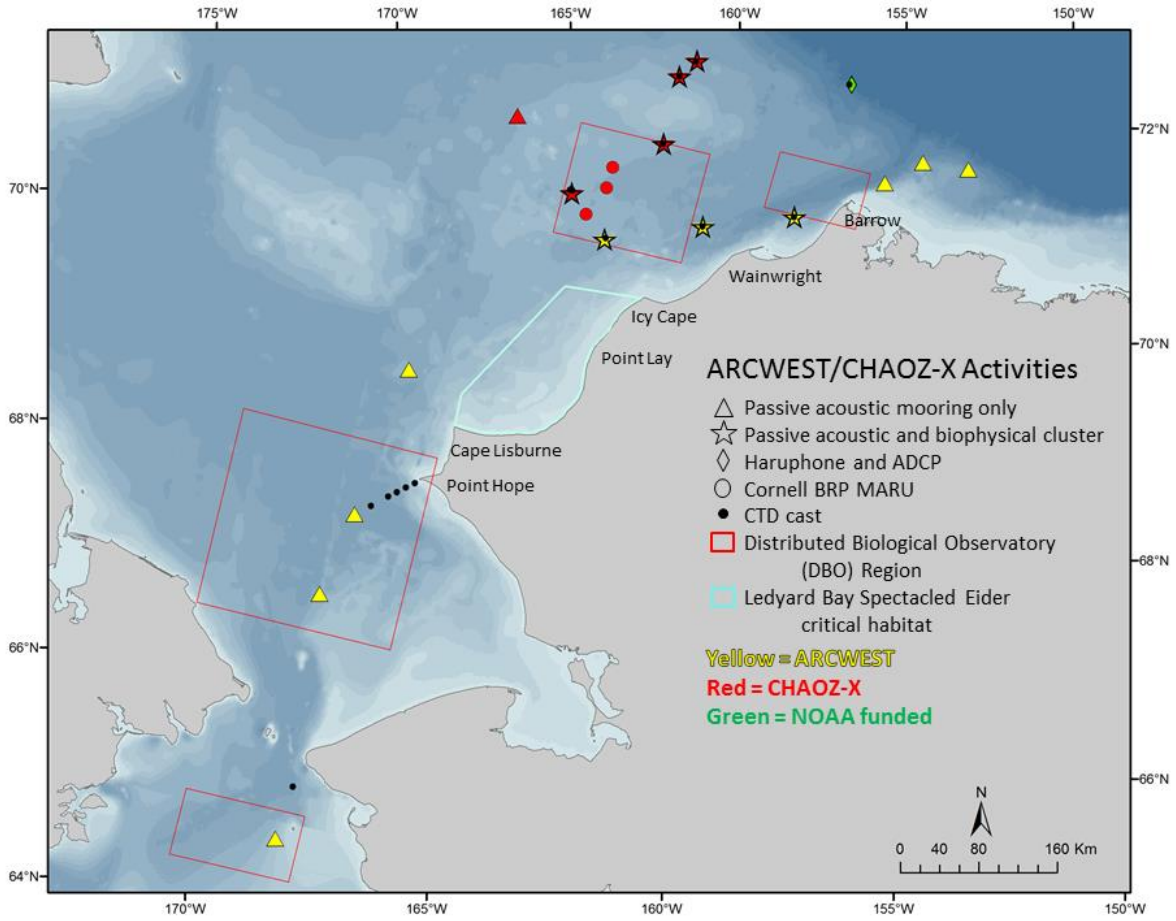



Figure 1. Overview of activities undertaken in the study area during the 2015 ARCWEST/CHAOZ-X cruise.

Planning has begun for the final data analysis and synthesis work which will begin in early 2016 to produce the final report in 2017. The ARCWEST team plans to use the framework which was developed for the CHAOZ 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 (Figure 2). 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 Pacific Marine Environmental Laboratory (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 (C5) site, and the fourth year at the rest of the sites in the Chukchi Sea. Furthermore, several of these recorders (IC1/C1, WT1/C4, PB1/C5) have been collocated with a cluster of biophysical moorings, and one (PH1) was redeployed with a microcat on the mooring in 2015. Locations for the 2014 and 2015 ARCWEST moorings were determined in coordination with the oceanographic and lower trophic level components of ARCWEST.

Funds are available through PMEL for a 2016 field cruise to retrieve and redeploy moorings and conduct transect line sampling. This will allow the continuation of our long-term multi-disciplinary dataset in the Chukchi Sea. Solicitation paperwork for the charter vessel is currently being drawn up by PMEL.

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 the AURAL mooring in Norton Sound (NS1). This retrieval will provide the third and final year of data collection at that site.

The NOAA-funded mooring HA14 (C9) was retrieved and redeployed for a two-year deployment. It will be recovered in 2017. This mooring is part of a NOAA-wide effort to monitor ambient noise throughout the entire US-EEZ.

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). Analyses are on-going for four new mooring locations: Cape Lisburne (CL1), Point Hope (PH1), Nome (NM1), and Peard Bay (PB1/C5). 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 from any research group to provide data in that near shore, up canyon location.

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 110 nm off Icy Cape) is shown in Figure 3. When the ARCWEST project is completed there will be at least a six-year time record on the Icy Cape mooring line; as recordings began there in 2010 as part of the CHAOZ project. 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 4). Results from these ARCWEST recorders will not only increase the time series at this important area in the Chukchi Sea , but will also increase thegeographic extent beyond this Icy Cape line.

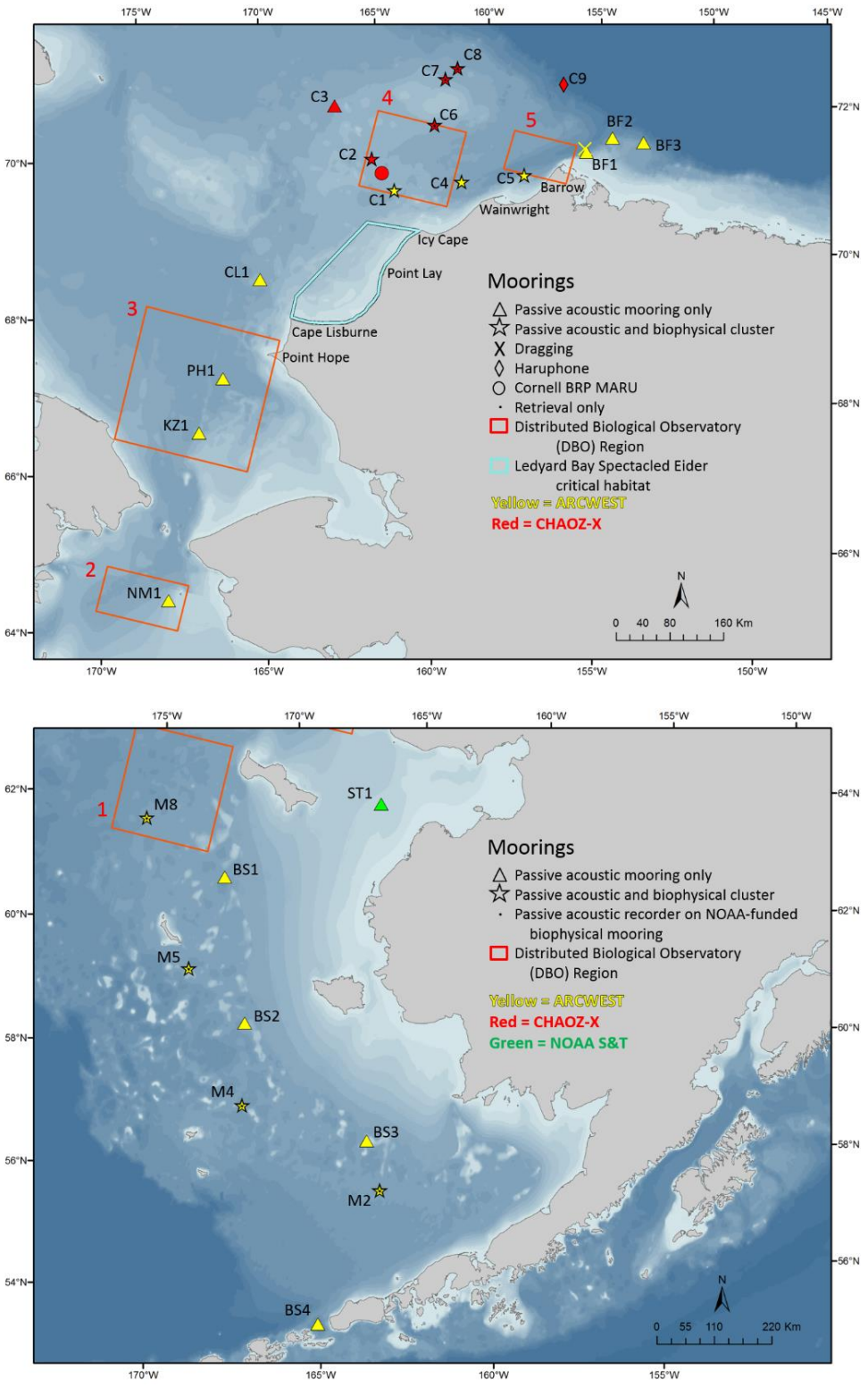



Figure 2. Passive acoustic moorings and biophysical mooring clusters retrieved and/or deployed during the 2015 ARCWEST/CHAOZ-X cruise. Yellow symbols indicate ARCWEST moorings. Red symbols indicate CHAOZ-X moorings. C6, C7, and C8 were retrievals only, and C9 will be retrieved in 2016. Top panel: primary operating area of the northern Bering Sea, the Chukchi Sea, and the western Beaufort Sea; bottom panel: Bering Sea.

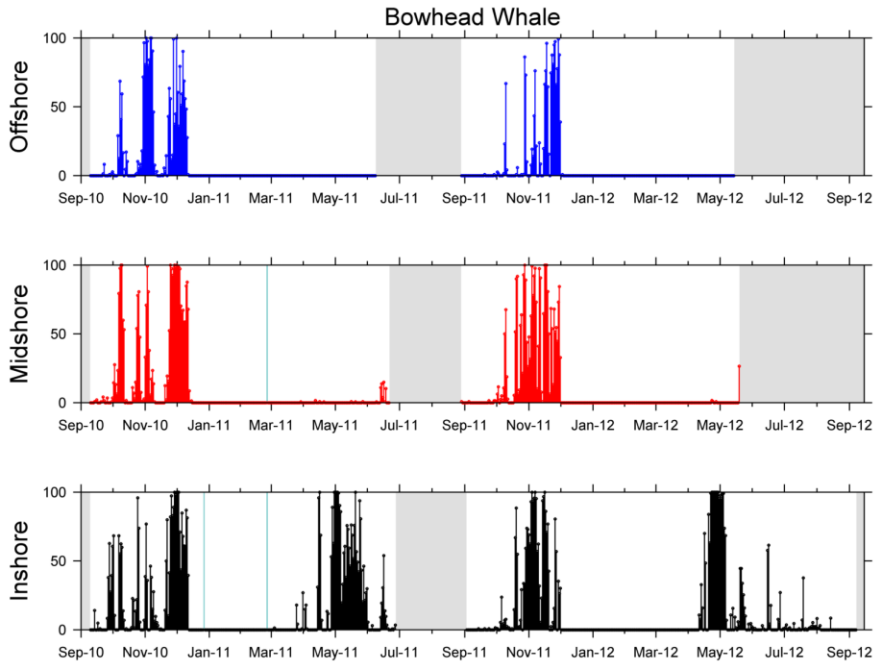



Figure 3. Bowhead whale calling activity (presented as the percentage of time intervals with calls) for inshore (IC1; lower panel), midshore (IC2; middle panel), and offshore (IC3; upper panel) locations, 2010-2012. Dark gray shading indicates no data, and teal shading indicates days where detections were masked by noise.

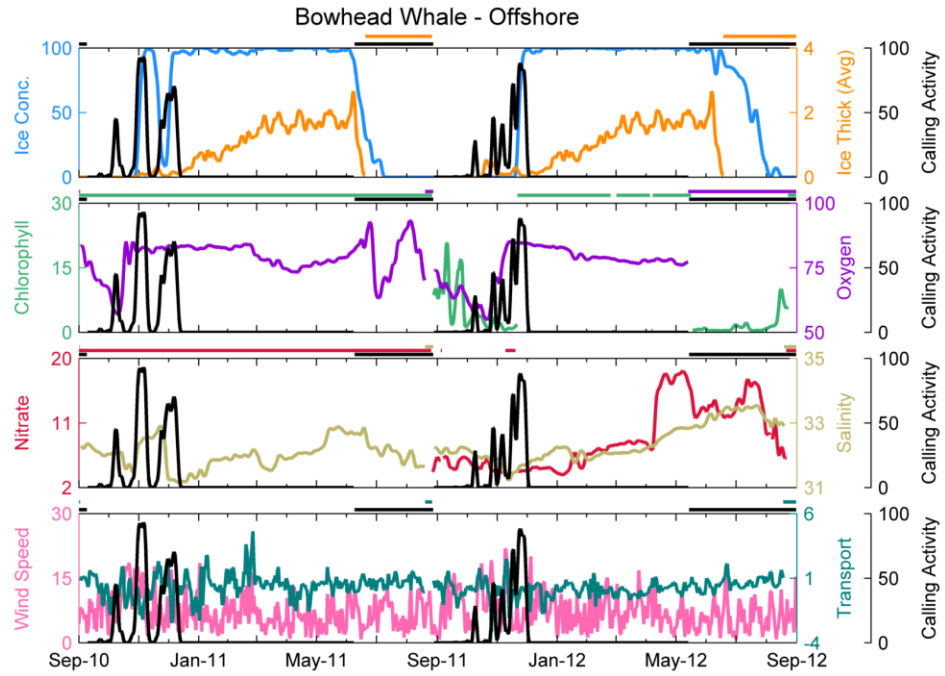



Figure 4. Bowhead whale calling activity as it relates to oceanographic variables at the offshore Icy Cape (IC3) location, 2010-2012. Black line = percent of time intervals with calls. Top row: percent ice concentration (blue line) and ice thickness (m; orange line). Second row: chlorophyll (µg/l; green line) and oxygen (m x 10; purple line). Third row: nitrate (µm; red line) and salinity (psu; tan line). Bottom row: wind speed (m/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.

The data drives from all 2014-15 ARCWEST AURALs were extracted, and the raw files batch converted into ten-minute wave files renamed with intuitive filenames containing mooring name, date and, time information. These wave files are almost finished being batch converted into spectrogram image files (.png) for low, medium, and high frequency bands.

For future analyses, we hope to use our in-house Matlab-based sound analysis program on data pre-processed using a low-frequency detection and classification system (LFDCS by Mark Baumgartner, Woods Hole Oceanographic Institute (WHOI); Baumgartner and Mussoline 2011). The LFDCS is an IDL-based program that uses manually created call libraries to apply discriminant function analysis across seven measurements, called call attributes, taken from each auto-detected call. The analyst selects exemplary calls to create a call library. The LFDCS is then run on novel data sets and uses this comprehensive call library for comparison in discriminant function analysis to classify all of its auto-detections. Once the library was deemed robust enough for real application, the LFDCS was run on each mooring data set, and the resulting auto-detections were checked for accuracy by a manual analyst.

Eliza Ives has been working to implement the LFDCS on our dataset; however, initial results are discouraging. Previous work determined that the LFDCS is not working well for bowhead whales; current work has focused on fin whales. Over two-hundred exemplars were carefully selected for the fin whale call library. The call library was then put through comprehensive and iterative logistical regression analysis, in order to determine its efficacy for application on novel data sets. The LFDCS analysis for fin whales on the 2011-2012 data set flagged over 2,000 signals, all of which were checked manually and determined to be either mooring noise or airgun signals. The recent completion of two additional moorings (CL1 and PH1) for fin whales will not only add to the call exemplar library, but also be used to groundtruth detector results and refine detector parameters. However, until the LFDCS is fully operational, we will continue to process data manually. We will also send some of our data to Chris Clark at the Bioacoustics Research Program (Cornell) and Xavier Mouy (JASCO Applied Sciences), to test the efficacy of their bowhead and fin detectors, respectively, on our recordings.

*Associated analyses*:

Ellen Garland, our NRC postdoctoral fellow, left at the beginning of 2015 for a Newton International Research Fellowship at the University of St. Andrews. In addition to collaborating with us on a multitude of papers (as well as our BOEM-funded project reports), Ellen continues to lead, and run analysis for, her beluga study on population differences in beluga vocal behavior for the Alaskan region. Before she left she completed two papers from her beluga whale study. 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 north through the eastern Chukchi (inshore (IC1)) at distinct times (Figure 5, 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 is in the process of completing the preliminary repertoire for the eastern Chukchi Sea population. Finally, with any repertoire, it is important to know how much it varies inter-annually. To this end, Ellen is using the results of NMML analyst Alexandra Ulmke, who has pulled beluga detections off the same mooring site in the Beaufort Sea over multiple years to determine the amount of repertoire drift.

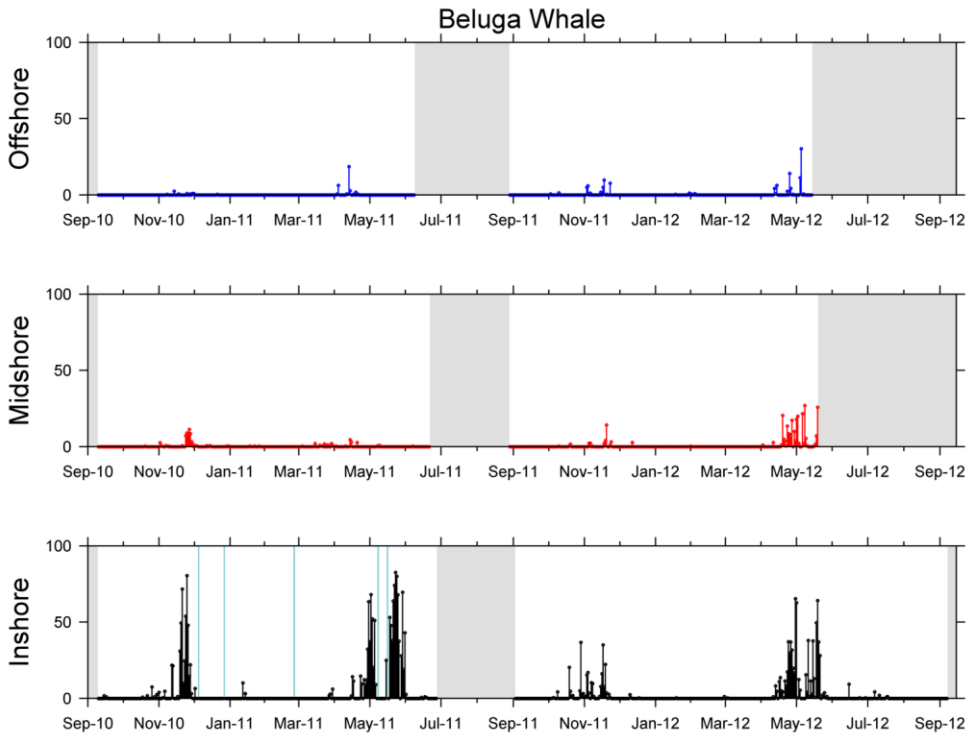



Figure 5. Beluga whale calling activity along Icy Cape line (presented as the percentage of time intervals with calls) for inshore (IC1; lower panel), midshore (IC2; middle panel), and offshore (IC3; upper panel) locations, 2010-2012. Dark gray shading indicates no data, and teal shading indicates days where detections were masked by noise. Note the bimodal distribution at the inshore location in the summer, which likely represents two different populations (eastern Chukchi and eastern Beaufort populations) migrating through at different times.

Dana Wright is working on an analysis of Bering Sea moorings for a project funded by the International Fund for Animal Welfare (IFAW) and the Marine Mammal Commission (MMC) on the North Pacific Right Whale (NPRW). While the project is externally-funded, the mooring deployments were funded by ARCWEST (or other NMML/BOEM studies). Because of the similarities in call types between the NPRW, humpbacks, and bowhead whales, Dana is analyzing the data sets for all of these species as well as gray whales. A side product of this effort will be a description of the spatio-temporal distribution of bowheads on their wintering grounds in the Bering Sea. Her first year of effort (IFAW-funded) has focused on the southern and northern Bering Sea shelf (the Aleutian passes, near St. Lawrence Island, and in Norton Sound. She will soon begin her second year of analysis (MMC-funded) continuing this work with the data retrieved this past season at the same sites as in the first year of analysis as well as at a few more sites further north. We are hoping to obtain an additional year of funding to allow an additional analyst to work on the critical mid-latitudes of the Bering Sea shelf to complete the overall picture of the spatio-temporal distribution of North Pacific right whales and bowhead whales on the Bering Sea shelf.

A NOAA Hollings Scholar, Srishti Dasarathy, used passive acoustic data from Arcwest recorders placed on PMEL oceanographic moorings to examine the effect of oceanographic parameters on fin whale presence in the northern and southern Bering Sea, she will be presenting this work at AKMSS and the AGU meetings in 2016. We have sent data recordings (some Arcwest- but all BOEM-funded) from the Bering, Beaufort and southern Chukchi Seas to Heloise Frouin-Mouy (JASCO Applied Sciences) for her

work on the spatio-temporal distribution of ribbon seals in the Bering, Chukchi, and Beaufort Seas. Her results for the Bering Sea were recently presented at the 21st Biennial Conference on the Biology of Marine Mammals in San Francisco, CA. We will continue to collaborate with scientists from JASCO as our combined analyses develop.

Our final collaboration is with Aaron Thode (Scripps Institution of Oceanography) and Julien Bonnel (Université Européenne de Bretagne), who are using some of our Bering Sea moorings to analyze upsweep vocalizations from North Pacific right, bowhead, and humpback whales (this call type is often confused among the species). By analyzing the multi-path arrivals of the signals, they hope to be able to determine the depth at which the call was produced, and use this information to potentially distinguish among species.

*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 6). Only 18% (14 of 78) buoys deployed north of the Bering Strait had acoustic detections, compared with 46% (69 of 149) in 2014. Seven species were detected in the Chukchi (bowhead, humpback, fin, and gray whales, walrus, bearded seals, and unidentified pinnipeds); however, humpbacks and fin whales were only detected south of Point Hope. For more details see the ARCWEST/CHAOZ-X 2015 Cruise Report. No sonobuoys were deployed from the NOAA Ship *Ronald H. Brown*.

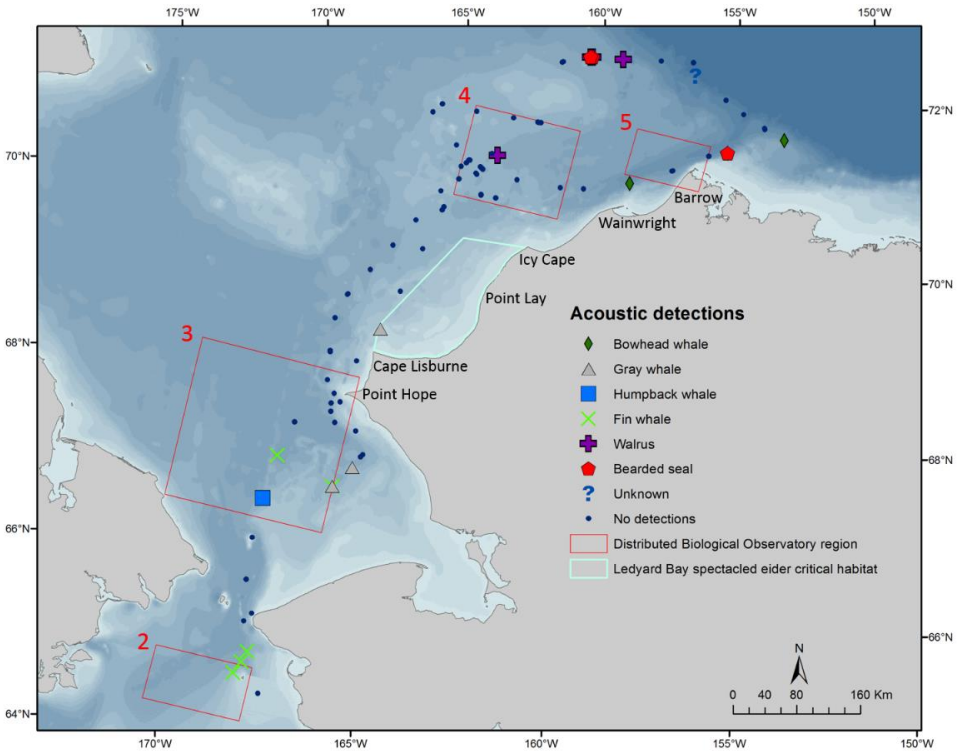



Figure 6. Sonobuoy deployment and acoustic detections from the ARCWEST/CHAOZ-X 2015 research cruise in the Chukchi Sea.

*Visual Observations Component:*

During the three cruises, a total of 3,769 nm of on-effort trackline (Table 1) were surveyed in the Beaufort and Chukchi Seas (Figure 7) and the Bering Sea and Gulf of Alaska (Figure 8). There was a grand total of 1,147 sightings (4020 individuals). This included 847 sightings (3650 individuals) of 16 confirmed marine mammal species and 300 (370 individuals) sightings of groups of animals that could not be identified to species level (Table 2, Figures 7 and 8).

Table 1. Completed visual effort for the ARCWEST 2013-2015 research cruises.

| Year | Effort (nm) |
|---|---|
| 2013 | 1,477 |
| 2014 | 1,663 |
| 2015 | 629 |
| Total | 3,769 |

Sightings from the 2013 to 2015 cruises revealed that the distribution of marine mammals was similar between years. In 2013 and 2014, specifically for large whales, relatively high densities of gray whales were observed in at least three different locations: coastal areas off Wainwright and Barrow, off of Point Hope and near the Bering Strait. While occasional sightings of Balaenopterid whales were recorded during all three surveys, sighting data suggests that humpback, fin, and minke whale densities in the Chukchi Sea are lower than those seen further to the south in the Bering Sea and the Aleutian Islands (e.g. Friday *et al*., 2012; 2013; Zerbini *et al*., 2006).

*Photo-ID*:

During the three cruises, photo-identification data was collected for killer, humpback, and gray whales. Two killer whales were photographed in the Bering Sea (2015), 32 along the Alaskan Peninsula in the Gulf of Alaska and in the Bering and Chukchi Seas (2013), and 15 were photographed in the Bering Sea (2014). Photographs are still being matched to existing catalogs. Two humpback flukes were obtained, one in the Chukchi Sea (2014) and one in the Gulf of Alaska (2013). Neither fluke was a match and were added to the NMML catalog. In 2013 and 2014, 50 gray whales were photographed in the Chukchi Sea, Bering Strait, and northern Bering Sea. Photographs have been submitted to the gray whale catalog curated by Cascadia Research Collective for matching. Additional details are available in previous ARCWEST/CHAOZ-X cruise reports.

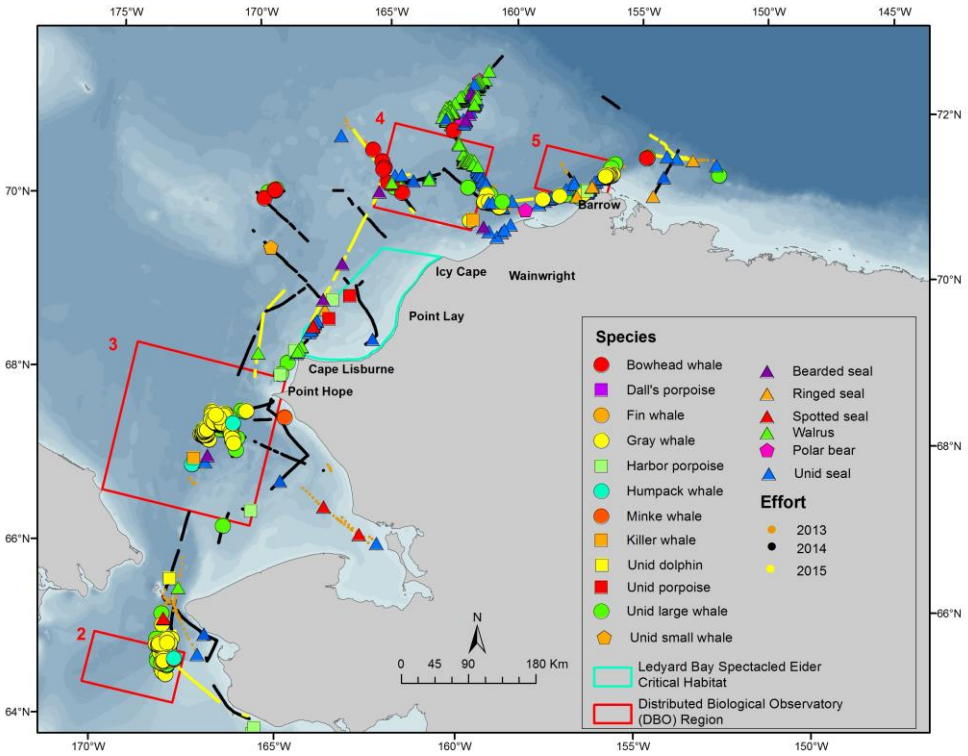



Figure 7. Marine mammal sightings and effort data from the ARCWEST/CHAOZ-X 2013-2015 research cruises, Beaufort Sea to Bering Strait.

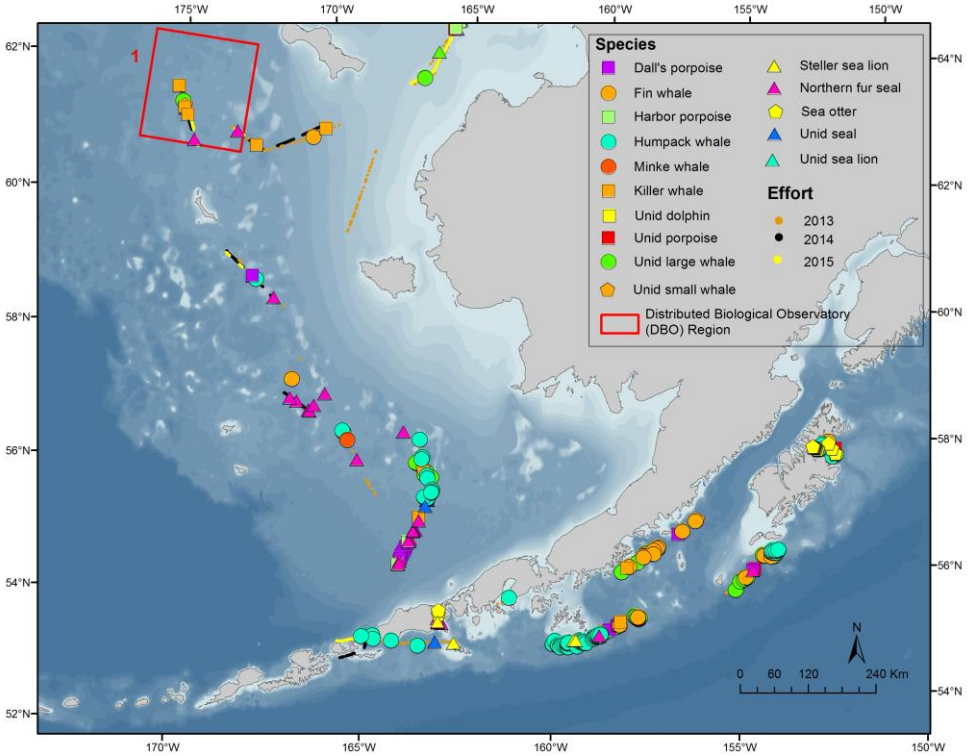



Figure 8. Marine mammal sightings and effort data from the ARCWEST/CHAOZ-X 2013-2015 research cruises, Bering Sea and Gulf of Alaska.

Table 2. Marine mammal sightings (with number of individuals within parenthesis) from the ARCWEST 2013-2015 research cruises.

| | 2013 | | | 2014 | | | 2015 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **On-Effort** | **Off-Effort** | **Total** | **On-Effort** | **Off-Effort** | **Total** | **On-Effort** | **Off-Effort** | **Total** | **Grand Total** |
| Fin Whale | 6(8) | 15(20) | 21(28) | 0 | 0 | 0 | 0 | 0 | 0 | 21(28) |
| Humpback Whale | 68(110) | 6(6) | 74(116) | 6(7) | 0 | 6(7) | 2(6) | 3(4) | 5(10) | 85(133) |
| Gray Whale* | 89(156) | 70(152) | 159(308) | 88(87) | 138(221) | 204(308) | 0 | 0 | 0 | 363(616) |
| Minke Whale | 0 | 1(1) | 1(1) | 0 | 1(1) | 1(1) | 1(1) | 0 | 1(1) | 3(3) |
| Bowhead Whale | 6(8) | 0 | 6(8) | 7(14) | 0 | 7(14) | 0 | 0 | 0 | 13(22) |
| Harbor Porpoise | 7(10) | 5(6) | 12(16) | 0 | 1(2) | 1(2) | 2(2) | 0 | 2(2) | 15(20) |
| Dall's Porpoise | 10(40) | 6(26) | 16(66) | 0 | 0 | 0 | 1(3) | 0 | 1(3) | 17(69) |
| Killer Whale | 3(21) | 4(39) | 7(60) | 0 | 3(14) | 3(14) | 1(2) | 0 | 1(2) | 11(76) |
| Unid Large Whale | 51(67) | 19(23) | 70(90) | 36(51) | 43(53) | 79(104) | 1(1) | 1(1) | 2(2) | 151(196) |
| Unid Small Whale | 1(1) | 1(1) | 2(2) | 2(2) | 0 | 2(2) | 0 | 1(1) | 1(1) | 5(5) |
| Unid Dolphin | 1(1) | 0 | 1(1) | 0 | 0 | 0 | 0 | 0 | 0 | 1(1) |
| Unid Porpoise | 4(17) | 3(4) | 7(21) | 1(1) | 1(1) | 2(2) | 1(1) | 0 | 1(1) | 10(24) |
| *Total Cetacean* | *236(399)* | *124(252)* | *377(717)* | *119(163)* | *186(291)* | *305(454)* | *9(16)* | *5(6)* | *14(22)* | 695(1193) |
| Fur Seal | 9(11) | 8(8) | 17(19) | 5(6) | 0 | 5(6) | 1(2) | 3(5) | 4(7) | 26(32) |
| Bearded Seal | 9(13) | 1(1) | 10(14) | 0 | 2(3) | 6(10) | 10(10) | 0 | 10(10) | 26(34) |
| Spotted Seal | 4(4) | 2(3) | 6(7) | 0 | 0 | 0 | 0 | 0 | 0 | 6(7) |
| Ringed Seal | 4(4) | 1(1) | 5(5) | 0 | 0 | 0 | 0 | 0 | 0 | 5(5) |
| Ringed or Spotted Seal | 27(32) | 6(8) | 33(40) | 0 | 0 | 0 | 0 | 0 | 0 | 33(40) |
| Walrus | 120(1158) | 67(639) | 187(1797) | 4(7) | 2(3) | 6(10) | 4(6) | 0 | 4(6) | 197(1813) |
| Steller Sea Lion | 3(23) | 1(1) | 4(24) | 0 | 0 | 0 | 0 | 0 | 0 | 4(24) |
| Sea Otter | 17(721) | 2(2) | 19(723) | 0 | 0 | 0 | 0 | 0 | 0 | 19(723) |
| Polar Bear | 1(1) | 2(4) | 3(5) | 0 | 0 | 0 | 0 | 0 | 0 | 3(5) |
| Unid Seal | 72(81) | 9(9) | 81(90) | 14(16) | 2(2) | 16(18) | 34(34) | 1(1) | 35(35) | 132(143) |
| Unid Sea Lion | 0 | 0 | 0 | 1(1) | 0 | 1(1) | 0 | 0 | 0 | 1(1) |
| *Total Other* | *266(2048)* | *99(676)* | *365(2724)* | *24(30)* | *4(5)* | *28(35)* | *49(52)* | *4(6)* | *53(58)* | 452(2827) |
| **Grand Total** | **502(2447)** | **223(928)** | **725(3375)** | **143(193)** | **193(296)** | **333(489)** | **58(68)** | **9(12)** | **67(80)** | **1147(4020)** |

* Several days of dedicated tagging operations were conducted in a high gray whale density area near Pt. Hope and King Island. Therefore, these numbers likely reflect a significant number of duplicate sightings and should be considered artificially high. A large portion of the unidentified large whales were in these same areas. Scientists plotted all sightings to keep track of animals in the area prior to and during small boat operations.

*Satellite Tagging Component:*

Analysis of the telemetry data collected in 2012 and 2013 is ongoing. Movement models (e.g. Jonsen *et al*., 2007; Johnson *et al*., 2008) have been applied to these data to evaluate fine scale habitat use (Figure 9). Preliminary results show distinct regions of area-restricted search (ARS) off Wainwright, southwest of Pt. Hope, and west of St. Lawrence Island. ARS indicate areas where movement is typically slow and erratic and are often associated with foraging habitats (e.g. Jonsen *et al*., 2007; Bailey *et al*., 2010). Figure 10 shows a detailed kernel density estimate for the high-use area southwest of Pt. Hope and near Wainwright. These preliminary results are consistent with results from aerial surveys and other telemetry project regarding preferred habitats used by gray whales in the Chukchi Sea.

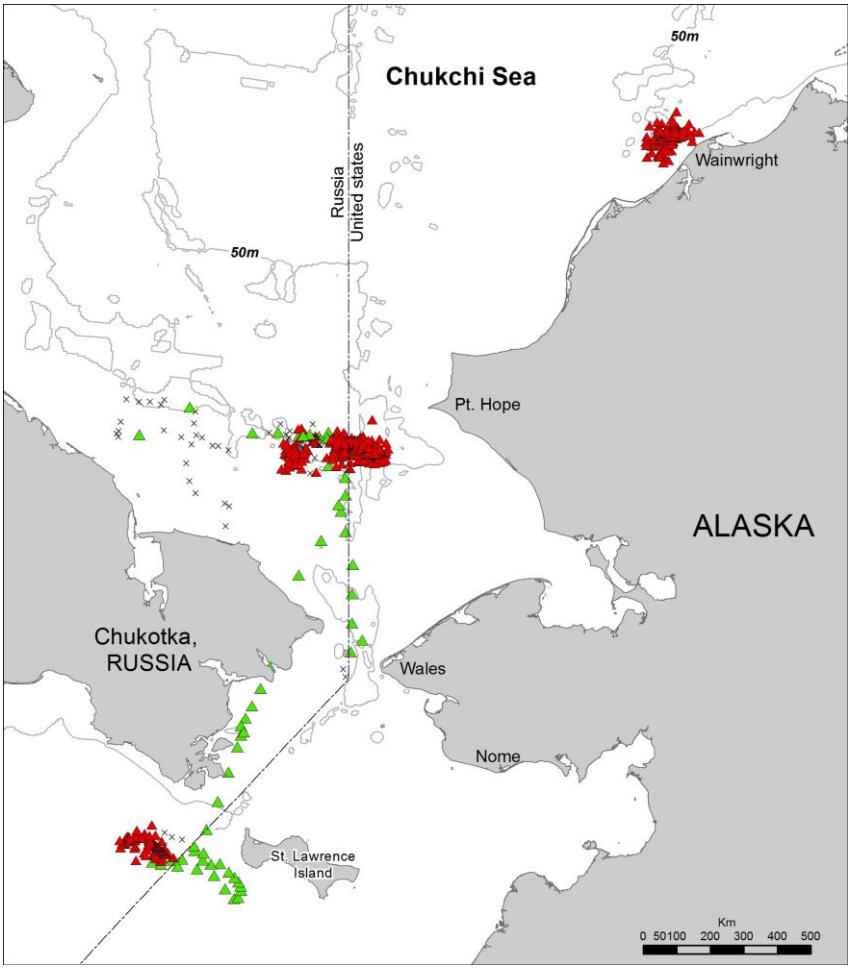



Figure 9. Habitat-use model results. Each triangle represents a switching state-space modeled position at a 6 hour time-step. Red triangles indicate where whales were engaging in area-restricted search (often associated with foraging) and green triangles indicate travel mode.

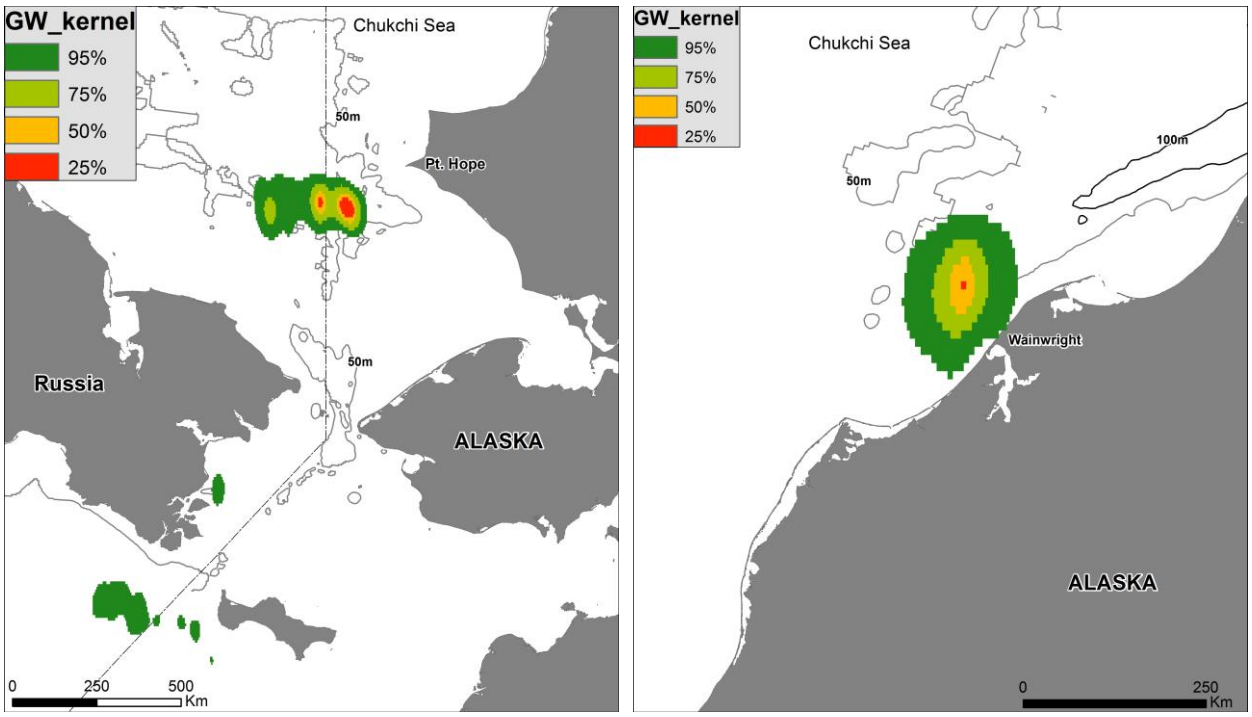



Figure 10. Kernel density estimate of the high-use area off Pt. Hope (2013 data, left) and Wainwright (2012 data, right). Colors indicate the percentage of time a whale is predicted to use each region.

An abstract with results from satellite tag data obtained during ARCWEST was presented at the Society for Marine Mammalogy's Biennial Conference in December 2015 (Appendix). In addition, a manuscript is in preparation for publication of these results. We expect submission will occur within the next few 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. The stations on the Brown cruise are shown in Figure 13a. See the Eco-FOCI's 2015 Arctic Cruise Report (http://www.afsc.noaa.gov/nmml/PDF/Eco-FOCI_CruiseReport2015.pdf) 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 11 (stars). See the PMEL mooring website (http://www.pmel.noaa.gov/foci/operations/mooring_plans/2015/aug2015_aq1501_moorings.html[1]) 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 11) to measure zooplankton bio-volume and size distribution.

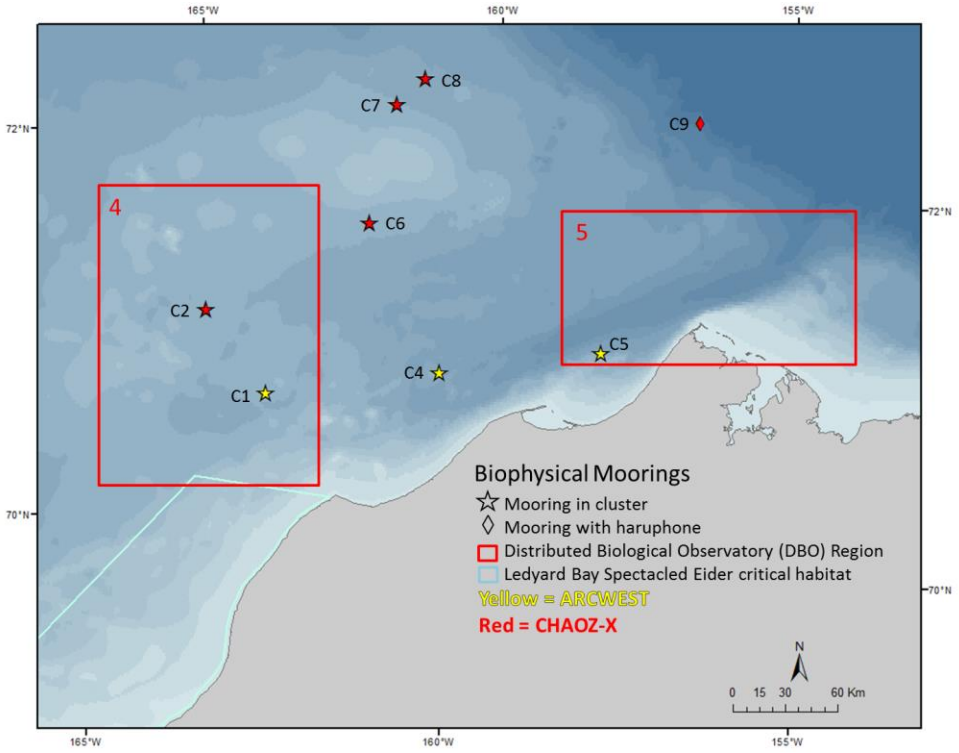



Figure 11. Biophysical mooring clusters to be retrieved during the 2015 ARCWEST/CHAOZ-X cruise. Yellow symbols indicate ARCWEST moorings. Red symbols indicate CHAOZ-X moorings. Moorings to be redeployed in 2015 are still to be determined.

The monthly mean transport at Icy Cape during 2010-2015 was strongly variable during winter and fall (Figure 12). During spring and summer (May-August), however, transport was consistently northeastward and less variable among years. Annual transport per deployment varied from 0.30 x $10^6$ $m^3$ $s^{-1}$ (Sv) to 0.50 Sv (Table 3), with an average of 0.40 Sv. Yearlong average transport ranged from 0.25–0.45 Sv. 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.

[1]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.

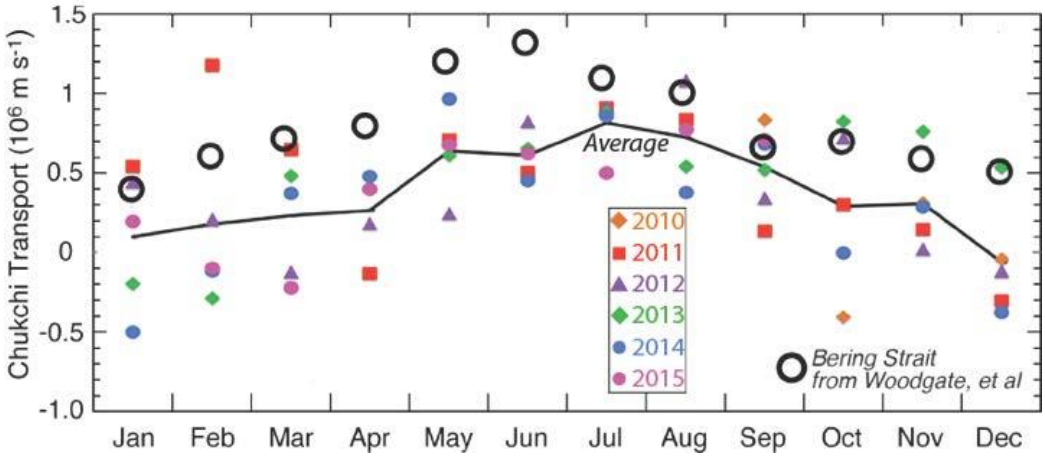



Figure 12. Mean transport per month for five years during 2010–2015 at Icy Cape, Alaska. Means combine the CHAOZ (2010–2011) and ARCWEST/CHAOZ–X (2012–2015) data. The open circles are the flow through Bering Strait for Woodgate et al., 2005.

Table 3: Transport each deployment cycle at Icy Cape. The average transport over all deployments was 0.4 Sv.

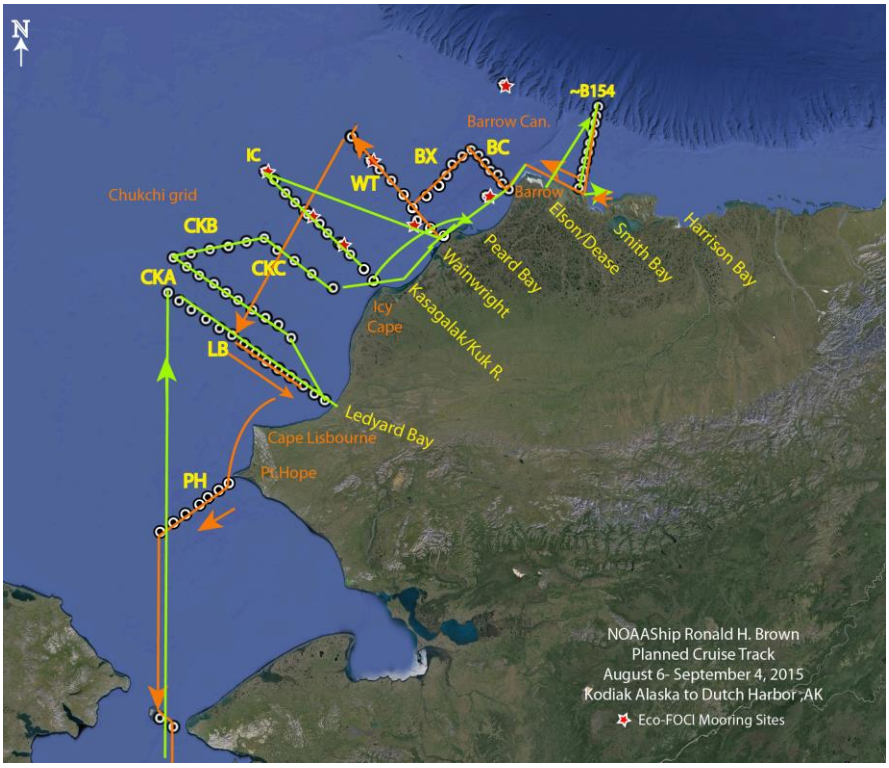
| | **Annual Transport (x $10^6$ $m^3$ $s^{-1}$)** |
|---|---|
| 2010-2011 | 0.50 |
| 2011-2012 | 0.35 |
| 2012-2013 | 0.36 |
| 2013-2014 | 0.48 |
| 2014-2015 | 0.30 |

*Hydrography & Plankton Sampling:*

In 2015, the sampling effort was conducted off the NOAA Ship *Ronald H. Brown* from 6 August to 4 September (Figure 13a). The line off Point Hope (Figure 13b, yellow dots in DBO3) was partially sampled by the F/V *Aquila* (see the 2015 ARCWEST/CHAOZ-X Cruise Report for details). The inner portion of many of the onshore/offshore transect lines are relevant to the ARCWEST project as they capture the flow along the coast line.

Nutrient samples were processed on board and have been 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.

In addition to the ARCWEST and CHAOZ-X sampling described above, the NOAA Program on Innovative Technology for Arctic Exploration (ITAE) 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 fieldwork will be incorporated into the ARCWEST synthesis analyses.



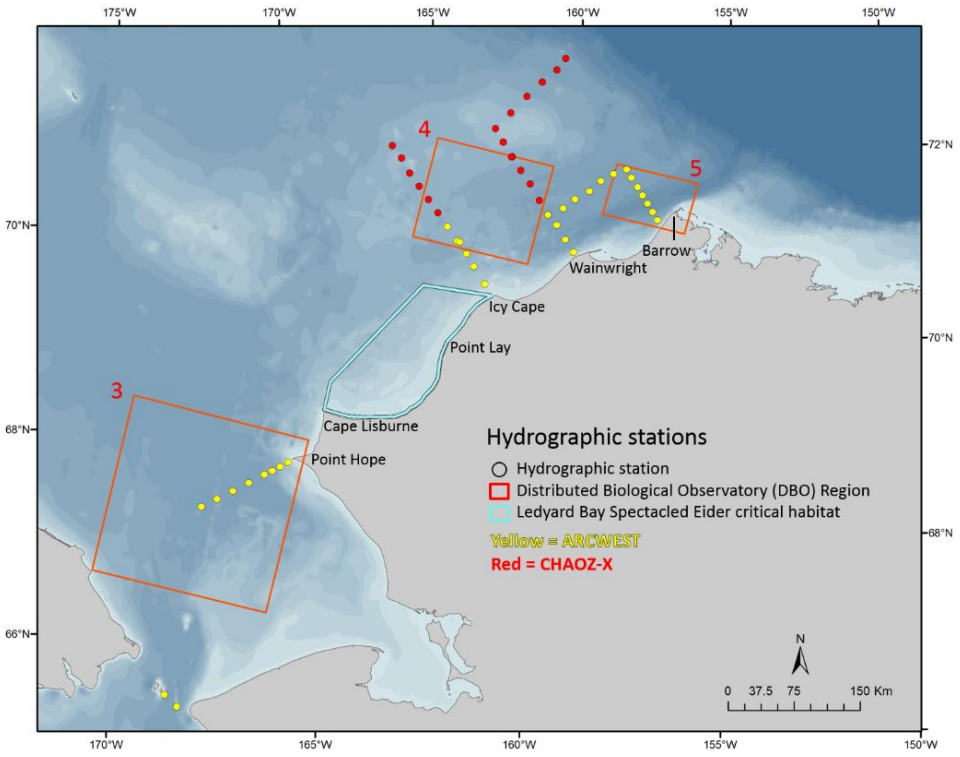




Figure 13a. Cruise track for the NOAA Ship *Ronald H. Brown*. Transect names appear in black. The Eco-FOCI mooring sites are shown as red stars. Figure 13b. Biophysical stations in regards to CHAOZ-X, ARCWEST, and the DBO. Yellow dots indicate ARCWEST stations. Red dots indicate CHAOZ-X stations. Red lined boxes indicate DBO regions.

*Satellite Tracked Drifters:*

Satellite-tacked drifters were deployed (Figure 14) 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. 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)*. Movies for the 2014-2015 deployment will be added to the website in February.

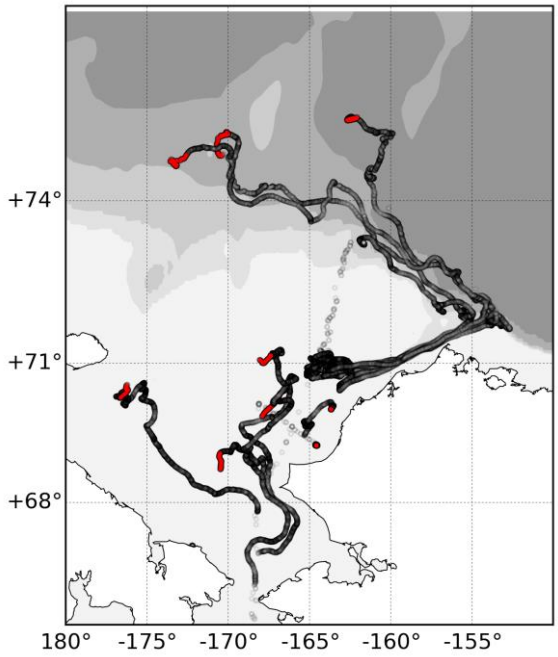



Figure 14. 2015 US Arctic Drifter Composite. Red indicates most recent data over a five-day period beginning 17 September 2015. Black shows the trajectories since the start of the deployment or start of the year for multiyear deployments. 2015 deployment locations can be found in Figure 8a.

*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). As in the previous year, the retrieved instruments sampled only for a couple of weeks before failing.

A new, simpler, control board was designed, built and preliminarily tested for the TAPS-6NG during 2015. 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 have examined the

data collected during those 6 days and are encouraged by the result. Further testing of the instrument with the new controller board will occur in February 2016 in Puget Sound.

An ADCP was deployed near one of the TAPS6-NG instruments, in the Icy Cape mooring cluster, in August 2011 and retrieved in 2012. The ADCP intended use is to measure current velocities, thus it is not calibrated to provide information regarding the size or abundance of organisms. However, due the relatively high vertical resolution, the ADCP data can be used to help reveal whole water column volume backscatter patterns, such as diel vertical migration of zooplankton, when paired with the TAPS-6NG instruments. The ADCP data has been fully processed and converted from echo intensity units to volume backscatter. Wavelet analysis was performed on the ADCP volume backscatter data to examine the dominant modes of temporal variation and to determine strength of these modes across the observation period (Figure 15). Initial examination of the data shows intermittent diel vertical migration. The analysis presented here is from the CHAOZ study, but similar analyses are being conducted with ARCWEST data.

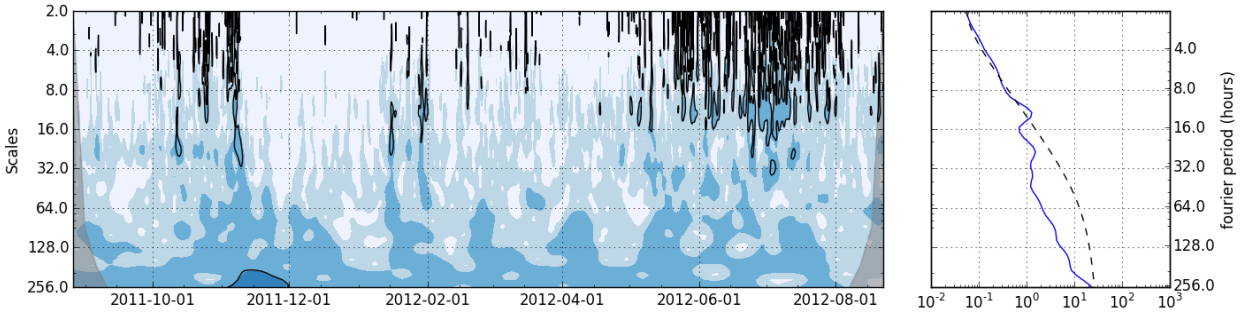



Figure 15. Wavelet analysis of ADCP data. Shown is an analysis of data at 28 m from the instrument deployed at site C3 in 2011. Diel vertical migration, when present, would show in the left panel as dark blue contours between 16 and 32 hrs on the (vertical) "Scales" axis. If diel vertical migration were a significant source of variability over the entire deployment, it would appear in the right panel as a peak on the blue line exceeding the dotted line in the same period (between 16 and 32 hours).

*Lower Trophic Level Sample and Data Analyses:*

Chlorophyll samples from 2014 were processed and in the database. 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. We completed our initial QC/QA procedures where every handwritten form is compared to what was entered into the computer in Poland and corrected as needed. In the first and second quarter of 2016 we will hire a contractor to load the remaining chlorophyll and zooplankton data into our database and produce maps and tables of the data to begin describing patterns. In addition, Mr. Adam Spear will apply multi-variate community analysis tools to the CHAOZ data from 2010-2012. Once he has determined the best way to accomplish these analyses with the older data, he can apply the same techniques to the ARCWEST and CHAOZ-X data.

**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.

**Contribution of data to meet Public Access of Research Results (PARR) compliance**

The metadata record for the long-term passive acoustic recorders is being refined, and data about the acoustic recordings will be submitted to National Centers for Environmental Information (NCEI) in the near future. NMFS is working on a process for making acoustics data available to the public which is complicated by the size of the data files. The metadata records for the sonobuoy data (https://inport.nmfs.noaa.gov/inport/item/17346), the visual sightings (https://inport.nmfs.noaa.gov/inport/item/17941), and the gray whale satellite telemetry (https://inport.nmfs.noaa.gov/inport/item/28151) are now available. In addition, the processed data for the sonobuoy deployments for all BOEM-funded NMML data (http://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0138863), the visual sightings data for ARCWEST and CHAOZ (http://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0137906), and the gray whale satellite telemetry data (http://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0139361) have been published at NCEI. Metadata and data about the photo-identification data are still under development.

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

Early in the ARCWEST project, budget issues were encountered due to increases in fuel, vessel costs, and mooring costs that occurred after the ARCWEST proposal was written and approved. Due to several fortuitous events and a number of cost savings procedures, we now project that we will be able to complete this project within budget and with the increased manpower needed to analyze the wealth of passive acoustic data collected by the ARCWEST project. These changes include: 1) NMML hiring Jessica Crance, one of the primary acousticians working with Dr. Catherine Berchok (the Passive Acoustics lead for ARCWEST), as a permanent employee, 2) sharing ARCWEST staff with other BOEM funded projects and outside projects thus reducing the salary costs to ARCWEST, 3) procuring outside funds through NOAA S&T, IFAW, and the Alaska Region for additional analyses which increased funding for processing acoustic data, 4) 0vessel sharing with PMEL (both combining NOAA and ARCWEST/CHAOZ-X activities on the F/V *Aquila* in 2013, 2014, and 2015 and conducting lower trophic level and physical/chemical oceanographic sampling off the NOAA Ship *Ronald H. Brown* in 2015) reducing survey costs, 5) low fuel prices in 2014 and 2015 further reducing survey costs, and 6), unfortunately, reducing the survey time spent on dedicated satellite tagging operation. The reduction in satellite tagging effort, combined with the scarcity of large aggregation of baleen whales, limited our satellite tagging success but was necessary given our budget projections in 2013 and 2014.

Additional expenses were incurred due to lost gear and skiff repairs after 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). We have been able to make all necessary repairs. However, we have limited our replacement of gear to just those items necessary for the

successful completion of the ARCWEST field season (i.e., some items, like cameras, were not replaced and were borrowed from other NMML researchers for the field season).

We feel that the continuation of our multi-disciplinary long-term time series, begun in 2010, is critical for monitoring this ecosystem as the Arctic environment continues to change. To this end, a revised supplemental funding request was submitted to Carol Fairfield on 30 November 2015 which would enable us to retrieve and redeploy biophysical mooring clusters (oceanography, zooplankton, and passive acoustics) in 2016 and continue the biophysical sampling stations and underway marine mammal monitoring for an additional year. These funds would supplement funds provided by NOAA/OAR for the 2016 vessel survey. Should these funds be provided, they would extend the ARCWEST objectives in an opportunistic manner, but not change the timing of any of the ARCWEST deliverables.

**Significant meetings held or other contacts made**

23 January, 2015 – Berchok, Fairfield, Kennedy, Napp, Stabeno and Wang attended an ARCWEST planning meeting.

18 February, 2015 – Berchok, Fairfield, Friday and Crance attended an ARCWEST planning teleconference.

16-18 April 2015: J. Crance attended a MMC-NMFS Acoustic Surveying Technology Workshop as the acoustic representative for the Alaska Fisheries Science Center. The workshop, which was held at the Southwest Fisheries Science Center, discussed current abilities, limitations, and research needs in the field of passive acoustic monitoring as they relate to marine mammal stock assessment.

28 May 2015 – C. Berchok and J. Crance presented at the annual Sonobuoy Liaison Working Group (SLWG) meeting at NAS Whidbey Island and met with sonobuoy suppliers.

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 AEWC, 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**

Berchok, C.L. 2015. 2015 ARCWEST/CHAOZ-X Cruise Plans and Overview. Oral presentation at the Annual Alaska Eskimo Whaling Captains Convention, Barrow, AK. 2 – 6 February, 2015.

Berchok, C.L. 2015. What makes the Chukchi Sea so rich with marine life? Oral presentation at the UAF Northwest Campus as part of their Expand Your Horizon/Strait Science Series. Nome, AK, Sept 8, 2015.

Berchok, C., Clark, C., Kennedy, A., Napp, J., Stabeno, P. and Wang, M. 2015 Chukchi Sea Whale Ecology Workshop: Introduction. Oral presentation at the BOEM Chukchi Sea Whale Ecology Workshop, Alaska Marine Science Symposium, Anchorage, AK. 23 January, 2015.

Berchok, C., Crance, J., Grassia, S., Ives, E., Garland, E., Mocklin, J., Ulmke, A., Kennedy, A., Rone, B. and Zerbini, A. 2015. Chukchi Sea Whale Ecology Workshop: Marine Mammal Visual and Passive Acoustic Data. Oral presentation at the BOEM Chukchi Sea Whale Ecology Workshop, Alaska Marine Science Symposium, Anchorage, AK. 23 January, 2015.

Berchok, C.L., Crance, J.L., Rone, B.K., and Moore, S.E. 2015. Marine mammal occurrence in the Distributed Biological Observatory (DBO) from ship-based visual and passive acoustic surveys. Poster presented at the Alaska Marine Science Symposium, Anchorage, AK, 19-23 January, 2015.

Clapham, P.J. 2015. Theme 4: Large Cetacean Science, Large Whales. Oral presentation at the Alaska Fisheries Science Center Protected Species Science Program Review, Seattle, WA. 16-20 March, 2015. (available at http://tinyurl.com/o8cyrkz).

Dasarathy, S. 2015. Integration of oceanographic data with fin whale (*Balaenoptera physalus*) calling presence in the Bering Sea. NOAA Hollings Scholarship oral presentation to NOAA Headquarters. Silver Springs, MD.

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**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**

Amy S. Kennedy[1,2], Brenda K. Rone[1], Alexandre N. Zerbini[1,3], Phillip J. Clapham[1]

1) National Marine Mammal Laboratory, Alaska Fisheries Science Center, NOAA Fisheries
2) Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
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.