CHUKCHI ACOUSTIC, OCEANOGRAPHY AND ZOOPLANKTON EXTENSION STUDY: (CHAOZ-X)

ANNUAL REPORT

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Executive Summary

Through an Inter-Agency agreement (IA) between the National Marine Mammal Laboratory (NMML) and the Bureau of Ocean Energy Management (BOEM), NMML is conducting a dedicated, multi-year study to document the temporal and spatial distribution of baleen whales near Hanna Shoal in the northeast Chukchi Sea and relate variations to oceanographic conditions, indices of potential prey density, and anthropogenic activities to improve understanding of the mechanisms responsible for observed high levels of biological activity around the Shoal. This annual report covers research conducted in 2015. The major activity during this period was data analysis and fieldwork onboard the ARCWEST/CHAOZ-X survey cruise.

Introduction and objectives

Hanna Shoal in the NE Chukchi Sea is an area of special biological concern near the boundary between Chukchi and Arctic Basin waters. The reason for this, however, is poorly understood. The shallower waters of the shoal have long been known to trap sea ice, which can ground on the shoal, and a recurring polynya is created down current of the grounded ice. In most recent years, floating pack ice in summer persists in this area longer than elsewhere in the Chukchi Sea, often surrounded by open water even to the north. Biological "hot spots" in the Chukchi Sea are thought to be related to strong coupling between pelagic and benthic productivity. A high abundance of bottom fauna is correlated with high pelagic phytoplankton concentrations, possibly associated with an ice edge, which reaches the seabed mostly ungrazed. The importance of the Hanna Shoal region to bowhead and gray whales and other marine mammals is not well known. In the 1980's and 1990's gray whales were frequently observed feeding near Hanna Shoal (Moore 2000), although they have seldom been observed during aerial surveys since 2008 (Clarke et al. 2014). Walruses, on the other hand, are still commonly seen near Hanna Shoal, presumably using the area to feed (Clarke et al. 2014).

The focus of this study is to determine the circulation of water around the Hanna Shoal area, the source of this water (Chukchi Shelf or Arctic Basin) and its eventual destination, and the abundance of large planktonic prey at the shoal. The dynamic nature of this circulation and prey delivery is being studied relative to whale distribution and habitat utilization in the northeastern Chukchi and extreme western Beaufort Seas.

Biophysical moorings supplemented existing data by collecting important information on current flow and water properties in that region, while concurrently deployed passive acoustic moorings provided year-round assessments of the seasonal occurrence of large whales in this planning area and their response to environmental changes (including oceanographic conditions, indices of potential prey density, and anthropogenic activities). The passive acoustic recordings also provided baseline information on ambient noise levels throughout this area which is undergoing rapid change. In addition, a passive-acoustic, auto-detection buoy was expected to be deployed in the vicinity of the scheduled Shell drilling operation area to provide near-real-time information on species presence and ambient noise levels. This deployment was canceled given logistical considerations and changes in Shell's drilling operation plans. Despite the fact that the auto-detection buoy was not deployed, its multi-faceted signal processing system went through several successful development upgrades that expand its capabilities as a real-time tool for regulators to monitor the effects of anthropogenic noise.

Our goal was to use the CHAOZ-X sampling tools to understand the mechanisms responsible for the high biological activity around the shoal, so that we can predict, in a qualitative way, the effects of climate

change on these preferred habitats. The use of moorings allowed us to quantify transport and water properties, especially during the more than 6 months the region is ice-covered.

The specific objectives were:

1. Refocus the passive acoustic and biophysical monitoring begun under the study "COMIDA: Factors Affecting the Distribution and Relative Abundance of Endangered Whales" from the initial lease areas to Hanna Shoal.
2. Describe patterns of current flow, hydrography, ice thickness, light penetration, and concentrations of nutrients, chlorophyll, and large crustacean zooplankton around the Shoal.
3. Assess the spatial and temporal distribution of marine mammals in the region of Hanna Shoal.
4. Evaluate the extent to which variability in environmental conditions such as sea ice, oceanic currents, water temperature and salinity, and prey abundance and noise conditions influence whale distribution and relative abundance.
5. Develop a quantitative description of the Chukchi Sea's noise budget, as contributed by biotic and abiotic sound sources, and continuous, time-varying metrics of acoustic habitat loss for a suite of arctic marine mammal species.
6. Continue development of a near-real-time passive acoustic monitoring system that can be used as an impact mitigation tool.

Cruise activities and summary

The 2015 CHAOZ-X field research occurred aboard the NOAA Ship *Ronald H. Brown* (6 August to 4 September) and the F/V *Aquila* (8-28 September). The mooring retrievals and redeployments and biophysical sampling station work were very successful, as was the visual survey and passive acoustic (sonobuoy) monitoring. The Auto-detection buoy, however, was not deployed this year due to logistical constraints; it will be deployed in 2016. For additional details on the two cruises, please see the two cruise reports: ARCWEST-CHAOZ-X_CruiseReport2015.pdf and Eco-FOCI_CruiseReport2015.pdf.

Post-cruise data analysis results and planning

Passive Acoustic Component

Long-term passive acoustic recorders:

[Note: All recorders used 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].

The data drives from the five 2014-15 CHAOZ-X 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.

Although the field seasons for CHAOZ-X are complete, we redeployed two of the CHAOZ-X moorings using NOAA funding to maintain our long-term dataset (initiated during the CHAOZ study). Locations for the 2015 moorings (Fig. 1) were determined in coordination with the oceanographic and lower trophic level components of CHAOZ-X. All 2015 mooring locations were the same as the 2014 deployments;

however, three moorings were not redeployed (HS1, HS2, WT2; Fig. 1). Two Cornell MARUs were deployed in 2015 using residual CHAOZ-X funding (Fig. 2); these recorders were deployed within visual ranges of the oil rig. Due to a software glitch discovered after its 2014 deployment, the deep-water Haruphone (Haru Matsumoto, NOAA/PMEL/CIMRS) recorder was also re-deployed for two years on its own mooring close to the Stabeno ADCP (See NRS1; Fig. 1). This recorder is part of a NOAA effort (by collaborator Holger Klinck (NOAA/PMEL/CIMRS)) to map deep water ambient noise throughout the U.S. EEZ. Results from this effort will be made available to the CHAOZ-X study.

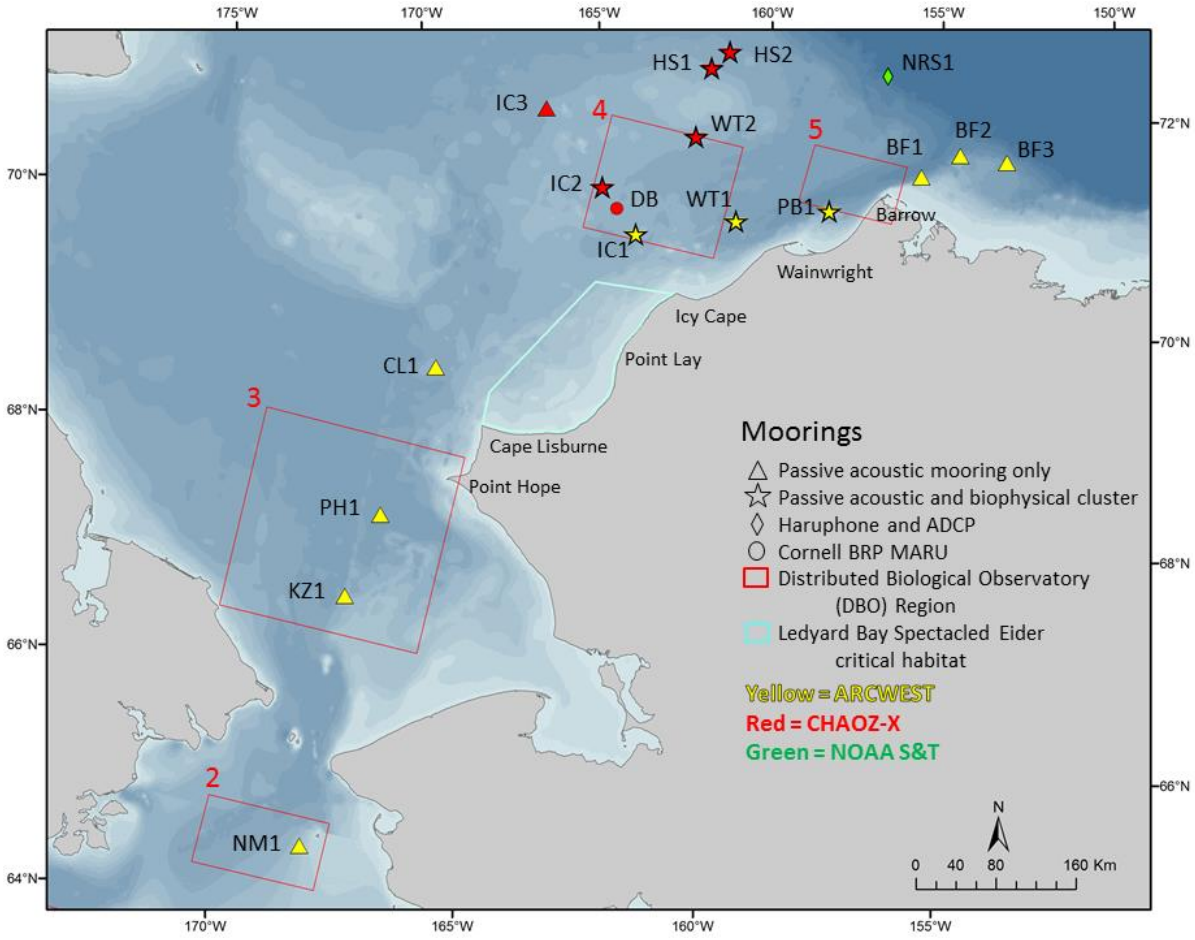

Figure 1. Location of the 2014 passive acoustic moorings retrieved in the Chukchi Sea for the CHAOZ-X project (red symbols).

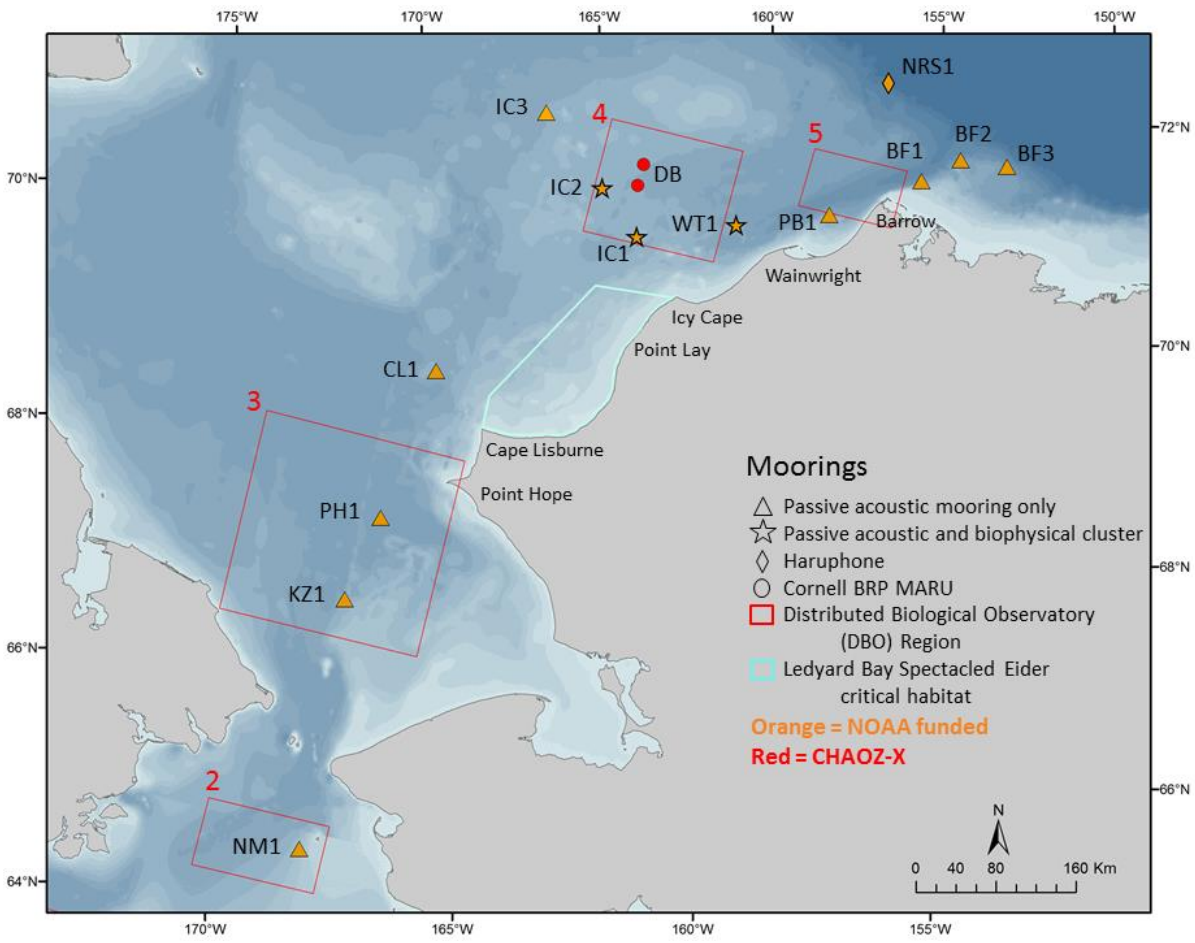

Figure 2. Location of the deployed 2015 NOAA-funded passive acoustic moorings (orange symbols), and the deployed 2015 CHAOZ-X funded MARUs (red circles).

Long-term acoustic data analyses are underway. We had planned 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 Institution (WHOI)). However, until this is fully operational, we will continue to process data manually.

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 using data from the ARCWEST project as those recorders were in better fin whale areas than those deployed for CHAOZ-X. We plan to send some of our data to Chris Clark at the Bioacoustic Research Program (Cornell) and Xavier Mouy (JASCO Applied Sciences), to test the efficacy of their bowhead and fin detectors, respectively, on our recordings. Once the fin whale call library is performing at expectations, it will be run on all datasets (including those from CHAOZ-X), with a randomized subsample manually checked to ground-truth the detector data. This will greatly reduce the overall time to analyze each mooring. In addition to this analysis, old mooring data are constantly being reformatted from .wav files to NetCDF files, the audio format understood by the LFDCS. This process will continue until all our mooring data are reformatted for use and analysis in the LFDCS.

The NMML acoustics program is also in the process of hiring additional short-term (15 month) analysts to assist with processing the passive acoustic data collected on the acoustic recorders. This will help ensure that data are analyzed in a timely fashion for inclusion in the CHAOZ-X final report.

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/CHAOZ-X) 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 (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 interannually. 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.

Sonobuoys:

We deployed 133 sonobuoys during the 2015 ARCWEST/CHAOZ-X cruise. The results from these sonobuoys, including those within the CHAOZ-X study area, are shown in Figure 3. Very few marine mammals were acoustically detected; only 18% (14 of 78) of deployed sonobuoys in the Chukchi Sea had acoustic detections. Species detected within the CHAOZ-X study area include walrus and bearded seals.

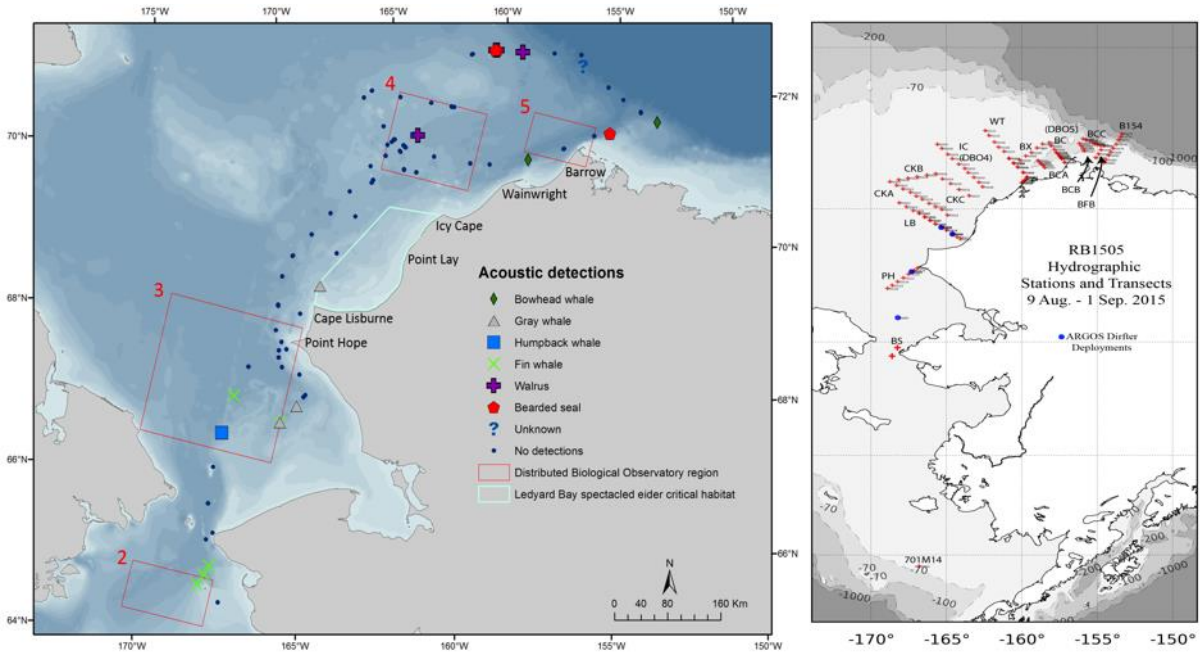

Figure 3. a) Sonobuoy deployment and acoustic detections in the Chukchi Sea during the 2015 ARCWEST/CHAOZ-X field survey, and b) stations occupied by NOAA Ship *Ronald H. Brown*.

Oceanographic and Lower Trophic Level Component:

Moorings:

Locations for the 2015 oceanographic and active acoustic moorings (Fig. 4; red stars) were determined in coordination with the passive acoustic component of CHAOZ-X and based upon our conceptual model of current flow and preliminary findings from the CHAOZ and ARCWEST/CHAOZ-X projects as well as results reported by other researchers (e.g., Tom Weingartner, University of Alaska Fairbanks (UAF); Robert Pickart, WHOI). Detailed maps are available in the ARCWEST/CHAOZ-X cruise report (http://www.afsc.noaa.gov/nmml/PDF/ARCWEST-CHAOZ-X_CruiseReport2015.pdf). See the PMEL mooring website (http://www.pmel.noaa.gov/foci/operations/mooring_plans/2015/aug2015_aq1501_moorings.html[1]) for information on the other instruments placed on each mooring.

[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: 15CKT for the Chukchi Sea (e.g., 15CKT-2A corresponds to C2) or 15BS for the Bering Sea (e.g., 15BS-2C corresponds to M2).

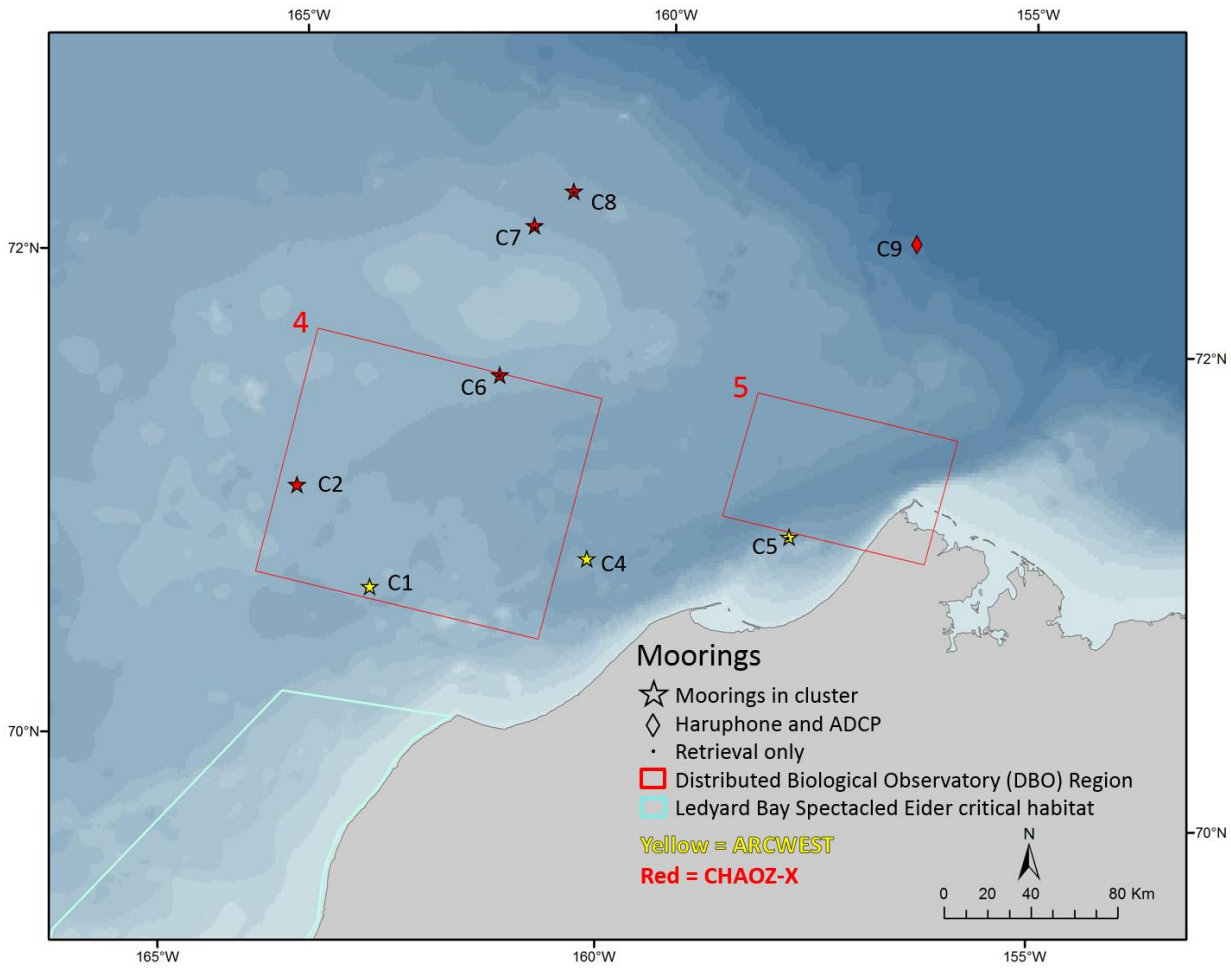

Figure 4. Biophysical mooring clusters retrieved and/or deployed during the 2015 ARCWEST/CHAOZ-X cruise. Yellow symbols indicate ARCWEST moorings. Red symbols indicate CHAOZ-X moorings. All moorings were redeployed under NOAA funding.

All moorings deployed in 2014 were successfully recovered in 2015. The data return was good for the CHAOZ-X moorings – all Seacats and ecofluorometers collected data for the entire period. One ISUS (measuring nitrate) and one RCM-9 (measuring turbidity, oxygen, temperature and currents) apparently failed because of defective batteries. Two ADCPs failed - one had interference patterns in record and the other a leaked. All these data have been processed and uploaded to the database. All instruments measuring keel depth collected data, but these data are very time consuming to process and will not be available until May or June.

We successfully recovered 6 out of 6 TAPS6-NG instruments in 2015. Three of the units were deployed for this project (C2, C6, C7). Unfortunately it appears that the instruments collected only a small amount of data before failing (about 2 weeks of data). We are working hard to understand if this was a software or hardware failure. All indications point to failure of the controller board to properly execute. During the year, our in house engineer built a very simple, but effective controller using a common, easily obtained processor chip. We deployed an instrument at one of the ARCWEST sites with the new

controller board. Results of that test are discussed in the ARCWEST annual report. Further testing of that controller board will take place in Puget Sound in February 2016.

Hydrography & Plankton Sampling:

In 2015, the sampling effort was conducted off the NOAA Ship *Ronald H. Brown* from 6 August to 4 September (Figure 5a). The line off Point Hope (Figure 5b, yellow dots in DBO3) was partially sampled by the F/V *Aquila* (see the 2015 ARCWEST/CHAOZ-X Cruise Report for details). Locations for lower trophic level and physical/chemical oceanographic sampling in 2015 are indicated in Fig. 5, and were determined in coordination with the passive acoustic component and based upon previous research and our conceptual model of current flow. These stations were sampled during a cruise of the NOAA Ship *Ronald H. Brown* (RB1505/1506) August 6 – September 4 2015. Forty-seven Tucker Sled tows were accomplished during that cruise. Data from the outer portion of transects IC, and WT are relevant to Hanna Shoal). Chlorophyll samples (N > 450) were collected and returned to Seattle. Chlorophyll samples will be analyzed in January/February and uploaded into the database. Nutrient samples were processed on board the Brown and those collected on the Aquila have also been processed. These data will be incorporated into the hydrographic files. Data will be uploaded to the database in the winter.

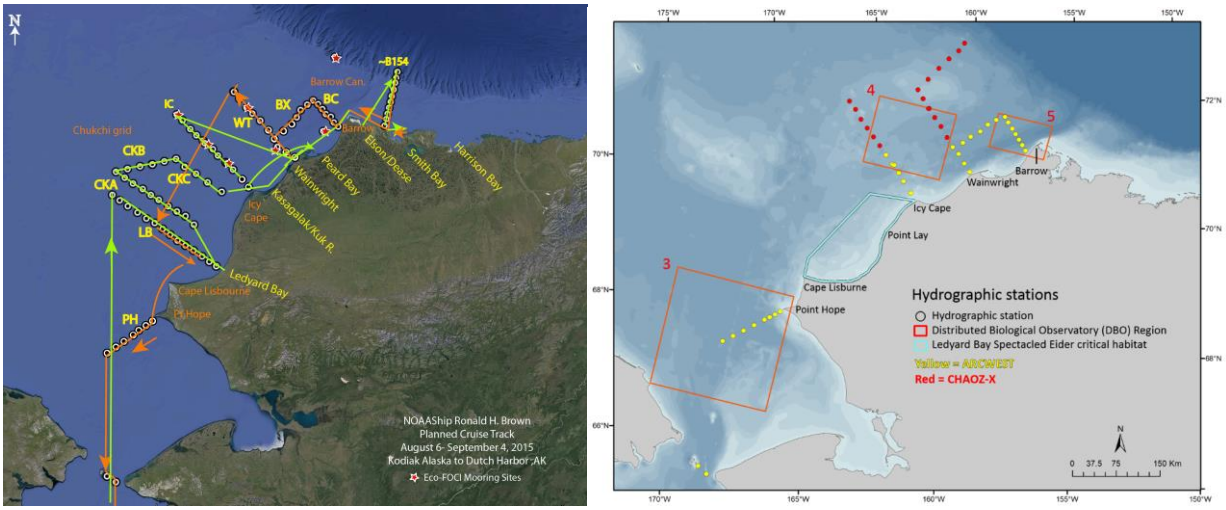

Figure 5. a) Cruise track for the NOAA Ship *Ronald H. Brown*. Transect names appear in yellow. The Eco-FOCI mooring sites are shown as red stars. B). Biophysical stations in regards to CHAOZ-X, ARCWEST, and the DBO. Yellow dots indicate ARCWEST stations. Red dots indicate CHAOZ-X stations. Orange lined boxes indicate DBO regions.

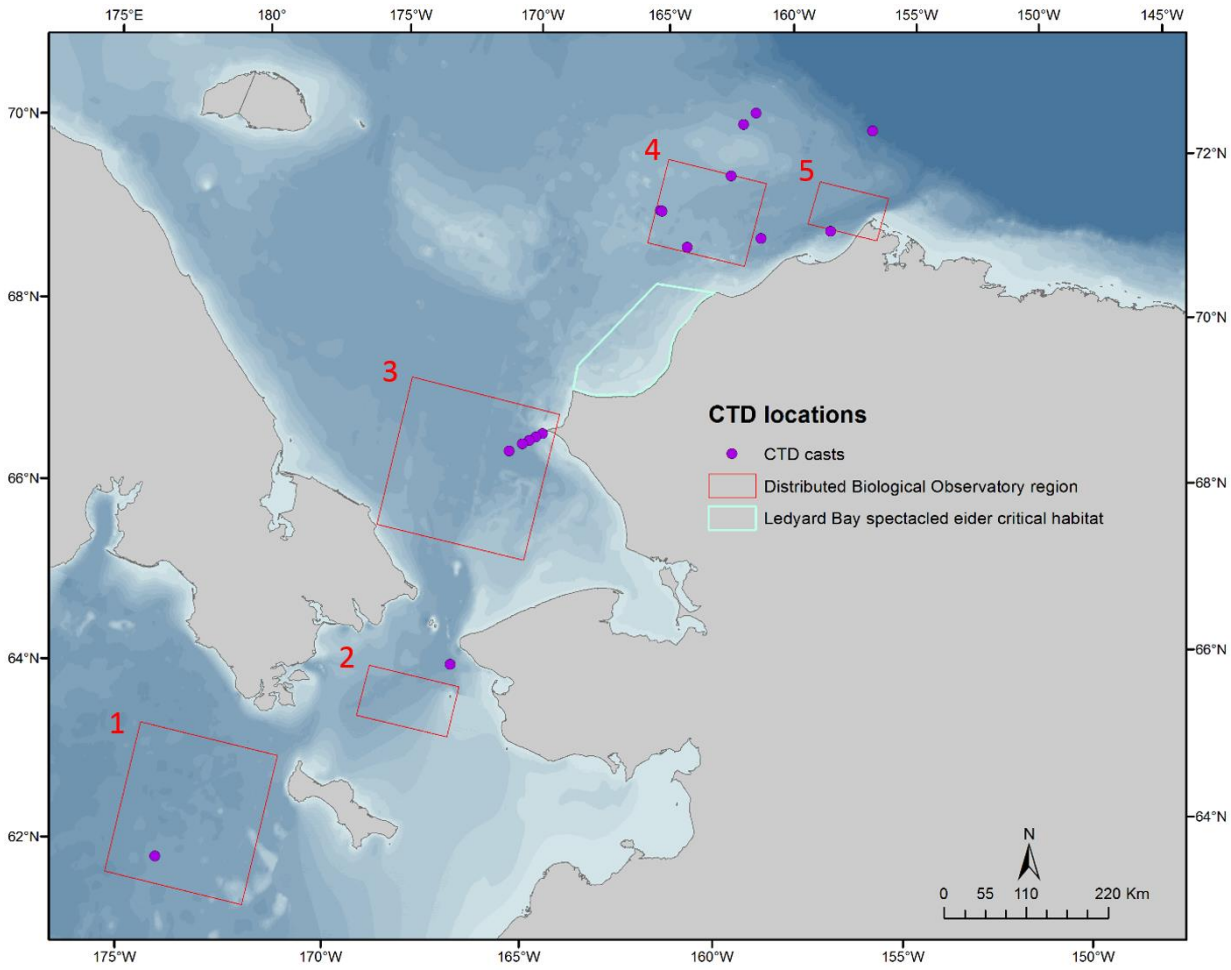

Figure 6. CTD casts conducted during the 2015 ARCWEST/CHAOZ-X cruise. The majority of biophysical stations were sampled on the NOAA ship *Ronald H. Brown*.

Satellite Tracked Drifters:

Satellite-tacked drifters were deployed (Fig. 7) 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. Note the sharp cooling and westward turn as the drifters exit Barrow Canyon. The cooling is indicative of slope water – the shelf water is more dense and slips beneath the surface basin water. This sinking of shelf water is evident in Figure 8.

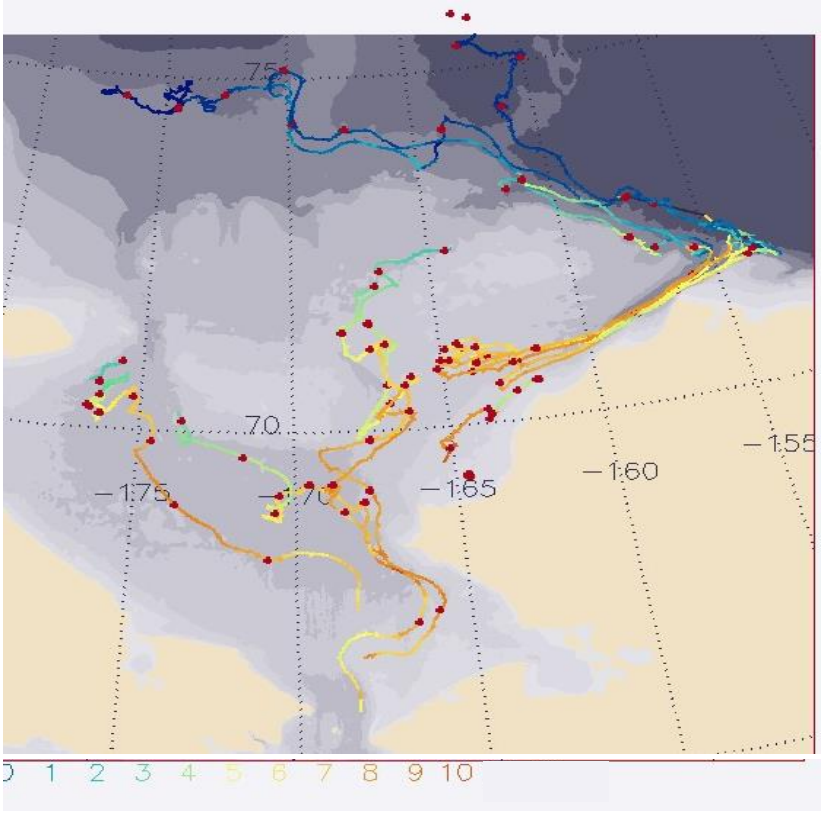

Figure 7. 2015 US Arctic Drifter plots. Colors indicate surface temperature (see scale at bottom of plot). The red dots indicate data every 10 days.

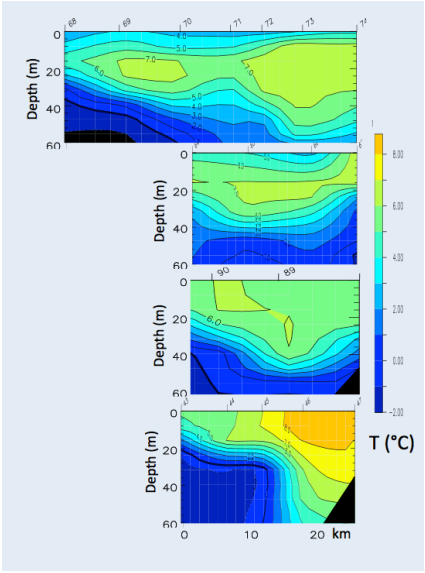

Figure 8. Temperature collected in Barrow Canyon. Top panel is near the mouth of the Canyon and bottom panel near is the head. Note the sinking of the warmest water as it moves northward. Data from August 2015, collected on the NOAA ship *Ronald H. Brown*.

Active Acoustics:

During the year we produced 5 new TAPS6-NG instruments and the group made significant progress on improving the tuning of transducers and calibration of the instruments. A large plastic (300 gallon) tank and chiller was obtained to approach temperatures experienced during the deployment. All transducers were tuned at the colder temperatures, but we ran out of time to conduct pre-cruise calibrations at these same temperatures. We will continue with this during 2016.

Lower Trophic Level Sample and Data Analyses:

Sample and data analysis continues on the 2014 samples. The 2014 chlorophyll samples have been analyzed and the data are in the database. Data from the 2014 zooplankton samples have been returned to Seattle. Data from all of the large mesh nets has been QA/QC'd, but not yet uploaded to the database.

Greater than 100 zooplankton samples were collected and preserved on the 2015 cruise. All samples were sent to the Polish Plankton Sorting and Identification Center in Szczecin, Poland. We expect that the initial counts of organisms will be returned to us by May of 2016. After applying our standard QA/QC procedures (every handwritten form will be compared to what was entered into the computer in Poland), and corrected. The data will then be uploaded to the database.

Processing of the 2015 chlorophyll samples began in January 2016 and should be complete by the end of the month.

During the 1st and 2nd quarters of 2016, AFSC will hire a contractor to produce maps and tables for all of the CHAOZ-X chlorophyll and zooplankton data available. This data synthesis will be very helpful for all of the BOEM projects and allow us to see trends and patterns in the data. In addition, Mr. Adam Spear will begin to assemble the 2010-2012 zooplankton data and conduct a community analysis using multivariate statistics. Once this is done and data analysis templates are completed, we will apply the same analyses to the CHAOZ-X zooplankton data.

<u>Ocean Noise and Real-time Passive Acoustic Monitoring Component</u>

The effort during this year was impacted by uncertainties regarding if and when Shell would begin its drilling operations. Charles Muirhead traveled aboard the F/V *Aquila* on the Chukchi Sea leg, 8-22 September, to deploy and recover two Marine Autonomous Recording Units (MARUs) configured with extra batteries and programmed to record continuously for one year. These units are referred to as "double-bubbles" or MARU-DBs. On 17 September two MARU-DBs were deployed at N 71.29893, W 163.27718 (primary MARU-DB) and at N 71.496533, W 163.190817 (secondary MARU-DB). The two MARU-DBs deployed in 2014 were recovered on 18 September.

Cornell continued to make significant progress with acoustic ecology software development such that the MatLab code can be run on either single systems (e.g. a laptop) or our high-performance computer (Cornell's multi-core system that involves a multicore machine with NAS). This system is now referred to as the Acoustic Ecology Toolbox and has been integrated into Cornell's RavenX system. The performance metrics of the RavenX system were evaluated by processing step-wise increasing amounts of data (i.e. number of channels and number of months). By this process, various system vulnerabilities were revealed and resolved; for example, very slight data file naming inconsistencies or periods of time with data drop-out. Several of the beneficial attributes of this system are that it can a) operate on acoustic data sets of any size (i.e. data ingestion is size-independent) and with variable file naming conventions

(i.e. file name format independent) and b) be operated remotely, which greatly facilitates the implementation. Dimitri Ponirakis added numerous RavenX features to increase its analytical functionality (e.g. added RAM propagation model, diel plots, and code optimization). As mentioned in our earlier report, these features are intended to enable collaborative coordination of data processing tools and results between Cornell BRP and NOAA-AFSC.

Post-doctoral Fellow, Dr. Yu Shiu focused on the development and testing of acoustic auto-detection analysis software for post-processing existing CHAOZ project acoustic data from MARUs and auto-detection buoys (ABs). This effort underscores a fundamental motivation of the research to understand the year-long acoustic environment of the Chukchi Sea, including sounds from biotic, abiotic and anthropogenic sources. However, the quantity of the sound data (e.g. 8,400 h from Aug 20, 2013 to Aug 5, 2014) is too large for human experts to process in a reasonable amount of time, even with the support of sound visualization software. Therefore, an automatic detection-classification system was designed to help reveal features of the Chukchi Sea acoustic environment (see Fig. 9). Currently, the software can detect acoustic objects, defined as any abrupt change in the time-varying spectrum or a gradual change in the spectrogram. We do not distinguish the types of acoustic objects. It is our ongoing work to classify them into different types (e.g. bowhead whale calls and songs, beluga whales, vessel engines and seismic airgun pulses).

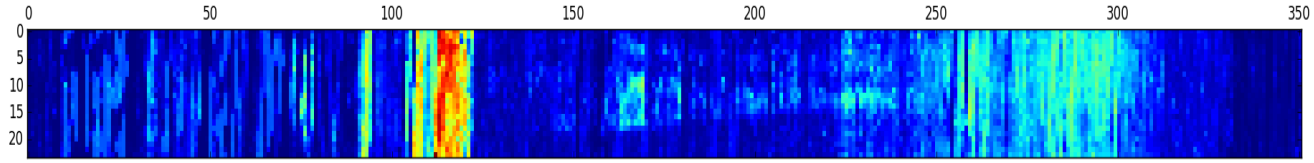

Figure 9: Number of daily detected acoustic objects (vertical axis) over 350 days (horizontal axis) from 20 Aug 2013 to 5 Aug 2014.

Significant technical, schedule, or cost problems encountered

None

Significant meetings held or other contacts made

2-6 February 2015: C. Berchok presented a talk on the upcoming 2015 ARCWEST/CHAOZ-X cruise (and a little bit on the projects themselves) for the Annual Alaska Eskimo Whaling Captains Convention in Barrow.

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 survey, 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 (NSB). 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 NSB. 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 and/or called the AEWC, Chukchi and North Slope whaling captain associations, village liaisons, communications centers, and the NSB with daily updates on the progress of the cruise.

Presentations and Publications

Berchok, C.L. 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.L., Crance, J.L., Rone, B.K., and Moore, S.E. 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.

Berchok, C.L. “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.

Clapham, P.J. 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).

Clark, C. “Noise Modeling and Auto-detection Buoy”, Oral presentation at the BOEM Chukchi Sea Whale Ecology Workshop (Alaska Marine Science Symposium), Anchorage, AK, 23 January, 2015.

Garland, E.C., Berchok, C.L. and M. Castellote. 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. The Journal of the Acoustical Society of America 137: 3054-3067.

Garland, E., Berchok, C. and Castellote, M. “Beluga whale (*Delphinapterus leucas*) vocalizations from the eastern Beaufort Sea population”, Oral presentation at the BOEM Chukchi Sea Whale Ecology Workshop (Alaska Marine Science Symposium), Anchorage, AK, 23 January, 2015.

Kennedy, A. “Whale Tagging”, Oral presentation at the BOEM Chukchi Sea Whale Ecology Workshop (Alaska Marine Science Symposium), Anchorage, AK, 23 January, 2015.

Ladd, C., C. Mordy, P. Stabeno, in prep. Winter Water Properties and the Chukchi Polynya, to be submitted to J. of Geophysical Res.

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. [accepted]

Napp, J. “Zooplankton” , Oral presentation at the BOEM Chukchi Sea Whale Ecology Workshop (Alaska Marine Science Symposium), Anchorage, AK, 23 January, 2015.

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