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

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Executive Summary

Through an Inter-Agency agreement (IA) between the Marine Mammal Laboratory (MML) and the Bureau of Ocean Energy Management (BOEM), MML 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 to 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 quarterly report covers the period between April 1st and June 30th, 2016.

The major activities during this period consisted of ongoing data analysis; some preliminary results are detailed below. The CHAOZ-X team has also been meeting regularly and developing the framework for how the data will be synthesized and incorporated into the final report. A few of the CHAOZ-X moorings (including the postponed auto-detection buoy) and sampling stations will be continued this September during a NOAA (OAR) funded (with some BOEM/ARCWEST funding) research 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 reach 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 the proposed 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 will be 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, the postponed auto-detection buoy from 2015 will be deployed in 2016 to further develop near-real time detection capabilities in the Arctic and also to continue the Chukchi Sea noise modeling that began with the BOEM-funded CHAOZ project. This auto-buoy data collection system is programmed for expanded frequency range in order to better capture the sounds of animals other than bowhead whales (i.e. beluga, ice seals, and walrus).

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 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

With funding from NOAA and additional BOEM (ARCWEST) funds, there will be a 2016 field survey from 3-26 September on board the F/V Aquila. This new research effort is known as the ALTIMA (Arctic Long-Term Integrated Mooring Array) project. Although the field work portion of the CHAOZ-X study is complete, we will collect data at a few of the CHAOZ-X sampling lines and turn around the former CHAOZ-X passive acoustic moorings IC2 and IC3 to maintain the long-term time series that was begun with the CHAOZ project (see Fig. 1 for planned 2016 ALTIMA cruise activities). This work will be done at no cost to the CHAOZ-X project. In addition,

the postponed auto-detection buoy will be deployed from the USCGC Healy in the vicinity of a previous Shell drill rig site to provide near-real-time information on species presence and post-drilling ambient noise levels. The signal processing system of the auto-detection buoy has gone through several successful development upgrades that expand its capabilities as a real-time tool for regulators to monitor the effects of anthropogenic noise. It will be retrieved by the R/V Siquliaq.

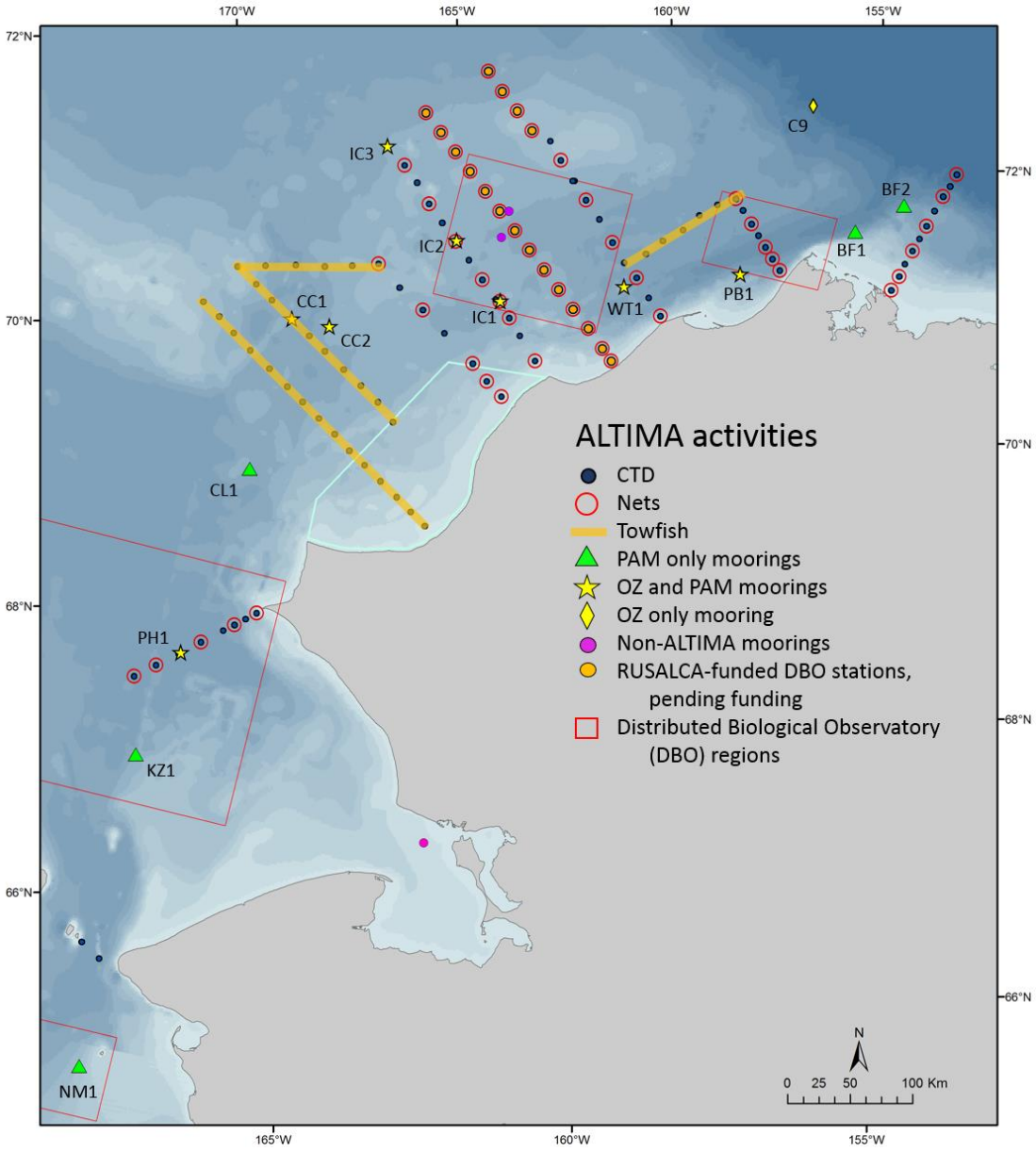

Figure 1. Planned activities in the primary working area during the 2016 ALTIMA cruise. PAM = passive acoustic mooring. OZ = oceanographic mooring.

Preliminary data analysis results and planning

Marine Mammal 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].

Even though the field seasons for CHAOZ-X are complete, in 2015 we redeployed two of the CHAOZ-X moorings using NOAA funding to maintain our long-term dataset (initiated during the CHAOZ study; IC2 and IC3). We plan to retrieve and redeploy those two moorings during the 2016 ALTIMA cruise to maintain our long-term time series. Planned locations for the 2016 moorings (Figure 2) were determined in coordination with the oceanographic and lower trophic level components. These two moorings are currently planned for the Arctic IERP project and should be turned around on its 2017 cruise. In any case, the acoustic releases on the moorings have a usable battery life of six years, and so collecting these recorders opportunistically by piggybacking on another cruise should not be a problem. The two-year, deep-water, Noise Reference Station (NRS) mooring, located close to the C9, will remain deployed until 2017. 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.

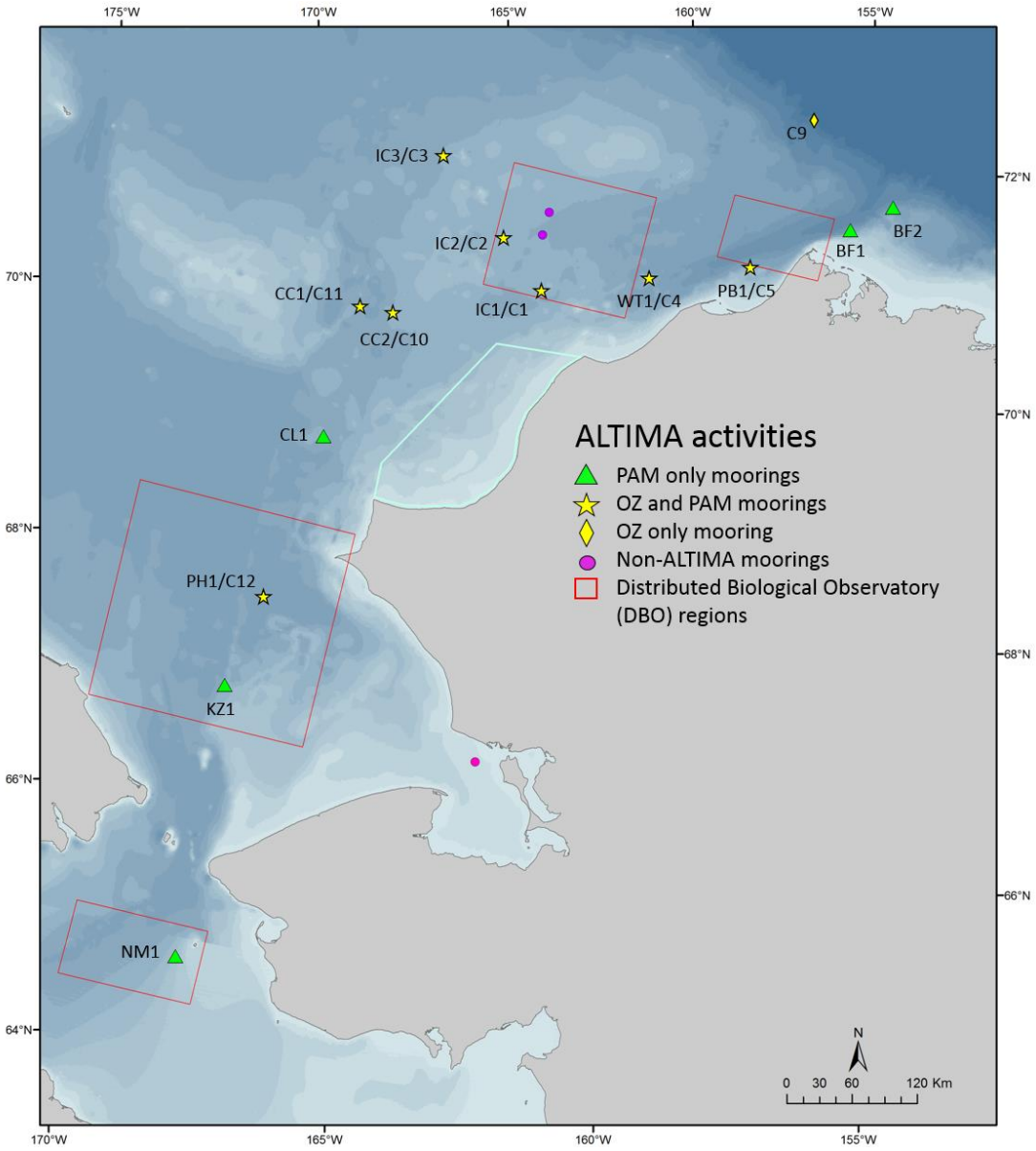

Figure 2. Planned mooring retrievals and/or deployments for the 2016 ALTIMA cruise.

All data from the five 2014-2015 CHAOZ-X AURALs have been extracted, converted, and processed for analysis. The acoustics team (including our 4 excellent new temporary hires) continues to analyze the data from the moored passive acoustic recorders to obtain the seasonal distribution of the following species: bowhead, gray, fin, humpback, minke, killer, beluga, sperm and right whales; bearded and ribbon seals, unidentified seals, and walrus. Vessel noise, airguns, and ice noise are also analyzed. When the CHAOZ-X 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. An example of the data series continuation is shown in Figure 3.

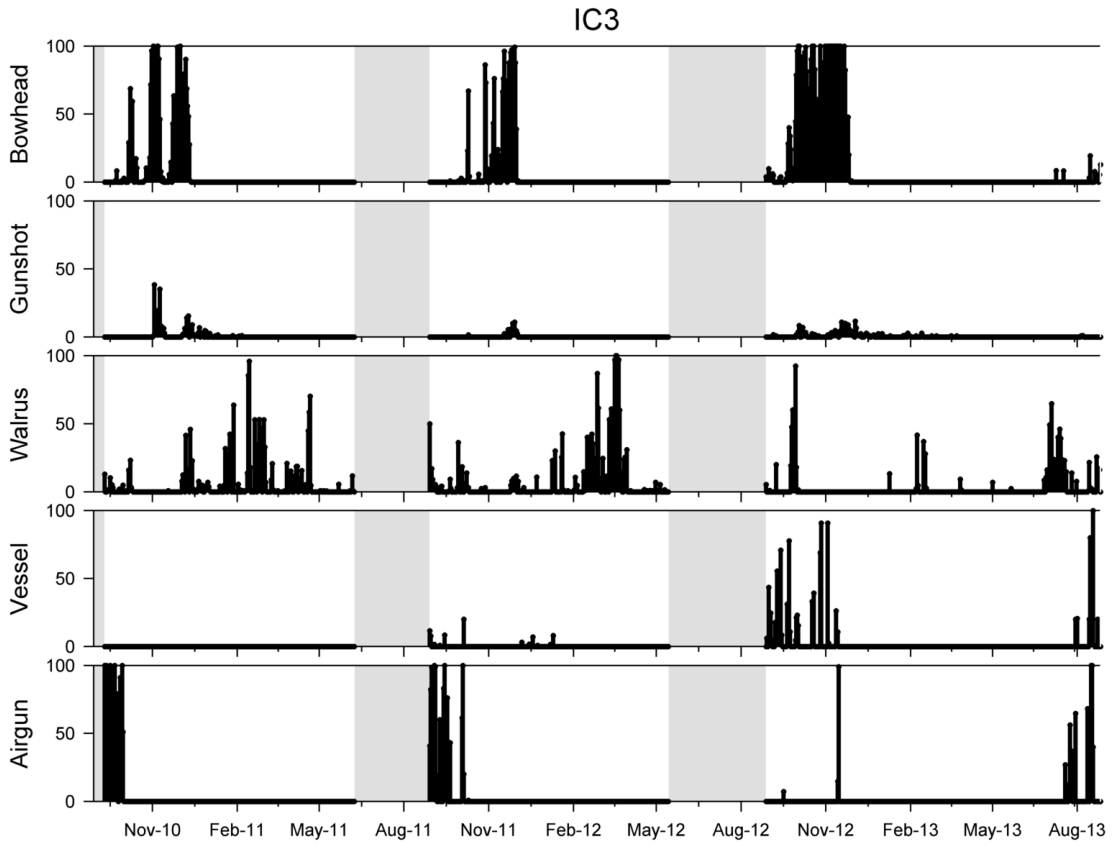

Figure 3. Long-term time series of marine mammal calling activity (presented as the percentage of time intervals with calls) for the offshore Icy Cape (IC3/C3) location, 2010-2013. From top to bottom: bowhead whale, gunshot call, walrus, vessel noise, and seismic airguns. Gray areas indicate no data.

Although we have had limited success implementing the low-frequency detection and classification system (LFDCS by Mark Baumgartner, Woods Hole Oceanographic Institution) onto our dataset, we continue to collaborate and work with colleagues to try and streamline our analyses. To this end, we have sent some of our data to Chris Clark, (Bioacoustic Research Program, Cornell University), Xavier Mouy (JASCO Applied Sciences), and Cheryl Aday to test the efficacy of their bowhead (Cornell) and fin detectors (JASCO, Aday) on our recordings. We have finished manually analyzing three moorings in the southern Chukchi for fin whale calls, and are in the process of using these data to improve the fin whale call library. Whichever method (LFDCS, Aday, or JASCO) works the best 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.

Sonobuoys:

We received one pallet of new sonobuoys from the Navy this spring. These will add to our stock of sonobuoys, which we use every year during our field season. We will have a sufficient number of sonobuoys for the 2016 ALTIMA cruise.

Oceanographic and Zooplankton Component

Although the field seasons for CHAOZ-X are complete, in 2015 using NOAA funds we deployed oceanographic moorings at four sites: C1 (2 moorings), C2 (3 moorings), C4 (2 moorings) and C9 (1 mooring) (Fig. 2). Instruments for the usual measurements were included - temperature, salinity, currents, oxygen, nitrate, keel depth, PAR, turbidity and chlorophyll fluorescence. C1 and C2 were first deployed as part of CHAOZ. We plan to retrieve and redeploy C1, C2 and C4 moorings in 2016 using NOAA funds to maintain our long-term time series. All data has been processed except for the instruments measuring keel depth, which is taking longer than anticipated and is now expected in the fall.

Initial analysis shows an intriguing result - intrusions of Atlantic water observed at C1 in 2014, but more surprisingly, extremely high salinity observed at salinity sensors. The extremely cold temperatures indicate that this water was a result of freezing ice (Fig. 4)

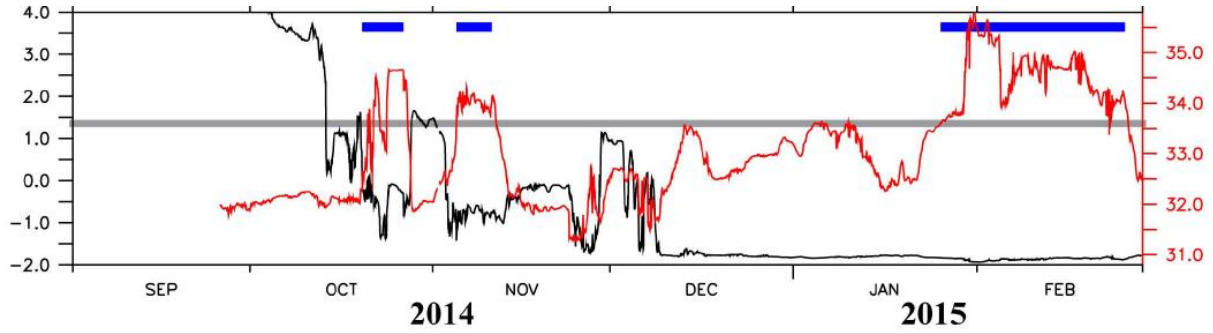

Figure 4. Temperature (black) and salinity (red) at C1. These are the highest salinities (35.9) that we have observed in the mooring recorders in Chukchi.

Data from the surface mooring and two wave gliders (Fig. 5) are being processed. These instruments were deployed as part of the NOAA Office of Exploration and Research to examine solar heat fluxes. These data will be integrated with BOEM data sets.

We successfully recovered 6 out of 6 TAPS6-NG instruments in 2015. Unfortunately, it appears that the instruments collected only a small amount of data before failing (about 2 weeks of data). 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 took place in Puget Sound in January-February 2016. Initial results of that test show that it functioned properly, however the signal-to-noise ratios were somewhat low. We will attempt to resolve the issue in 2016 using an increased pulse length to compensate for the poor signal-to-noise ratios.

Figure 5. Schematic of PRAWLER mooring which profiles the upper water column and Wave Glider (NOAA-PMEL) which is a remotely controlled autonomous vehicle consisting of a surfboard-like surface float with solar panels and a lower tethered portion to power communications and instrumentation.

Hydrography & Plankton Sampling:

Forty-seven Tucker Sled tows were accomplished during the 2015 cruise. Data from the outer portion of the Icy Cape and Wainwright transects are relevant to Hanna Shoal. Chlorophyll samples (N > 450) were collected and returned to Seattle. The 2015 cruise season chlorophyll samples were processed in January at AFSC. Chlorophyll data from cruise seasons 2013, 2014, and 2015 have all been QA/QC'd and uploaded to 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 and uploaded to the database. Most of the hydrography and net tows in 2015 were done on the NOAA ship Ron Brown (Fig. 6). In spite of extensive ice on the Beaufort shelf, most of the standard hydrographic transects were completed. This was a NOAA cruise with both NOS, Fisheries and OAR researchers on board. The hydrographic data will be incorporated with the BOEM data collected on the Aquila.

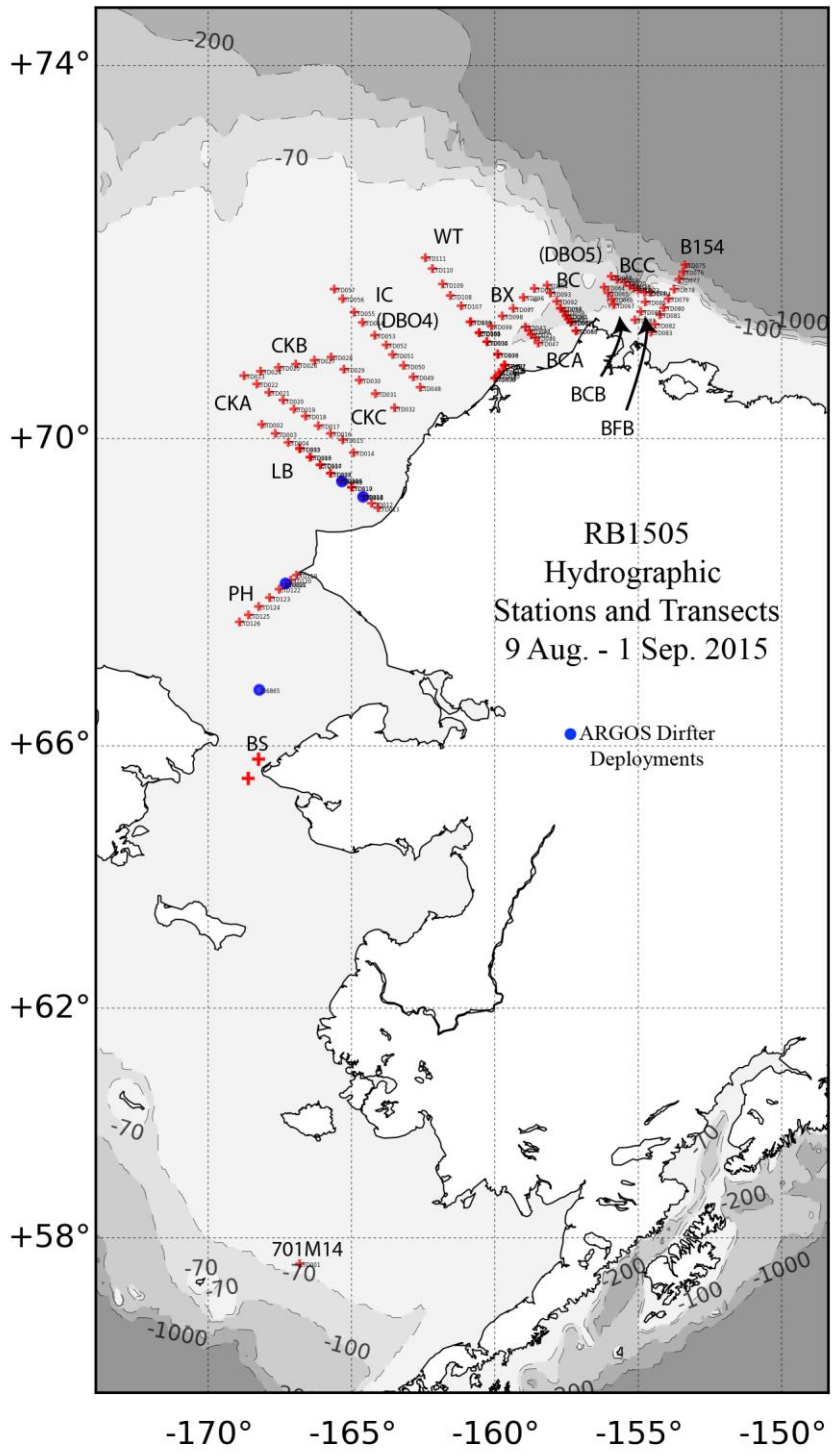

Figure 6. Map of CTD sections. Transect names appear in black. The Eco-FOCI mooring sites are shown as red stars.

Lower Trophic Level Sample and Data Analyses:

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 and returned to us in May of 2016. The zooplankton data will be made available in the database sometime in late 2016, after the process of applying our standard data QA/QC procedures (every handwritten form will be compared to what was entered into the computer in Poland), and taxonomic verification processes have been completed. The full QA/QC process for zooplankton data for the years 2012-2014 have been completed and uploaded to the database During the 1st quarter of 2016, AFSC hired a contractor to produce maps and tables for all of the CHAOZ-X chlorophyll and zooplankton data available. Analysis of chlorophyll data from the years 2013-2015 have been completed. Initial results show that mean integrated chlorophyll-*a* was similar for all three years (Fig. 7). There were consistently higher than average integrated chlorophyll values within the Wainwright and BX3 transects for all three years. In addition, the lowest integrated chlorophyll values were located at the nearshore stations of the Beaufort line.

In addition, Adam Spear has begun to assemble the 2010-2012 zooplankton data and conduct a community analysis using multivariate statistics. Initial results show similar zooplankton assemblages in 2010 and 2011 in the north east Chukchi (Figure 8, dark green circles) which were characterized by larvaceans, cnidarians, cirripedia, and smaller copepods. In 2012, a dissimilar north east assemblage (Figure 8, dark red circles) was characterized by lower numbers of the above mentioned species and a significant increase in *Calanus glacialis,* a lipid-rich Arctic copepod species. There was also a greater heterogeneity in the species assemblages in 2012 compared to previous years. Overall, these assemblage patterns are highly influenced by advection from the Bering Strait, northwest advection on the shelf, as well as the timing of sea ice melting. Once these data analysis templates are completed, we will apply the same analyses to the CHAOZ-X zooplankton data.

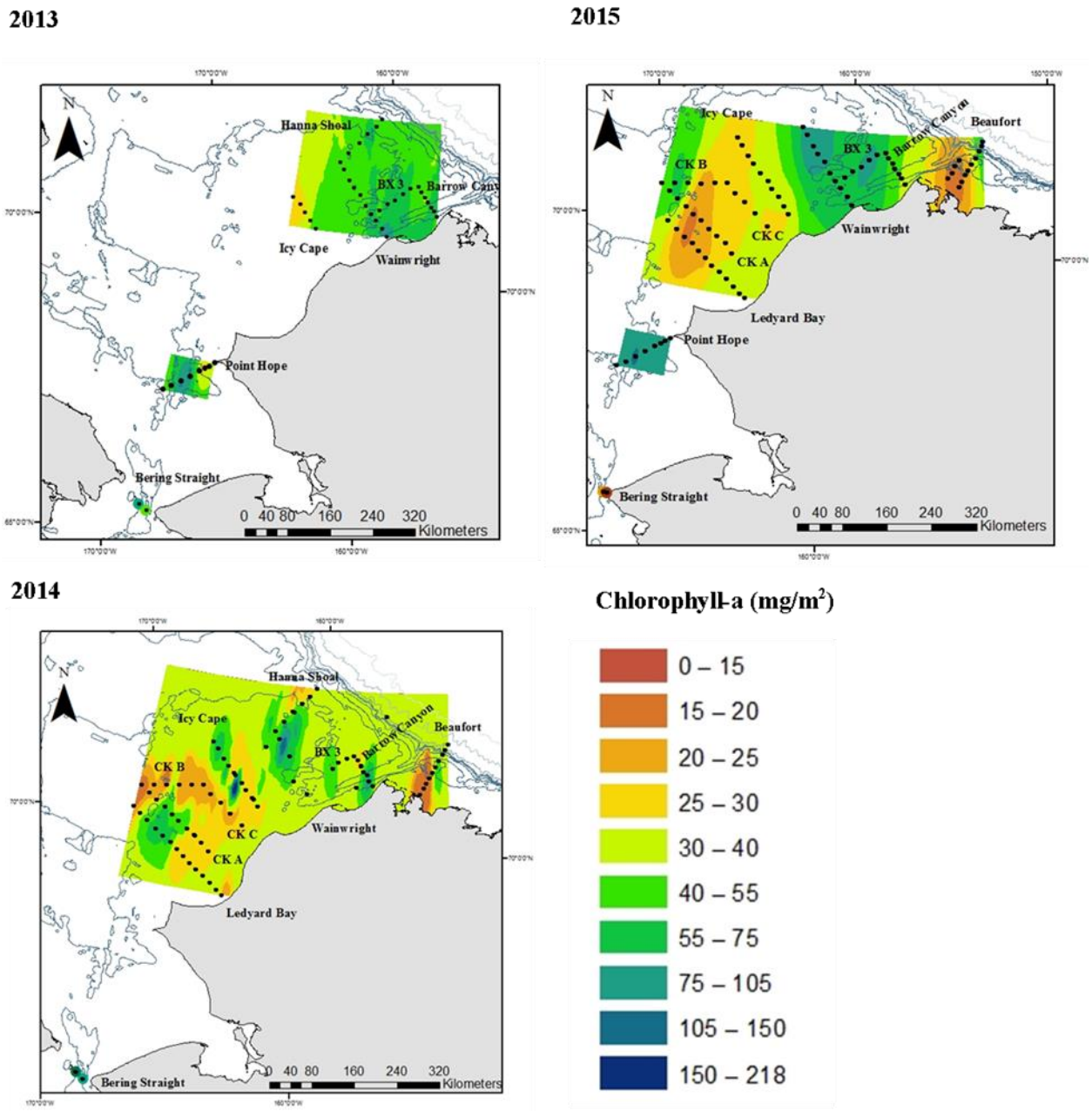

Figure 7. Maps display interpolated integrated chlorophyll-a (mg/m2). Average integrated chlorophyll-a was similar for all years with 2013(SD) at 51.5 (± 23.2), 37.5 (± 23.2) for 2014, and 48.9 (± 39.5) for 2015. The lowest record was in 2014 with 4.8 mg/m2 at the first nearshore station of the Beaufort line. The highest record was in 2015 with 217.9 mg/m2 at the offshore stations of the Wainwright line.

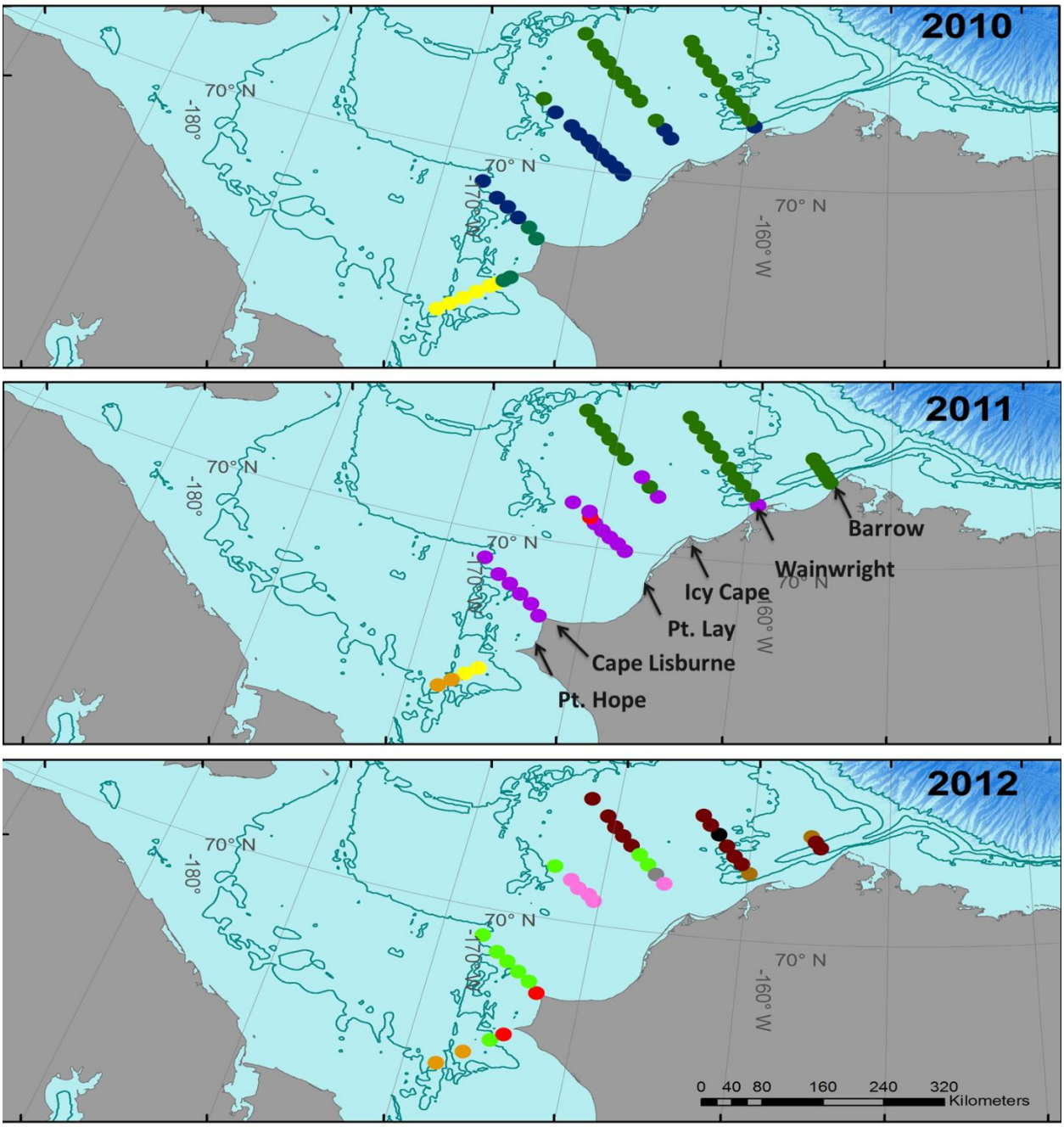

Figure 8. Results of the zooplankton community cluster analysis 2010-2012. Different colored circles indicate different assemblages of zooplankton.

Ocean Noise and Real-time Passive Acoustic Monitoring Component

Cornell Bioacoustics continued the development, testing and application of the Acoustic Ecology Toolbox. The Toolbox has now been mostly assimilated into Raven-X operating on a high-performance-computer system and was applied to explore data from Long-term Aural recorders. We continued to devote analysis efforts on exploring relationships between wind speed, ice concentration and ambient noise levels (Fig. 9), and are beginning to build in object-

oriented code to account for biological and anthropogenic sound sources.

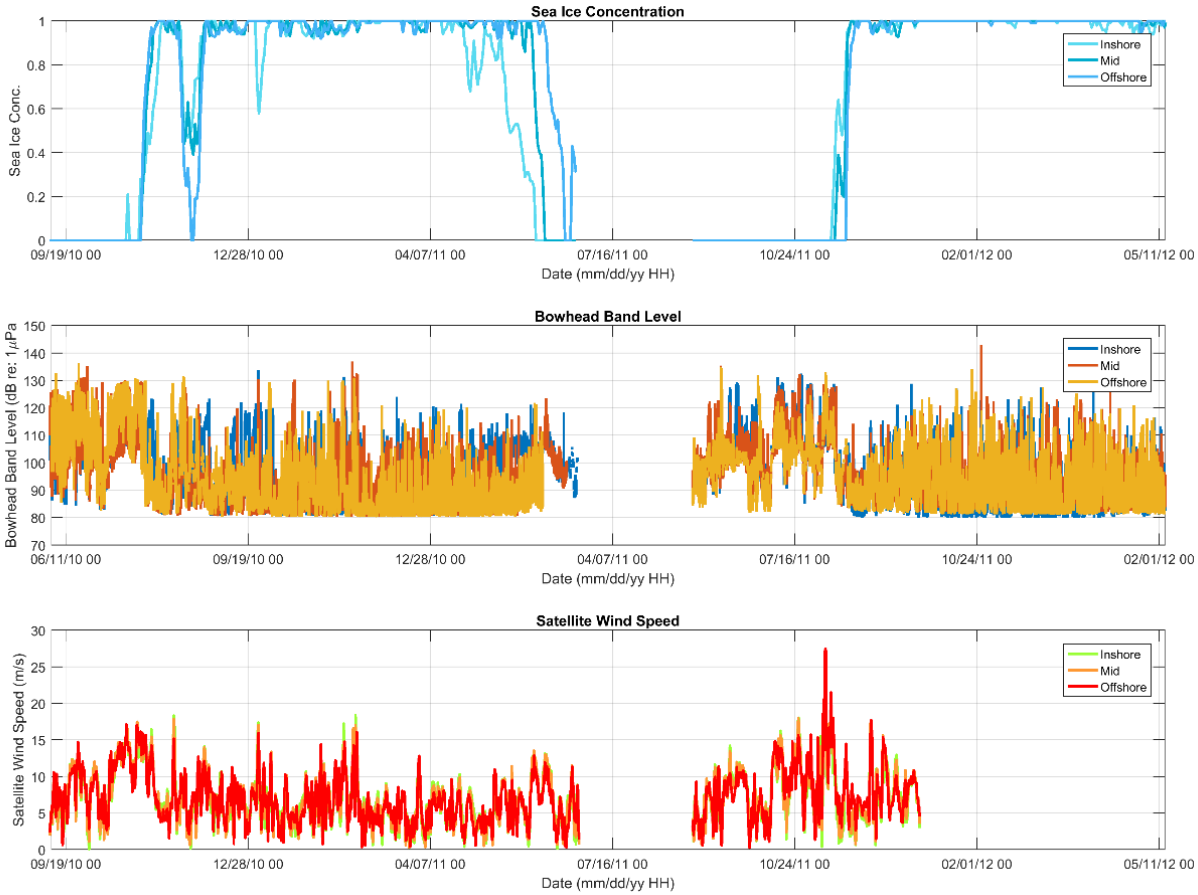

Figure 9. Time-series comparison of sea ice concentration (top panel), broadband noise levels (1-min res., 10-8910 Hz) (middle panel) and satellite wind speed (bottom panel) from September 2010 to May 2012. Note that satellite wind speed data end at the end of 2011 due to decommissioning of that satellite system.

A second major effort focused on an acoustic detection-clustering process using data from the 2013-2014 double-bubble seafloor recorder, focused on five major classes of acoustic events: bearded seal sounds, bowhead whale calls, bowhead whale songs, and seismic airgun impulses.

By this process, sound events of the same color indicate events in the same class (Fig. 10). 100 is used as the number of the classes in clustering. This approach circumvents involvement of human analysts and instead relies on automated detections of acoustic events and clustering of events based on simple acoustic features. However, the clustered classes often do not correspond one-to-one to the sound as perceived by a human. For example, there are at least over 10 classes that correspond to seismic airgun pulses and Bowhead sounds. Thus, a corresponding relationship needs to be built in order to estimate how many seismic airgun pulses and Bowhead sounds there are. Classes (instead of sound), from 12 days of sound were

labelled. For each class, a true-positive rate is calculated and used to convert the original class count. For example, a class corresponding to seismic has 90 sound events. Based on the sampled sound data, we find that the true-positive rate is 90% and then we estimate what the count of seismic airgun pulses should be.

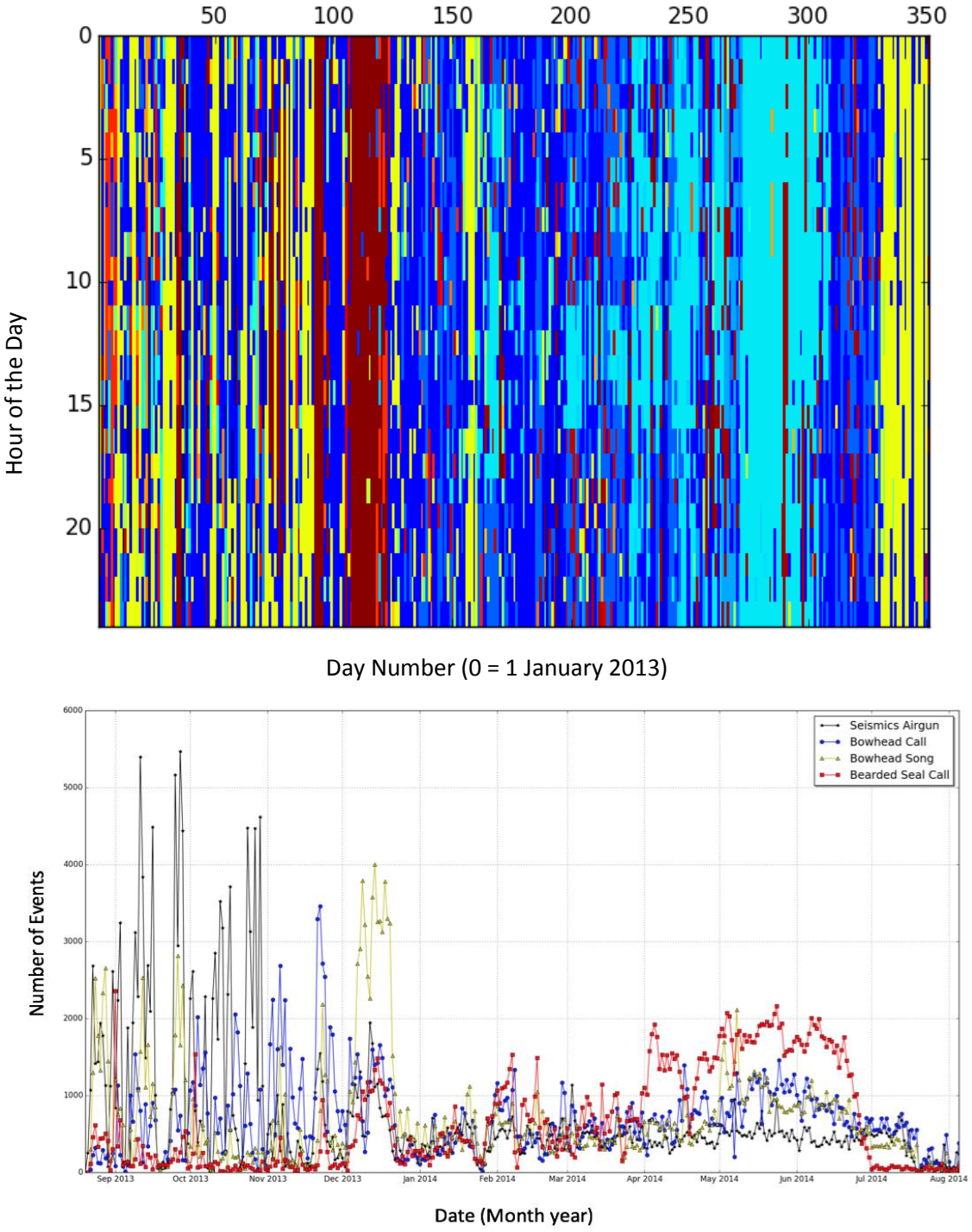

Figure 10. Examples of acoustic events based on analysis of 12 months of MARU-DB data from 2013-14. The color scale represents the number of acoustic event detections per 1-h time bin. Top panel: The high event levels in late November, early December 2013 (dark red) represent a surge in bowhead song detections, while the broader cloud of detections in the April-June 2014 period (light blue) represent bearded seals. Bottom Panel: The very narrow, high event level in late November 2014 represents a few days with bowhead song detections, while the high event level in May - June 2015 represent bearded seals.

Contribution of data to the Distributed Biological Observatory (DBO)

The CHAOZ-X program has agreed to contribute data to the DBO Workspace, supported by AOOS/AXIOM. CHAOZ-X 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/about) and is in its early stages. The contribution of information from the CHAOZ-X program is considered foundational to the development of the workspace, especially for the visual and acoustic data provided on marine mammals. Because we have to make our data accessible to the public through PARR, we will be linking the DBO data website to the PARR location to reduce duplicating data storage efforts.

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) and the visual sightings (https://inport.nmfs.noaa.gov/inport/item/17941) 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) and the visual sightings data for ARCWEST and CHAOZ (http://data.nodc.noaa.gov/cgi-bin/iso?id=gov.noaa.nodc:0137906) have been published at NCEI. Metadata and data about the photo-identification data are still under development. Metadata for the moorings and hydrographic data are being refined. All data will submitted to data public data base by the end of June.

Significant technical, schedule, or cost problems encountered

None.

Significant meetings held or other contacts made

April 7, 2016: Berchok, Crance, Friday, Mocklin, Zerbini, Stabeno, Tabisola, Napp, Kimmel, Ferm meet to discuss the ARCWEST and CHAOZ-X projects, current status, data analysis results, report construction, and other general project updates.

June 16, 2016: Berchok, Friday, Mocklin, Kennedy, Stabeno, Napp, Ferm, and Spear meet to discuss the ARCWEST and CHAOZ-X projects, current status, data analysis results, report construction, and other general project updates.

Presentations and Publications

Berchok, C.L., Rone, B., Napp, J., Stabeno, P., Wang, M., and Clark, C. 2016. CHAOZ in a nutshell: Five years of work in eight minutes. Presented to the IARPC Chukchi & Beaufort Sea Ecosystem Collaboration Team, March 2, 2016.

Crance, J.L., C.L. Berchok, E.C. Garland, J. Napp, P.J. Stabeno. 2016. Five years of CHAOZ in the Arctic: Results from a multi-disciplinary study in the Alaskan Chukchi Sea. Presented to the IARPC Chukchi & Beaufort Sea Ecosystem Collaboration Team, June 1, 2016.

Ladd, C., C. Mordy, S. Salo, and P. Stabeno. (In Press). Winter water properties and the Chukchi polynya. J. Geophys. Res. - Oceans.

Martini, K.I., P.J. Stabeno, C. Ladd, P. Winsor, T.J. Weingartner, C.W. Mordy, and L.B. Eisner. 2016. Dependence of subsurface chlorophyll on seasonal water masses in the Chukchi Sea. J. Geophys. Res., 121, doi:10.1002/2015JC011359.

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Spear, A., J.M. Napp, J. Duffy-Anderson, S. Salo, and P.J. Stabeno. 2016. Spatial and Temporal Variability of Zooplankton Community Structure in the Chukchi Sea (2010-2012). Poster presentation at the 2016 Ocean Sciences Meeting, New Orleans, LA., February 21-26.

Spear, A., J.M. Napp, J. Duffy-Anderson, S. Salo, and P.J. Stabeno. 2016. Spatial and Temporal Variability of Zooplankton Community Structure in the Chukchi Sea (2010-2012). Poster presentation at ICES/PICES 6th Zooplankton Production Symposium "New Challenges in a Changing Ocean," May 9-13, Bergen, Norway.

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