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

QUARTERLY REPORT

Julie Mocklin¹, M.S.
Catherine L. Berchok¹, Ph.D.
Jeff Napp², Ph.D.
Adam Spear², M.S.
Phyllis Stabeno³, Ph.D.
Christopher Clark⁴, Ph.D.
Phillip J. Clapham¹, Ph.D.

¹National Marine Mammal Laboratory
Alaska Fisheries Science Center

²Resource Assessment and Conservation Engineering Division
Alaska Fisheries Science Center

³Pacific Marine Environmental Laboratory
Ocean Environment Research Division

7600 Sand Point Way NE
Seattle, WA 98115

⁴Bioacoustics Research Program, Cornell University
159 Sapsucker Woods Road, Ithaca, NY 14850

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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 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 January 1\textsuperscript{st} and March 31\textsuperscript{th}, 2015.

The major activities during this period consisted of preparations for the 2015 field season and data analysis from 2014. Analyses are currently ongoing, and some preliminary results are detailed below. 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. The CHAOZ-X team has also been meeting regularly and developing the framework for how the data will be synthesized.

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 will supplement existing data by collecting important information on current flow and water properties in that region, while concurrently deployed passive acoustic
moorings will provide year-round assessments of the seasonal occurrence of bowhead, humpback, right, fin, gray, and other 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 will also provide baseline information on ambient noise levels throughout this area which is undergoing rapid change. In addition, a passive-acoustic auto-detection buoy will provide near-real-time information on species presence and ambient noise levels. These buoys are in the second stage of development towards their use as a real-time tool for regulators to mitigate the effects of anthropogenic noise.

Our goal is 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 will allow us to quantify transport and water properties, especially during the more than 6 months the region is ice-covered.

The specific objectives are:

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.
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 85 minutes of recordings made every 5 hours, for an entire year].

The acoustics team continues to process 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. The first two years of this time series is shown and depicts bowhead calls at the three moorings off Icy Cape (Fig. 1).
Figure 1. Two-year time series of bowhead whale calls detected on three moorings off Icy Cape, AK. The Y-axis shows the percentage of 3 minute time intervals with bowhead calls detected per day. The data were collected and analyzed as part of the BOEM-funded CHAOZ project.

The data drives from the four CHAOZ-X AURALs have been extracted, and the raw files batch converted into ten-minute wave files with file names indicating the date, time, project, and mooring for that recording. The wave files have also been batch converted into spectrogram image files (.png) for low, medium, and high frequency bands. The AURALs have also been cleaned, tested, and inspected.

A subset of the 2014 CHAOZ-X moorings will be redeployed during the ARCWEST/CHAOZ-X cruise in 2015 to maintain the long-term time series even though retrieval in 2016 is currently unfunded. The acoustic releases have a usable battery life of six years, and so collecting these recorders opportunistically by piggybacking on another cruise will not be a problem. Locations for the 2015 CHAOZ-X moorings (Fig. 2) are consistent with those from 2014, which were determined in coordination with the oceanographic and lower trophic level components of CHAOZ-X. The deep-water Haruphone (Haru Matsumoto, NOAA/PMEL/CIMRS) recorder mooring (Fig. 2; HA14) is a two-year deployment and will not be recovered until 2016. This recorder is part of a NOAA-funded effort (by collaborator Holger Klinck (Cornell &
NOAA/PMEL/CIMRS) to map deep water ambient noise throughout the U.S. EEZ. Results from this effort will further inform the CHAOZ-X study.

Figure 2. Planned passive acoustic mooring retrievals and/or deployments for the 2015 ARCWEST/CHAOZ-X survey cruise. Red symbols indicate CHAOZ-X moorings. Yellow symbols indicate ARCWEST moorings. Both Hanna Shoal (HS1&HS2) and one of the Wainwright (WT1 or WT2) moorings will not be redeployed in 2015. The HA14 mooring is NOAA-funded and will not be retrieved until 2016.

For future analyses, we plan 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)). However, until this is fully operational, we will continue to process data manually. This system is still not performing adequately for bowhead whales. The comparison with fin whales is ongoing and should be completed by the next quarterly report. Eliza Ives, who is implementing the LFDCS on our data, has been pulled off this work to help with the manual analysis. Next week she will be back to adjusting the LFDCS for bowhead and fin whales, and will begin work on a ribbon seal detector.
Ellen Garland, our NRC postdoctoral fellow, has moved on to the University of St. Andrews in Scotland as their Newton International Research Fellow. Before she left she completed two papers. The first investigates the timing of seasonal peaks in beluga whale calling. These peaks correlate with satellite tag and genetic data which suggests passive acoustics can be used to monitor the movements of individual populations (Garland et al., 2015). Her second paper, which is in review, describes beluga whale vocalizations and call classification from the eastern Beaufort Sea population (Garland et al., in review).

In addition to collaborating with us on a multitude of papers (as well as our BOEM-funded project reports) that will be using GAM analyses, Ellen will continue to work with our group on the work she started with the beluga whales by guiding the analyses of Alexandra Ulmke. Alex will be processing the data from a temporal calling peak suggested to be the Eastern Chukchi population of belugas and will develop a call repertoire from that population. After this work is completed she will then compare the results to those from the Eastern Beaufort population to see if the populations can be differentiated by their call repertoires.

Our newest team member, Dana Wright, is working on an analysis of Bering Sea moorings for a project funded by IFAW on the North Pacific Right Whale (NPRW). 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 will focus on the southern and northern Bering Sea shelf (the Aleutian passes, near St. Lawrence Island, and in Norton Sound). We are hoping to obtain a second year of funding so that she can continue this work in the mid-latitudes of the shelf and complete the overall picture of the spatio-temporal distribution of bowhead whales on the Bering Sea shelf. The data she is currently processing were collected from moorings deployed as part of CHAOZ-X.

We have also contributed part of our data set to Heloise Mouy, from JASCO Applied Sciences. She will be working on determining the spatio-temporal distribution of ribbon seals in the Bering, Chukchi, and Beaufort Seas. She is also writing a proposal to the Office of Naval Research to do the same, using our same data set, with spotted seals. We have also agreed to contribute part of our data set to Xavier Mouy and Julien Delarue, also from JASCO Applied Sciences, if they obtain funding from the North Pacific Research Board (NPRB) to conduct broad-scale walrus analyses. In each case, autodetectors will be developed and compared with our full manual analysis. If the results are good, we will then begin to implement those detectors on our complete dataset.

Sonobuoys:

Our sonobuoys have gone through their post-season inventory. We will have a sufficient number of sonobuoys for the 2015 ARCWEST/CHAOZ-X cruise.
Oceanographic and Zooplankton Component

The oceanographers retrieved 3 moorings at site C2 and deployed clusters of moorings at sites C2, C6, and C7 for CHAOZ-X on the BOEM-funded ARCWEST cruise (Fig. 3). At sites C2 and C6 we deployed 3 moorings each (ADCP, Ice Profiler, and TAPS-6NG) and at site C7 we deployed only the ADCP and Ice Profiler moorings. See the following website for other instruments placed on each mooring: (http://www.pmel.noaa.gov/foci/operations/mooring_plans/2013/jun2013_contVes_moorings.html1). Mooring cluster C8 was deployed in 2014 and an ADCP, C9, was deployed in 2014 and will be re-deployed in 2015 (Fig. 3). All instruments were programmed to sample throughout the year. A new addition in 2015 is that NOAA’s Ocean Exploration program will be deploying an oceanographic mooring and two wave gliders in the study area and the data will help inform this research.

In addition, plankton tows and hydrographic stations (CTD, nutrients, dissolved oxygen and chlorophyll a) were conducted across the southern and northeastern flanks of Hanna Shoal (Fig. 4). The transect began off Wainwright with a series of ARCWEST stations, continued from the southern flank to the top of Hanna Shoal with 6 CHAOZ-X stations and then doglegged to the northeast with four more stations towards the shelf break (Fig. 4). Hydrographic samples (nutrients, salt, dissolved oxygen and chlorophyll) were returned to Seattle and processed in our laboratories. These stations will be sampled again in 2015.

We have initially examined TAPS6-NG data collected in 2013-2014. Unfortunately it appears that the instruments collected only a small amount of data before failing. Preserved zooplankton samples from the Tucker sled were inventoried and sent to Poland in November 2014 for processing. It is anticipated that the resulting data will be returned by June, 2015. After applying our standard QC/QA procedures those data will be ready for uploading in a database. Chlorophyll samples were analyzed in January/February and will be uploaded into the database in the coming weeks.

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1 Note: On this webpage subsurface moorings relevant to this project are titled 13CK (i.e., Chukchi Sea 2013) and the number on the end corresponds to the mooring clusters shown in Figure 2 (e.g., 13CKT-2A corresponds to C2 in Figure 3).
Figure 3. Planned Biophysical mooring clusters to be retrieved and/or deployed during the 2015 ARCWEST/CHAOZ-X survey cruise. Red symbols indicate CHAOZ-X moorings. Yellow symbols indicate ARCWEST moorings.
Figure 4. Planned biophysical stations (hydrography and plankton) to be sampled during the 2015 ARCWEST/CHAOZ-X survey cruise. Red symbols indicate CHAOZ-X, yellow symbols indicate ARCWEST, and green symbols indicate NOAA-funded sampling stations.

The monthly mean transport at Icy Cape during 2010-2013 was strongly variable during winter and fall (Fig. 5). During spring and summer, however, transport was consistently northward and less variable among years. Yearlong average transport ranged from 0.25 – 0.45 Sv.
Figure 5. Mean transport per month for four years during 2010 – 2013 at Icy Cape, Alaska. Means combine the CHAOZ (2010 – 2011) and CHAOZ-X (2012 – 2013) data.

Ice cover and ice thickness data from the C2 mooring displayed a clear signal of the Arctic sea ice mega-fracture event during February 2013 (Fig. 6; for background on this event see: http://nsidc.org/arcticseaicenews/2013/03/a-fractured-maximum/). During the first two years of deployment (CHAOZ) percent ice cover was consistently near 100% during November – May (Fig. 7). Average ice thickness increased steadily throughout the cold season, with keels > 24 m. During 2012-2013 (CHAOZ-X), however, percent ice cover dropped below 80% on several occasions during winter and spring. Daily ice draft in this year was lower and did not have the positive trend of seasonally increasing depth observed in the previous two years.
Figure 6. Satellite images of extensive sea-ice fracturing during February 2013 with the location of the C2 mooring shown in blue.

Figure 7. Percent ice cover from satellite data and ice depth data from the C2 mooring during CHAOZ and CHAOZ-X.
At the C2 mooring, chlorophyll from the spring bloom was evident on the bottom in June and July of all three years during CHAOZ (2010 - 2011) and CHAOZ-X (2012 – 2013). During the beginning of the bloom, PAR (Photosynthetically Active Radiation) was reduced to zero even when ice cover fell below 20% (Fig. 8). This suggests that blooms can be dense enough to prevent light from reaching the bottom.

**Figure 8.** Bottom PAR (Photosynthetically Active Radiation) values in red, observed at C2 during three years of the CHAOZ (2010 – 2011) and CHAOZ-X (2012 – 2013) studies. Blue bars show ice cover greater than 20% and green bars show bottom chlorophyll fluorescence.

Ocean Noise and Real-time Passive Acoustic Monitoring Component

The effort during this year was partially impacted because of bureaucratic delays in securing
funding. Cornell-BRP finally obtained official permission to spend in early June. Thus, Cornell-BRP efforts in July were conducted under considerable pressure to prepare and ship equipment for deployment in the Chukchi Sea in August, which meant that Cornell-BRP had to ship the equipment by mid-July. As a result of considerable logistical and project management assistance from Sheyna Wisdom (Arctic Program Manager, Olgoonik Fairweather) and the generous offer of deployment support from Michael Macrander (Shell, chief scientist, Alaska), Fred Channel (Field Operations Specialist, Cornell-BRP) deployed five marine autonomous seafloor recording units (MARUs) from the R/V *Westward Wind* on 4 August 2014 (Fig. 9). Before departing from the ship on 7 August, Fred briefed and trained the deck crew for the deployment of the auto-detection buoy (AB-2014) and two double-bubble marine autonomous seafloor recording units (Dbs). On 20 August the R/V *Westward Wind*’s deck crew deployed the AB-2014 at 70.9999.57 N by -163.676712W and the two Dbs within close proximity (Fig. 9). On 13 October 2014, Fred Channel, aboard the R/V *Westward Wind*, successfully recovered all five MARUs, the single Db that was deployed in 2013 (Db-2013) and the AB-2014. The two Dbs that were deployed in August 2014 will operate through the next 12 months and be recovered in summer 2015. All the equipment was shipped back to Cornell-BRP, and the acoustic data were extracted from the five MARUs, Db-2013 and the AB-2014. The MARU at the most northern site (Fig. 9, MARU-5) failed to record data, but the acoustic data from the four other MARUs, Db-2013 and the AB-2014 were all extracted successfully.

![Deployment arrangement](image)

**Figure 9.** Deployment arrangement of the five Cornell MARUs relative to the auto-detection buoy (AB-2014) and the two Db-2013 bubbles (Db-1 and Db-2). MARU-5 was the unit that failed to record data.
During its deployment period the AB ran real-time software that detected bowhead whale calls and calculated background noise spectral distributions. A total of 342 audio detection clips and spectral measurements, which were collected once every 10 minutes, were transmitted back via Iridium satellite. Furthermore, the AB-2014 audio data were recorded to onboard FLASH memory throughout the deployment. These data will be used in post-processing analysis to evaluate and quantify the performance of the real-time software detection system.

Cornell-BRP continued to make significant progress with SEDNA sound analysis MatLab code such that the code can be run on either single systems (e.g. a laptop) or Cornell-BRP’s high-performance computer (oDeLMA, multi-core, distributed system that involves a multicore machine with NAS). The performance metrics of this system are being evaluated by processing step-wise increasing amounts of data (i.e. number of channels and number of months). By this process, various system vulnerabilities have been revealed and resolved; for example, very slight data file naming inconsistencies or periods of time with data drop-out. A beneficial attribute of this system is that it can ingest 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). As mentioned in Cornell-BRP’s earlier report, these features are intended to enable collaborative coordination of data processing tools and results between Cornell-BRP and NOAA-AFSC.

Acoustic analyses of the data from each of the four MARUs (Fig. 9, MARU-1, MARU-2, MARU-3, and MARU-4) have been completed using the SEDNA acoustic analysis system. For each of the four recorders daily sound level metrics at 1-sec resolution and 1-Hz, 3rd-octave, and broadband resolutions were computed (Fig. 10).

Similar acoustic analyses were also completed on the data from Db-2013 and the AB-2014. Initial evaluation of these analyses revealed that the areas sampled by the MARUs and AB-2014 were very quiet by comparison to earlier years. In fact, for major portions of time evidence suggests that ambient noise levels were below the noise floor of the recording instruments.

Post-doctoral Fellow, Yu Shiu, became fully engaged in the project. Dr. Shiu has focused on a) auto-detection software for post-processing the acoustic data from the Db-2013 and the four 2014 MARUs and b) becoming facile with concepts, algorithms and software (e.g. SECR, from CREEM, University of St. Andrews, Scotland) related to translating acoustic occurrence data (e.g. detections per unit time per unit area) into density estimates. This is a primary reason why we deployed the five MARUs as a set of distributed recorders, with only partial overlap in their individual acoustic detection areas, rather than as a more tightly spaced array that might be used to locate, track and count the number of acoustically active whales.
2015 Field Season Planning

Planning for the 2015 vessel cruise has begun. Sampling and mooring locations and cruise plans continue to evolve as plans are fine-tuned. The Contracting Officer at the Western Acquisition Division has been notified of our intention to exercise the option year on our vessel contract to charter the R/V *Aquila*. CHAOZ-X will be vessel sharing with the BOEM funded ARCWEST cruise again this year. Field equipment and supplies are being purchased. Passive acoustic staff have been hired through the Joint Institute for the Study of Atmosphere and Ocean (JISAO). Analysis of the data collected during the 2013 and 2014 vessel cruises has begun.

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

Figure 10. Example daily 4-panel figure (from top to bottom) showing a 1-Hz spectrogram; 3rd-octave spectrogram; $L_{eq,10\text{-min}}$ values in the bowhead frequency band (71-708 Hz) and broadband (9-891 Hz); and noise level statistics (5%, 25%, 50%, 75% and 95%).
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. 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.

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

None.

**Significant meetings held or other contacts made**

Berkholtz 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 (February 2 - 6, 2015).

**Presentations and Publications**


Literature Cited
