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 variability in animal occurrence to oceanographic, atmospheric, and sea ice conditions, indices of 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 July 1st and September 30th, 2016.

The major activities during this period consisted of data analysis in preparation for the Final Report as well as field work aboard the F/V Aquila that was not funded by CHAOZ-X but is a continuation of the sampling effort.

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 shallow 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 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 supplement existing data by collecting important information on current flow and water properties in that region, while concurrently deployed passive acoustic moorings provide year-round assessments of the seasonal occurrence of bowhead, humpback, right, fin, gray, and other whales in this lease area and their response to environmental changes (including oceanographic conditions, indices of potential prey density, and anthropogenic activities). The passive acoustic recordings 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. This type of buoy is in the second stage of development towards its use as a real-time tool for regulators to mitigate the effects of anthropogenic noise.

Our goal is to use these 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, water properties, and marine mammal presence, 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.

Cruise activities

Field research in 2016 occurred during the Arctic Long-Term Mooring Array (ALTIMA) cruise aboard the F/V Aquila (1-29 September). The ALTIMA cruise was supported by funding from NOAA’s Office of Oceanic and Atmospheric Research (OAR, Stabeno) with supplemental funding from BOEM through ARCWEST. It is referenced here because of the continuation of CHAOZ-X work that occurred during the cruise. 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 was deployed from the USCGC Healy and will be retrieved from the R/V Sikuliaq by WHOI personnel. This deployment of the Auto-detection buoy in 2016 was shifted from the 2015 season due to logistical constraints that had prevented deployment in 2015. For additional details on the ALTIMA cruise, please see the cruise report: ALTIMA2016_CruiseReport.pdf.
Preliminary data results and analysis plans

**Marine Mammal Component**

*Long-term passive acoustic recorders:*

[Note: All recorders used by MML 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].

Although the field work portion of the CHAOZ-X study is complete, we turned 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 a map of the 2016 ALTIMA cruise activities). This work was done at no cost to the CHAOZ-X project. In addition, the postponed auto-detection buoy was deployed from the USCGC *Healy* on 23 August 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 *Sikuliaq* in October 2016.
The locations of the two, long-term passive acoustic moorings, IC2 and IC3, were determined in coordination with the oceanographic and lower trophic level components of the CHAOZ-X project (Fig. 2). These moorings are anticipated to be turned around again in 2017 during the North Pacific Research Board’s (NPRB) Arctic IERP project cruise. Otherwise, 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, although data gaps may exist. 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/Cornell)) to map deep-water ambient noise throughout the U.S. EEZ.
Figure 2. Moorings retrieved and/or deployed during the 2016 ALTIMA cruise.

Data from the 2015-16 IC2 and IC3 AURALs have been extracted and converted, and are in the queue for processing. The acoustics team continues to analyze the data from the CHAOZ-X 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. These results, along with those from CHAOZ and CHAOZ-X, will be presented by Crance at the 2016 Acoustical Society of America conference in November in Honolulu, HI. 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, 2010-2015. 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 (for bowhead and fin whales), we continue to collaborate and work with colleagues to try and streamline our analyses. Data were sent to Chris Clark, (Bioacoustics Research Program, Cornell University) to test the efficacy of their bowhead detector. The results were poor, and so that auto-detection work is no longer being pursued. Instead a different method – acoustic class detection, is being tested (described in the ‘Cornell Ocean Noise and Real-time Passive Acoustic Monitoring Component’ section below). We have also sent some of our data to Xavier Mouy (JASCO Applied Sciences) and Cheryl Aday to test the efficacy of their fin detectors (JASCO, Aday) on our recordings. Cornell has offered to run their fin detector on these data as well, and we have asked them to do so with the recordings we have already sent.

Sonobuoys:

We deployed 142 sonobuoys during the 2016 ALTIMA cruise on the F/V Aquila. Very few marine mammals were detected (Figure 4). In the CHAOZ-X study area bowhead whales, gunshot calls,
walrus, bearded and ribbon seals, seismic airguns, and an unidentified anthropogenic signal (~250 Hz and 1 min long - possibly from the Canada Basin Acoustic Propagation Experiment (CANAPE)) were the species/signal heard. For more details see the cruise report: ALTIMA2016_CruiseReport.pdf.

**Figure 4.** Sonobuoy deployment and acoustic detections from the ALTIMA 2016 research cruise in the Chukchi Sea.

**Visual observations:**

A team of two visual observers surveyed 1140 nm of on-effort trackline during the ALTIMA research cruise on the F/V *Aquila*. In the CHAOZ-X study area only bowhead whale, walrus, bearded seals, polar bears and unidentified cetaceans and pinnipeds were sighted (Figure 5). For more details see the cruise report: ALTIMA2016_CruiseReport.pdf.
Figure 5. Marine mammal on-effort sightings and effort data from the ALTIMA 2016 research cruise in the Chukchi Sea.

Oceanographic and Zooplankton Component

Although the field seasons for CHAOZ-X are complete, in 2016 using NOAA funds we deployed oceanographic moorings at two former CHAOZ-X sites: C2 (3 moorings) and C3 (2 moorings)). Instrumentation included an ASL upward-facing ice profiler to measure ice thickness as well as a Recording Current Meter (RCM) 9. The biophysical moorings included an ADCP and a linked set of instruments containing a Sea-bird (SBE) SeaCAT (temperature, conductivity, and oxygen), an ECOfluorometer (fluorescence), a Photosynthetically Active Radiation (PAR) sensor, and an in situ ultraviolet spectrometer (ISUS) nitrate sensor. At the C2 location, an upward-facing TAPS 6NG (Tracor Acoustic Profiling System Next Generation) instrument was deployed to measure zooplankton bio volume and size distribution. The TAPS 6NG assembly consists of a PVC block at the top containing 6 transducers, a 40" syntactic foam float, an electronic controller pressure case (inside the float) and two PVC pressure cases containing batteries. These instruments are engineered to optimize the detection of krill. All data have been processed except for the
instruments measuring keel depth, which is taking longer than anticipated and is expected later in the fall.

GAMs data entry into Excel spreadsheets is near complete for all sites from 2010-2014, with the exception of the ADCP data, which will be completed shortly.

Stabeno is currently working to finish her manuscript on Chukchi Sea currents from 2010-2015, which will be submitted to the Journal of Geophysical Research.

Because of software glitches in the past preventing the TAPS-6NG from working, this instrument was deployed on 13 September at the start of the cruise for a test period and was retrieved 6 days later. A download of data confirmed that the instrument was working successfully, and so the instrument was redeployed on 19 September to collect data for the full year.

**Hydrography & Plankton Sampling:**

Thirty-three Tucker Sled tows and eighteen bongo tows were accomplished during the 2016 cruise. Data from the outer portion of the Icy Cape transect (and the outer DBO4 line) are relevant to Hanna Shoal. Chlorophyll samples (N = 423) were collected and returned to Seattle.

![Figure 6. Map of CTD and zooplankton tow stations completed during the 2016 ALTIMA survey.](image-url)
Lower Trophic Level Sample and Data Analyses:

A total of 140 zooplankton samples were collected and preserved on the 2016 cruise. All samples were sent to the Polish Plankton Sorting and Identification Center in Szczecin, Poland and will be returned to us in May of 2017. The zooplankton data will be made available in the database sometime in late 2017, 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.

Cornell 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. Cornell continued to devote analysis efforts to explore relationships between wind speed, ice concentration and ambient noise levels (Fig. 7), and are beginning to build in object-oriented code to account for biological and anthropogenic sound sources.

Scientists aboard the F/V *Aquila* attempted to recover the two Cornell Marine Autonomous Recording Units configured with extra batteries and programmed to record continuously for one year. These units are referred to as “double-bubbles” or MARU-DBs and were programmed to record continuously at 2 kHz. The primary MARU-DB was successfully recovered at N 71.29893, W 163.27718 on 13 September. The secondary MARU-DB at N 71.496533, W 163.190817, responded to multiple “burn” commands but failed to surface. It was due to automatically release on 07 Oct 2016.
Figure 7. 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 four 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. 8). The number 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. We have now started to apply this process to a set of manually analyzed AURAL recordings from 2014-15, so that its efficacy can be determined.

Figure 8. 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 2013 represents a few days with bowhead song detections, while the high event level in May - June 2014 represents predominantly bearded seal songs.
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 have contributed data and data products (maps and figures) as have 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 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 MML 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 for the photo-identification data are still under development.

Metadata for the moorings and hydrographic data are being refined. EcoFOCI/PMEL is in the process of compiling all metadata into an in-house ISO-friendly metadata document and format. Data are being gathered together and staged for submission as processing and QC steps are finished. Preliminary action has occurred within the NCEI S2N interface toward submittal of all data sets to NCEI.

All data will be submitted to the public database by the end of June.

Significant technical, schedule, or cost problems encountered

None

Significant meetings held or other contacts made

27 July 2016: Berchok, Clark, Crance, Ferm, Friday, Mocklin, Napp, Rone, Spear, Stabeno, Tabisola meet to discuss the ARCWEST and CHAOZ-X projects, current status, data analysis results, report construction, and other general project updates.
25 August 2016: Berchok, Crance, Ferm, Friday, Kennedy, Mocklin, Napp, Stabeno, Tabisola meet to discuss the ARCWEST and CHAOZ-X projects, current status, data analysis results, report construction, and other general project updates.

Presentations and Publications


Through several inter-agency agreements with the Bureau of Ocean Energy Management, the Chukchi Acoustics, Oceanography, and Zooplankton (CHAOZ), CHAOZ-Extension, and Arctic Whale Ecology (ArcWEST) studies have conducted integrative marine mammal, oceanographic, and zooplankton research in the Alaskan Arctic since 2010. Upon its conclusion in 2015, the CHAOZ study branched into CHAOZ-X and ArcWEST. These three projects combined have allowed for seven continuous years of field surveys, real-time summer sampling, and long-term data collection. At multiple locations in the Alaskan Chukchi Sea, year-long mooring deployments have collected passive acoustic, oceanographic, and zooplankton data. Since 2010, 113 year-long passive acoustic recorder deployments yield spatio-temporal information on marine mammal occurrence, as well as environmental and anthropogenic noise sources. A total of 81 year-long oceanographic moorings provide a 7-year time series on ice, currents, and seven different parameters. As an additional measure of currents, 36 ARGOS drifters were deployed over five years. In addition to long-term mooring deployments, short-term in situ sampling was conducted during the surveys. In total, 381 CTD casts and 358 zooplankton net tows were conducted at various transect lines throughout the Chukchi. In 2016, an underway water sampling system and an acrobat towfish collected oceanographic measurements over ~1500 nm and ~245 nm, respectively. While underway in all years, opportunistic visual (4800 nm) and passive acoustic (894 sonobuoys) surveys for marine mammals and seabirds occurred. Finally, a near-real time passive acoustic auto-detection buoy was deployed in three separate years for a total of ~150 days of recordings. The 2015 CHAOZ final report analyzed this extensive, integrative dataset and provided an initial, ecosystem-wide synthesis of the Chukchi Sea. With the inclusion of the additional years from the ArcWEST and CHAOZ-X projects, a fully integrative seven-year time series will provide a more comprehensive understanding of marine mammal distribution in the Alaskan Chukchi Sea as it relates to oceanographic variables and indices of prey availability.


During the summers of 2010 through 2016, the Marine Mammal Lab, with funding from the Bureau of Ocean and Energy Management (BOEM), conducted 3 multi-disciplinary research
projects in the northern Bering, Chukchi and Beaufort Seas: CHAOZ (Chukchi Acoustics, Oceanography and Zooplankton Study, 2010-2012), ARCWEST (Arctic Whale Ecology Study, 2013-2016) and CHAOZ-X (CHAOZ extension, 2013-2015). During these cruises, teams of 2-3 marine mammal observers conducted big-eye or hand-held binocular visual observations during daylight hours while underway. Excluding the 2016 results (which are still being processed), observers recorded 565 sightings of 1007 cetaceans and 248 sightings of 2077 pinnipeds, otters, and polar bears over nearly 6,000 nm of effort. Remarkably, in 2013, observers photographed and recorded a killer whale predation event on a gray whale calf approximately 30 nm west of Wainwright, Alaska. Gray whale satellite tagging operations were conducted opportunistically between 2012 and 2014. In August and September of 2012 and 2013, five individuals were tracked with satellite tags deployed in the Chukchi Sea for an average of 44 days (range = 12-67d). Results from switching state-space models of the telemetry data reveal area-restricted search behavior in well-known gray whale foraging habitats. One tag equipped with dive-depth sensors recorded regular dives of 55-60m during periods of area-restricted search approximately 120 nm southwest of Pt. Hope and 150 nm west of St. Lawrence Island, further underscoring the significance of these habitats for gray whale foraging. The sighting results, while opportunistic, provide additional marine mammal distribution information in an area with very little systematic vessel-based coverage. Additionally, telemetry results provide invaluable fine-scale habitat use information for gray whales in the Chukchi and northern Bering Seas.

**Literature Cited**
