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 2014. The major activity during this period was fieldwork onboard the ARCWEST/CHAÖZ-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 reached the seafloor 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.

Cruise activities and summary

The ARCWEST/CHAOZ-X joint cruise occurred between September 7 and October 20, 2014 aboard the R/V Aquila. The mooring retrievals and redeployments and biophysical sampling station work was successful, as well as the visual survey and passive acoustic (sonobuoy) monitoring. There were no satellite tags deployed, however. Please see the ARCWEST/CHAOZ-X Cruise Report (http://www.afsc.noaa.gov/nmml/PDF/ARCWEST-CHAOZ-X_CruiseReport2014.pdf) for details.

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 all 2013 ARCWEST AURALs were 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 are in the process of being batch converted into spectrogram image files (.png) for low, medium, and high frequency bands.

Locations for the 2014 CHAOZ-X moorings (Fig. 1) were determined in coordination with the oceanographic and lower trophic level components of CHAOZ-X. All 2014 mooring locations were the same as the 2013 deployments, with the exception of one additional mooring deployed on Hanna Shoal. A deep-water Haruphone (Haru Matsumoto, NOAA/PMEL/CIMRS) recorder was also deployed on its own mooring close to the Stabeno ADCP (See HA14; 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 deployed in the Chukchi Sea for the CHAOZ-X project (red symbols).

For the upcoming 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 Institution (WHOI)). However, until this is fully operational, we will continue to process data manually.

Eliza Ives, tasked with implementing the LFDCS on our data, has conducted iterative testing of the Chukchi Sea bowhead whale call library to establish baseline efficacy against moorings from which she selected the call type exemplars. She spent two additional weeks at WHOI under the guidance of Dr. Baumgartner refining the logistic regression analysis of the Chukchi Sea bowhead call library. Results indicated that a minimum of 25 bowhead calls ($N_{min}$) per 15-minute recording period is necessary for the LFDCS to establish 95% certainty of bowhead presence. It is not uncommon to detect only one or two bowhead calls in a 15-minute period during certain times of the year. Therefore this $N_{min}$ is unrealistically high for real application and thus the library needs further adjusting (Fig. 2). Dr. Baumgartner acknowledged the difficulty of autodetecting such a variably vocal species as bowhead and suggested the answer may lie in determining which single call type is used most consistently by the Chukchi population. This will be explored further and will result in additional tweaking of the Chukchi Sea bowhead whale call library.
Figure 2. Bowhead whale occurrence predicted from 15-minute autodetection periods. Logistic regression was fit to the autodetector’s occurrence data, then the minimum number of calls ($N_{min}$) needed to achieve at least 95% probability of occurrence was calculated.

Eliza has also completed a Bering Sea fin whale call library based on the stereotyped 20Hz downsweep call. She has undergone a few rounds of testing the fin whale call library’s efficacy against moorings from which she selected the call type exemplars, as well as a novel data set. Preliminary results from the fin whale call library indicate the autodetector is missing a lot of calls; however, these results are comparable to current auto-detectors used by other institutions/research organizations (Fig. 3). She was able to run logistic regression analysis on the Bering Sea fin whale call library after her work at WHOI with Dr. Baumgartner. Results indicated that the $N_{min}$ for the call library is 3.26, which is encouraging (Fig. 4). When fin whales are vocalizing, they tend to call at regular intervals and with a frequency unlikely to be missed by a detector with such a low $N_{min}$. Now that the Bering Sea fin whale call library has tested well in logistic regression, a manual analyst will go through the library’s autodetections from the moorings from which exemplars were sampled, as well as the novel data set, to help identify the causes of the missed and false detections evident in Figure 3. Information garnered from this manual analysis will help inform future adjustments to finalize the Bering Sea fin whale call library. Once the Bering Sea 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 for ground-truthing. 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.
Figure 3. Comparison of manual analysis results (blue line) with the preliminary results of the LFDCS fin whale call library (red line) on a novel data set for a 2011 Bering Sea mooring (Mooring = BS11_AU_M02a, data plotted using a 3 day zero-phase moving average, Time Interval = 3 hours).

Figure 4. Fin whale occurrence predicted from 15-minute autodetection periods. Logistic regression was fit to the autodetector’s occurrence data, then the minimum number of calls ($N_{min}$) needed to achieve at least 95% probability of occurrence was calculated.
Jessica Crance ran an analysis of gray whale calls at the low frequency band (0-250Hz) to see if anything is missed by conducting that analysis on the mid-range frequency band (0-800Hz). The analysis was suspended because it was determined that it was too difficult to tell gray whale calls apart from bowhead calls in the 0-250 Hz frequency band. Therefore, the gray whale analysis will be conducted only in the mid-frequency band. Fin whales will be the only species run in the low-frequency band. Given the satisfactory results from Eliza’s LFDCS analysis, we will use an autodetector on that frequency band and verify the positive results manually. This will reduce our processing time for a complete recording considerably.

Ellen Garland, our NRC postdoctoral fellow, has analyzed four 2010-2011 moorings for beluga vocalizations; one in the western Beaufort Sea, two CHAOZ moorings in the Chukchi Sea (inshore and offshore Icy Cape), and one in the northern Bering Sea (M8, deployed under CHAOZ funds). The aim of this study is to identify peaks in beluga vocal activity over a single year to better understand the migratory movements and timing of the eastern Beaufort Sea and eastern Chukchi Sea populations as they undertake their extended migrations in the Alaskan Arctic and Subarctic. After overwintering in the Bering Sea, belugas from the eastern Beaufort Sea and eastern Chukchi Sea populations migrated north through the northeastern Chukchi and western Beaufort Seas in multiple waves which were temporally distinct. These results suggest peaks in vocal activity are able to capture temporal movements of populations when temporal or spatial differences between detection peaks are large enough to be identified as independent events. This study complements and supports the population identity of peaks suggested by satellite telemetry, aerial surveys, and other acoustical studies, and highlights the successful application of passive acoustic monitoring to improve our understanding of the migratory timing of populations for management and conservation in a region undergoing rapid change. A manuscript of this work is now in press in Polar Biology (Garland et al., 2015), and was presented at the Alaska Marine Science Symposium in January and the Ecology and Acoustics Conference in June. She is currently extracting and measuring individual beluga calls to generate a beluga call repertoire for each population. A repertoire is now available for the eastern Beaufort Sea population, and a manuscript has been submitted to The Journal of the Acoustical Society of America (Garland et al., in review). After the repertoires are built, she will investigate the feasibility of using differences in repertoires (dialects) to identify each population, and thus track the migration and movement patterns of different beluga populations based entirely on passive acoustics. Although no CHAOZ-X data is currently being used in her analysis, the data collected from passive acoustic recorders deployed under the CHAOZ-X project will likely be included in future work on belugas. Specifically, if the vocal repertoires (dialects) of populations are able to be distinguished from call types, the CHAOZ-X passive acoustic data set will be invaluable for investigation of movement patterns at the broad scale.

**Sonobuoys:**

We deployed 305 sonobuoys during the 2014 ARCWEST/CHAOZ-X cruise. The results from these sonobuoys, including those within the CHAOZ-X study area, are shown in Figure 5.
Figure 5. Sonobuoy deployment and acoustic detections in the Chukchi Sea.

Oceanographic and Lower Trophic Level Component:

Moorings:

Locations for the 2014 oceanographic and active acoustic moorings (Fig. 6; red stars) were determined in coordination with the passive acoustic component of ARCWEST 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_CruiseReport2014.pdf). See the PMEL mooring website (http://www.pmel.noaa.gov/foci/operations/mooring_plans/2014/aug2014_ContVes_moorings.html1) for information on the other instruments placed on each mooring.

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1 On this webpage subsurface moorings relevant to this project are titled 14CK (i.e., Chukchi Sea 2014) and 14BS (i.e., Bering Sea 2014). The number on the end corresponds to the mooring clusters: 14CKT for the Chukchi Sea (e.g., 14CKT-2A corresponds to C2) or 14BS for the Bering Sea (e.g., 14BS-2C corresponds to M2).
All moorings deployed in 2013 were successfully recovered in 2014. The data return was good for the 3 ARCWEST 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. All ADCPs collected data, but one has intermittent periods of poor data quality. All these data have been processed and uploaded to the database. All three instruments measuring keel depth collected data and these data are being processed and should be uploaded to the database by June.

We successfully deployed 6 out of 7 TAPS6-NG instruments in 2014. The 7th unit was damaged during the attempted deployment. Three of the units were deployed for this project. All 5 of the TAPS6-NG units that were deployed in 2013 were successfully recovered in 2014. We have initially examined data collected in 2013-2014 (2 instruments were for this project). Unfortunately it appears that the instruments collected only a small amount of data before failing. 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. We had been working with a contractor for the last several years to redesign this card whose electronics and software are very old and outdated. The contractor delivered a preliminary design and electronic circuit boards were produced from the design for testing and firmware coding.
However the contractor defaulted on the contract and is not answering our calls. Our in house engineer believes he can build a very simple, but effective controller using a common, easily obtained processor chip. We are going to pursue that path, rather than finding a new contractor to pick up the work dropped by the old one.

*Hydrography & Plankton Sampling:*

Locations for lower trophic level and physical/chemical oceanographic sampling (Fig. 7; red dots) were also determined in coordination with the passive acoustic component and based upon previous research and our conceptual model of current flow. Detailed maps are available in the ARCWEST/CHAOZ-X cruise report (http://www.afsc.noaa.gov/nmml/PDF/ARCWEST-CHAOZ-X_CruiseReport2014.pdf). Note the existence of several new transect lines and the deletion of others. This year we did not sample the Cape Lisburne line. New transect lines originating in Ledyard Bay and in the Beaufort Sea were added using NOAA funding. A total of 86 CTD casts for this cruise (measuring temperature, salinity, oxygen, PAR, pressure and chlorophyll fluorescence) have been processed and uploaded to the database. Nutrient samples are being run now and will be incorporated into the hydrographic files and uploaded to a database by the end of February. Chlorophyll samples (N > 400) were collected and are stored in a freezer in Seattle. We expect to analyze these samples within 1 year of the cruise.
Figure 7. Planned biophysical stations sampled during the 2014 ARCWEST/CHAOZ-X cruise. Yellow symbols indicate ARCWEST stations. Red symbols indicate CHAOZ-X stations. Blue symbols indicate NOAA-funded stations.

Satellite Tracked Drifters:

Due to the late timing of the cruise, it was decided that it was not cost effective to deploy the satellite-tracked drifters this year. They will be deployed in 2015 from the USCGC Healy (nine in July) and the ARCWEST cruise (three in September). Several of the 12 drifters deployed in 2013 (Fig. 8) were still active during the first quarter of 2014 and continued to be tracked, and two of these were still active during the second quarter. A movie showing drifter tracks can be viewed at the following website: [http://www.pmel.noaa.gov/foci/visualizations/drifter/chuk2014.html](http://www.pmel.noaa.gov/foci/visualizations/drifter/chuk2014.html). Previous movies showing drifter tracks since 2011 can be viewed at the following website under the heading Drifter Movies/Chukchi Sea: [http://www.ecofoci.noaa.gov/efoci_drifters.shtml](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).
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 2015.

Lower Trophic Level Sample and Data Analyses:

Greater than 225 zooplankton samples were collected and preserved on the 2014 cruise. All samples were sent to the Polish Plankton Sorting and Identification Center in Szczecin, Poland. We expect that the initial counts of organisms will be returned to us by May of 2015. 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.

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) and two double-bubble marine autonomous seafloor recording units (Dbs). On 20 August the R/V *Westward Wind*’s deck crew deployed the AB 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. 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, and the acoustic data were extracted from the five MARUs, Db-2013 and the AB. One of the five MARUs failed to record data, but the data from the four other MARUs, Db-2013 and the AB were all extracted successfully.

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 were transmitted back via iridium satellite as well as spectral measurements, which were collected once every 10 minutes. Furthermore, the AB audio data were recorded to FLASH memory throughout the deployment. These data will be used in post-processing analysis to evaluate and quantify the

![Figure 9. Deployment arrangement of the five Cornell MARUs relative to the auto-detection buoy (AB-2014) and the two double-bubbles (Db-1 and Db-2). MARU-5 was the unit that failed to record data.](image-url)
performance of the real-time software detection system.

Cornell continued to make significant progress with SEDNA such that the MatLab code can be run on either single systems (e.g. a laptop) or our high-performance computer (SEDNA-DeLMA, our multi-core 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 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, Yu Shiu, became fully engaged in the project. Dr. Shiu focused on a) auto-detection software for post-processing the acoustic data from the Db-2013 and the five 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.

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

None

**Significant meetings held or other contacts made**

Berchok and Stabeno both attended the Pacific Arctic Group (PAG) Fall Meeting (October 28-29, Seattle, WA), as well as the 2nd Distributed Biological Observatory (DBO) Data Workshop (29-31 October; Seattle, WA). Data from CHAOZ-X was presented by Berchok for both the meeting and workshop.

Berchok attended the Tethys passive acoustic metadata database workshop (Dec 8-12, La Jolla, CA).

**Presentations and Publications**


**Literature Cited**

WA 98115-6349.

