PASSIVE ACOUSTIC DETECTION AND MONITORING OF ENDANGERED WHALES IN THE ARCTIC (BEAUFORT, CHUKCHI)

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ECOSYSTEM OBSERVATIONS IN THE CHUKCHI SEA: BIOPHYSICAL MOORINGS AND CLIMATE MODELING

QUARTERLY 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 of the distribution and relative abundance of endangered whales in the Chukchi Sea Planning Area and relate variation in those parameters to oceanographic conditions, indices of potential prey density, and anthropogenic activities. This quarterly report covers the period between January 16th and April 15th 2012.

The major activities during this period consisted of data analysis as well as preparation for the Chukchi Sea Acoustics, Oceanography, and Zooplankton (CHAOZ) cruise that will take place from 8 August through 5 September 2012. The cruise will take place on a TBD chartered vessel. Analyses are currently ongoing, and some preliminary results are detailed below.

Introduction and objectives

The western Arctic physical climate is rapidly changing. The summer minimum sea ice extent in 2007 and 2008 covered an area which was 37% less than that of two decades ago. The speed of these changes was unexpected, as the consensus of the climate research community just a few years ago was that such changes would not be seen for another thirty years. As sea temperature, oceanographic currents, and prey availability are altered by climate change, changes in baleen whale species composition, abundance, and distribution are expected (and evidenced already by local knowledge and opportunistic sightings). In addition, the observed northward retreat of the minimum extent of summer sea ice has the potential to create opportunities for the expansion of oil and gas-related exploration and development into previously closed seasons and localities in the Alaskan Arctic. It may also open maritime transportation lanes across the Arctic adding to the ambient noise in the environment. This combination of increasing anthropogenic impacts coupled with the steadily increasing abundance and related seasonal range expansion by the bowhead, gray, humpback, and fin whales, indicates that more complete information on the year-round presence of large whales is needed in the Chukchi Sea planning area. Timing and location of whale migrations may play an important role in assessing where, when, or how exploration or access to petroleum reserves may be conducted to mitigate or minimize the impact on protected species.

This study has four component projects: oceanography, passive acoustics, zooplankton, and climate modeling. Each component project is a technical discipline and is coordinated by a Project Leader with extensive experience in that discipline. Passive acoustic moorings, deployed concurrently with bio-physical moorings will provide previously unattainable 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, climate, indices of potential prey density, and anthropogenic activities). Moorings permit observations during long periods when ice covers the region, especially during the critical spring and early summer periods when spring phytoplankton blooms occur. Such measurements are virtually impossible to obtain from ships, because of the relatively short duration of cruises and severe limitations in the availability of ships able to work in ice-covered seas.

The overall goal of this multi-year IA study is to document the distribution and relative abundance of bowhead, humpback, right, fin, gray, and other whales in areas of potential seismic surveying, drilling, construction, and production activities and relate changes in those variables to oceanographic conditions, indices of potential prey density, and anthropogenic activities.

The specific objectives are:

1. Assess the year-round seasonal occurrence of bowhead, gray, and other whale calls in the Chukchi Sea.

2. Estimate relative abundance of these whales.
3. Obtain two full years of biophysical measurements on the shallow Chukchi shelf utilizing moorings at three sites, and collect hydrographic and lower trophic level data during deployment/recovery of the moorings.
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. Run the National Center for Atmospheric Research (NCAR) climate model (Community Climate System Model: CCSM) for future projections using the sea ice extents from 2007/2008 as initial conditions.
6. Analyze multiple ensemble members from the NCAR model and other IPCC models to assess the future variability of sea ice cover and extended sea ice free seasons during fall for the Chukchi Sea.
7. Evaluate whether changes in seasonal sea ice extent are resulting in a northward shift of Bering Sea cetacean species such as fin, humpback, and North Pacific right whales.
8. Provide long-term estimates of habitat use for large whale species and compare this with predictions about annual ice coverage to establish predictive variables that describe large whale occurrence.

ACOUSTICS COMPONENT

Preliminary results

NMML Long-term moorings:
The first deployments of the long-term passive acoustic recorders were retrieved in fall 2011 and analyses have begun. These units recorded on a duty cycle of 95 minutes every 5 hours, at a sampling rate of 16kHz. Table 1 lists the 15 passive acoustic moorings, and the actual time period when they were recording data. The reason that no unit recorded for the full year span was because of an unpublicized design change in the Duracell batteries that were used in the recorders, giving us a much reduced power supply. The units redeployed in 2011 were set to a shorter duty cycle, so those units should record for the full year. Preliminary analyses of the 2010-2011 units consist of one recorder from each array being analyzed for presence of bowhead, gray, fin, and beluga whales, and bearded seals. Results showing bowhead and fin whale, and bearded seal detections from one mooring within the middle B array are shown in Figure 1. Results showing bowhead whale detections from one mooring within the A array (inshore) are shown in Figure 2.

Ellen Garland, a new post-doc from the University of Queensland, Australia, has begun analyzing the CHAOZ arrays for the presence of beluga whales. Once initial presence/absence has been established, her analysis will then focus on cataloguing beluga vocalizations, and determining if they have population-specific vocalizations. Kalyn MacIntyre, a graduate student at the University of Washington, is analyzing these recorders along with numerous others to determine bearded seal spatial and temporal presence throughout the entire Bering, Chukchi, and Beaufort Seas. Modifications to existing array localization code will be completed in 2012 by Berchok.

Table 1. Recording period, position, and depth of all long-term passive acoustic recorders deployed off Icy Cape, AK.

Mooring	Record Start	Record End	Latitude	Longitude	Depth (m)
CZ10_AU_A01	9/10/2010	7/8/2011	70.9071500	-163.2394000	42.5
CZ10_AU_A02	9/10/2010	7/7/2011	70.8717167	-163.0441667	44.3
CZ10_AU_A03	9/10/2010	6/27/2011	70.7983833	-163.0811167	43.4
CZ10_AU_A04	9/10/2010	6/10/2011	70.7826000	-163.2872500	44.3
CZ10_AU_A05	9/10/2010	6/8/2011	70.8536000	-163.3698500	42.5
CZ10_AU_B01	9/10/2010	6/7/2011	71.2527500	-164.2770167	42.5
CZ10_AU_B02	9/10/2010	6/11/2011	71.2357333	-164.1898000	42.5
CZ10_AU_B03	9/10/2010	6/21/2011	71.2020333	-164.1922333	42.5
CZ10_AU_B04	9/10/2010	6/25/2011	71.1961500	-164.2969833	43.4
CZ10_AU_B05	9/10/2010	6/5/2011	71.2285833	-164.3444333	43.4
CZ10_AU_C01	9/10/2010	5/28/2011	71.8534000	-165.9958000	44.3
CZ10_AU_C02	9/10/2010	6/8/2011	71.8339500	-165.9033000	44.3
CZ10_AU_C03	9/10/2010	5/23/2011	71.8024167	-165.9220333	44.3
CZ10_AU_C04	9/10/2010	6/3/2011	71.7982167	-166.0302000	44.3
CZ10_AU_C05	9/10/2010	5/23/2011	71.8287333	-166.0707667	44.3

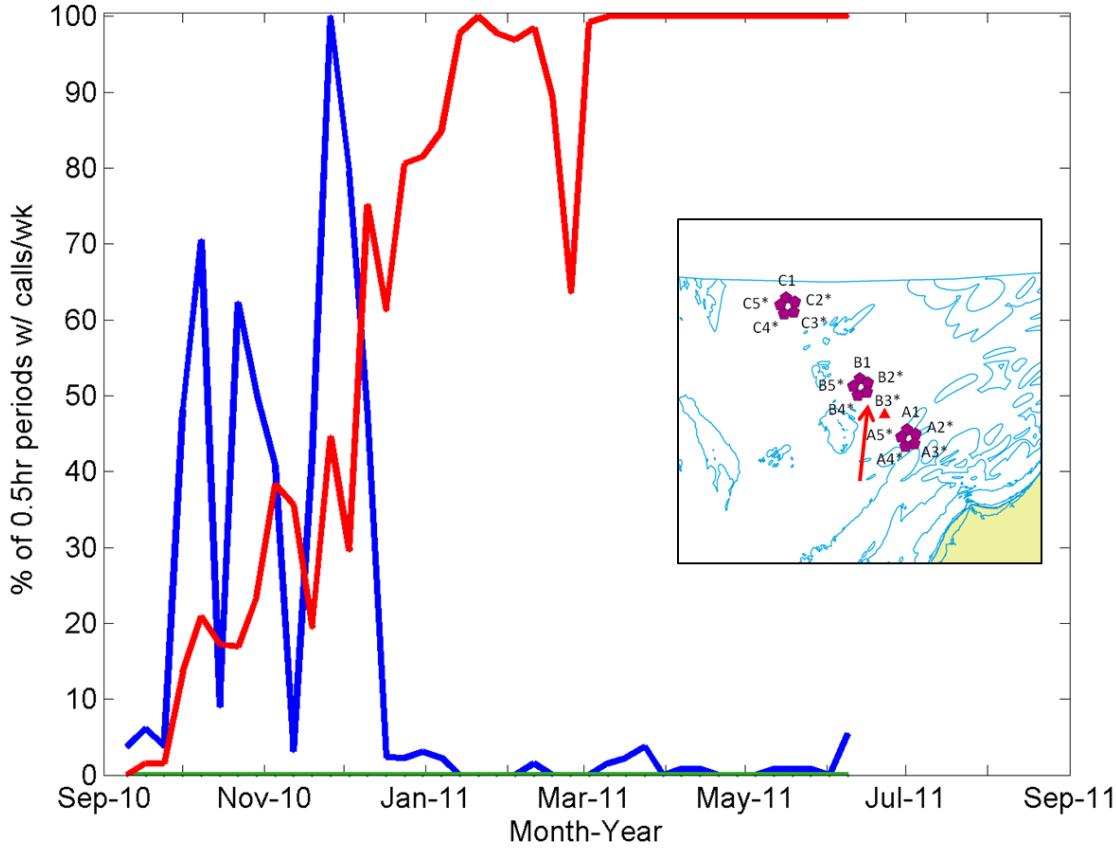

Figure 1. Seasonal acoustic detections of bowhead whales (blue), fin whales (green), and bearded seals (red) at mooring B3 (indicated by arrow in inset map) off Icy Cape, AK (Sept. 10, 2010 – June 21, 2011).

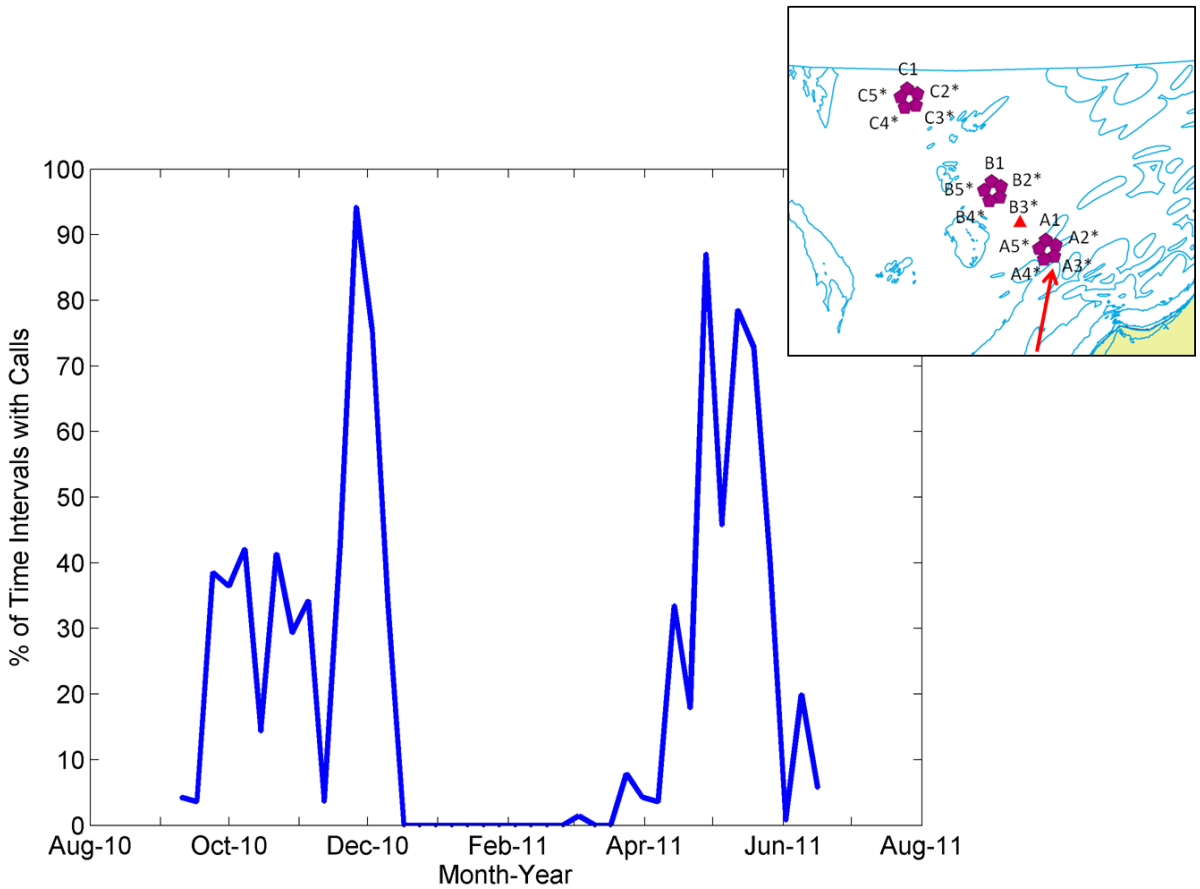

Figure 2. Seasonal acoustic detections of bowhead whales at mooring site A3 (indicated by arrow in inset map) off Icy Cape, AK (Sept. 10, 2010 – June 27, 2011).

2012 preparations and analysis plans

The vessel contract for the 2012 field season was submitted in November 2011, and is currently up for bid. The closing date on the contract bidding period is April 24th. The technical committee will begin reviewing all proposals on the 25th of April. We are hoping for an award date of late May. Preparations for the 2012 cruise are already underway. Equipment purchase orders and contractor task orders are being drafted and will be submitted shortly.

Data analysis of the recovered long-term moorings has begun. Edits to the localization code will be completed on 2012 by Berchok.

OCEANOGRAPHIC COMPONENT

Preliminary results

Long-term moorings:
We successfully recovered all oceanographic moorings which were deployed in August 2010. Only one instrument failed completely (an ISUS nitrate meter), all other instruments collected data for most of the deployment time. Processing has been completed for instruments measuring currents (both ADCP and point current meters), PAR, oxygen, nitrate, chlorophyll fluorescence, temperature and salinity.

The instruments measuring ice thickness require more complex processing. All instruments have been processed at the preliminary stage; only the final temperature correction for speed of sound still needs to be done. Average ice thickness increased from November, typically reaching a maximum in April or May at all mooring sites. The deepest keel was observed at A1 (29.6 m) in April (Figure 3). The maximum keel depth at A2 was less (24.3 M) occurring in early June. The maximum keel depth at A3 was only ~20.1 m. The mean keel depth decreases as function of distance.

There was significant correlation among currents at each mooring site (Fig. 4), with mean flow toward the northwest. From the current meters (ADCP), a calculation for transport has been completed revealing that mean transport is 0.4×10^6 m^3 s^{-1}, approximately half the transport which flows through the Bering Strait. Transport was weakly correlated with the winds at Barrow. These data and results were presented at the Alaska Marine Science Symposium (AMSS) in January 2012.

Shipboard measurements:
Data were collected at all planned hydrographic sites during the August 2011 cruise. Temperature, salinity, nutrients, PAR, oxygen and chlorophyll fluorescence from the hydrographic lines have all been processed and are available for use. The Alaska Coastal Current water is clearly evident in each of the southern transects. We have contributed our data to the Distributed Biological Observatory (DBO).

Satellite-tracked drifters:
Three satellite-tracked drifters (drogued at 25 m) were deployed during the August 2011 cruise. These drifters were provided by FOCI/PMEL. Two were deployed near Bering Strait and traveled generally north/northwestward toward Harold Canyon. The third was deployed near Hannah Shoal and travelled first eastward along the slope and then westward in deeper water. All were caught in the advancing ice in November and December. Two movies of drifters are available, and both show the trajectory of the three drifters. The first includes just bathymetry (http://www.pmel.noaa.gov/foci/visualizations/drifter/chuk2011.html) and the second shows the advance of sea ice (http://www.ecofoci.noaa.gov/efoci_drifters.shtml, click on new Chukchi drifters, ice).

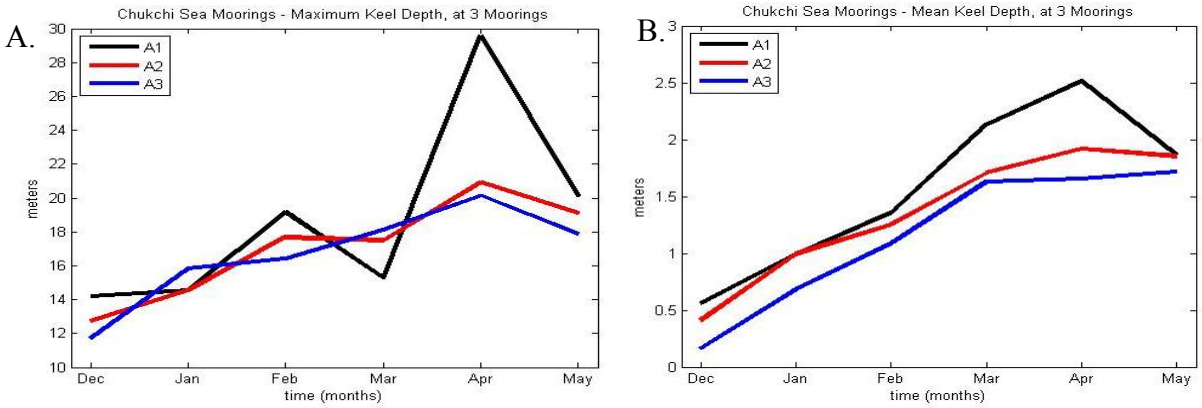

Figure 3. A) Maximum ice thickness each month at each of the mooring sites. Notice the high variability at A1, which is nearest the coast. B). Mean ice thickness at the three mooring sites. A1 at IC3, A2 at IC6, and A3 at IC11.

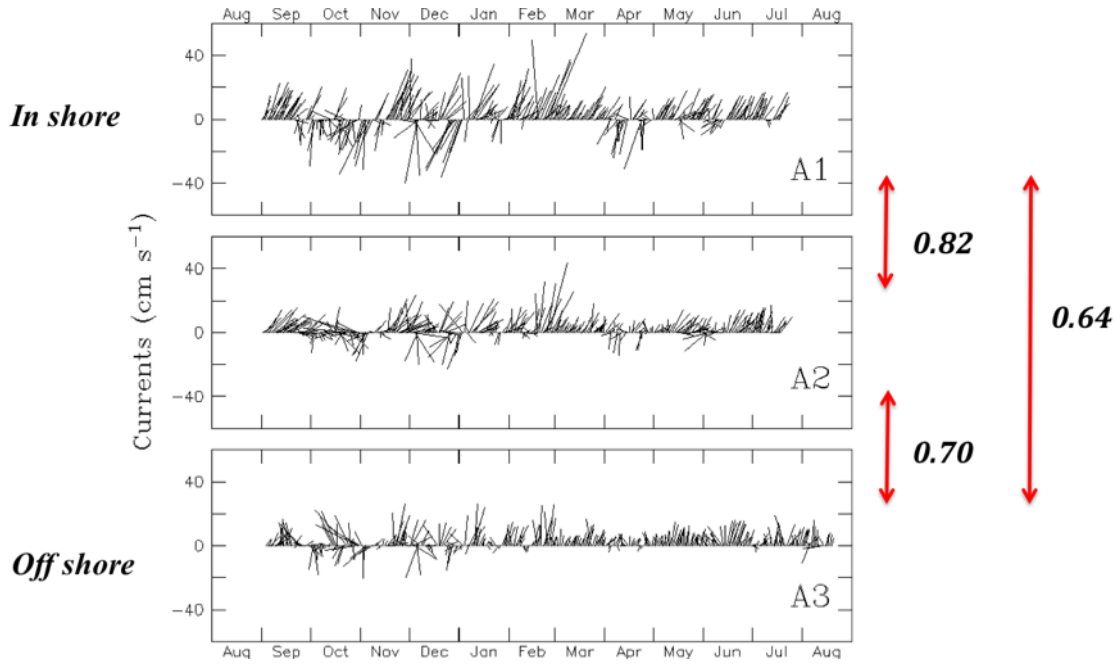

Figure 4. The bottom currents (up is toward the northeast) at each of the three mooring sites. The time series have been low-pass filtered to remove tides, and daily date vectors are shown. The correlation (R value) among the time series is given to the right of plot. A1 at IC3, A2 at IC6, and A3 at IC11.

Satellite Remote Sensing:
Satellite images have been processed and made available for chlorophyll. In addition, ice concentrations from the National Ice Center have been used to complement both the trajectories of satellite-tracked drifters and to help in the analysis of the mooring data.

<u>2012 preparations and analysis plans</u>
We are preparing for the summer cruise in 2012. All equipment has been calibrated and prepared for deployment, and personnel for the upcoming cruise have been notified. We plan to deploy moorings at IC6 in 2012. The configuration of equipment used in 2011 was very successful and will be replicated in 2012.

ZOOPLANKTON COMPONENT

<u>Preliminary results</u>

TAPS Data Processing:
We continue to work with the instrument designer to correctly process and interpret the data collected last year from the TAPS-8 at site IC6. New MatLab scripts have been written to: 1) perform signal to noise ratio QA/QC, 2) test to ensure that each data point meets the volume scattering assumption, 3) provide a more user friendly interface that can be applied to all data, and 4) allow the user to select up to 3 different sound scattering models to be used in a simultaneous inverse solution (truncated fluid sphere, Distorted Born Wave Approximation – euphausiids, Distorted Born Wave Approximation – chaetognaths). In addition, we have begun to make length-width measurements on preserved zooplankton collected during 1AE10. These measurements will be used to refine the shape parameters used in our sound scattering models. We continue to discuss and work on the appropriate scattering models for the inverse solutions.

TAPS-6 data collected during the August 2011 cruise were presented at the AMSS meeting. Two types of data were collected – a diel series at the mooring site IC6 and vertical casts at each of the hydrographic stations.

2012 preparations and analysis plans

Instrument Design and Construction:
Our efforts were hampered by the late finalization of the Interagency Agreement between BOEM and NOAA. We obtained parts (transducers, boards, electrical components) to build two more instruments and began building the tuning cards. One set of transducers and cards will be ready to calibrate 9-13 April when our contractor, Charles Greenlaw visits Seattle. The third instrument will not be ready until after he leaves. We will have to calibrate that one on our own. Our current plan is to test the second instrument by placing it in Puget Sound or Lake Washington for several weeks during the next quarter. It will then be retrieved and deployed in the Chukchi late this summer. During Mr. Greenlaw's visit we will discuss with him and another engineer the steps needed to modernize the TAPS6-NG controller board.

Preserved Samples:
A contract was let to Ms. Nissa Ferm to perform QA/QC on the 2010 zooplankton samples processed in Poland. She began at the end of the quarter and will continue her work into the next quarter. Data from those samples have been uploaded into our database. Data from the preserved zooplankton samples taken during the August 2011 cruise have been returned to Seattle. The next step for those samples is to perform QA/QC procedures to ensure that the data were correctly entered into the digital data tables.

Other Activities:
We continue planning activities for the 2012 field season and have had multiple discussions with other researchers on how to coordinate CHAOZ activities with other programs such as ArcWEST.

OCEAN NOISE AND REAL-TIME PASSIVE ACOUSTIC MONITORING

The Bioacoustics Research Program at the Cornell Laboratory of Ornithology (BRP) is providing scientific and technical expertise in marine acoustics and bioacoustics; analysis and interpretation of existing and new acoustic data; and the deployment, maintenance and operation of auto-detection buoys.

The project's long-term goals for the Chukchi Sea acoustic ecosystem are to:

1. Report occurrences of acoustically active marine species and ocean noise metrics in near-real-time,
2. Quantify the ocean noise "budget",
3. Quantify the contributions of anthropogenic sounds to the ocean noise budget, and
4. Assess the influence of anthropogenic sounds on the acoustic habitats of marine species.

These goals are accomplished through an acoustic monitoring & mitigation component and an analysis component. The acoustic monitoring & mitigation component includes a near-real-time acoustic system (hereafter referred to as the auto-buoy, or AB) and a marine autonomous recording unit, hereafter referred to as a MARU. The acoustic analysis component consists of a) processing data collected via the AB and MARU systems and b) further developing mechanisms for quantifying noise budgets and masking metrics, with specific application to the Chukchi Sea acoustic ecosystem.

Accomplishments this quarter were:

Acoustic Ecology: We continued to work on conceptual and empirical data factors that are part of a model for quantifying and evaluating the cumulative effects of human-made sounds on the acoustic ecology of

the Arctic marine environment. We began collecting preliminary sound feature measurements during seismic airgun surveys conducted on the Arctic Ocean shelf at known distances from acoustic recorders. We also began engineering a software system for automating the overall acoustic ecology analysis algorithm.

Auto-Detection Buoy System (AB): We recovered the test buoy, which we had deployed in December and evaluated the successes and failures of the system. We determined that there was a bug in the continuous storage system (USB flash device), and potentially an issue in the new I2C bus communication chain which we use to enable/disable the modems. New code was written to address these issues, and we'll be upgrading a couple of components as well. New circuit boards have been ordered, and we're awaiting their arrival in the next couple of weeks. We hope to begin stress testing the system on the bench, shortly.

We finally have a good data set in hand for training the bowhead detector, which we expect to be able to test shortly. We're currently experimenting with a new background spectra measurement system, which we hope to run in parallel with the bowhead detector. We've also made progress on a mechanism to retrieve larger audio files, which are recorded to persistent on-board storage. We hope this will periodically allow us to send back longer audio recordings surrounding a time period (vs. triggered by a detection event) of particular interest. We'll need to calculate what we can do within power/fiscal budgetary constraints.

WHOI Mooring: WHOI has decided to redesign the mooring for this deployment, based on the navigational requirements of operating near potential shipping. The tower has been re-added with a radar reflector, beacon, and asset tracking system (Figure 5). The current plan is for us to integrate our electronics inside their battery well, using our electronics cage fixed to the underside of the well lid (Figure 6).

According to WHOI, the deployment and recovery details are still being worked out. The deployment might be on a commercial vessel, with recovery by the Healy in October. In any event, BRP and WHOI intend to begin integration testing on land in May at WHOI. So far, we think we're on schedule.

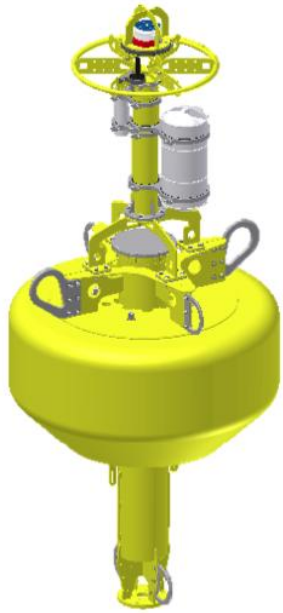

Figure 5. WHOI’s latest redesign of auto-detection buoy mooring system.

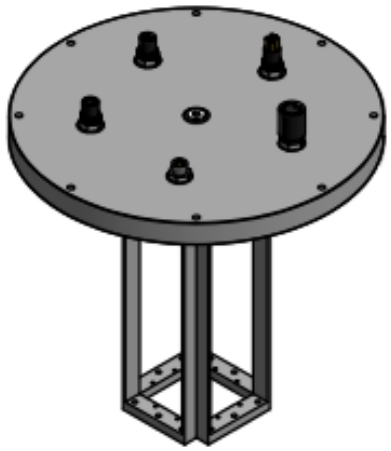

Figure 6. Cornell's electronics cage design, which will be fixed to the underside of the well lid on the top of the WHOI auto-detection buoy mooring system.

CLIMATE MODELING COMPONENT

In order to make the most of the computational resources we have received from NCAR supercomputing facility, we used the following configuration of the CESM1.0.4 (as shown in Figure 7): CAM2 for the atmospheric component, CLM2 for the land surface component, CICE for the sea ice model, and POP2 for the ocean component. These four model components are coupled via the coupler, CPL (yellow circle in the middle, Figure 7). The model has atmospheric resolution close to 0.9x1.25 degree. This is consistent with NCAR CMIP5 runs, and therefore we could use NCAR's CMIP5 simulations as additional references (more ensemble members). We did not use CCSM3/CCSM4 for our current simulation, as stated in the proposal, because NCAR does not support CCSM3 anymore, and users are encouraged to use CESM, their updated version of the global climate model.

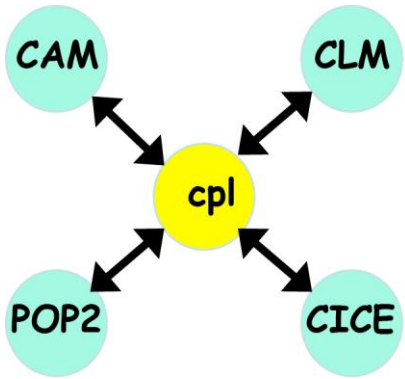

Figure 7. The configuration of the CESM1 used in current simulations. Blue circles represent model components, yellow circle represents the coupler.

For the CMIP5 simulations, NCAR produced 14 runs under three emissions scenarios (5 for Rcp4.5, 4 for Rcp6.0 and 5 for Rcp8.5). The September sea ice extent shows declines under all three emissions scenarios, at different rates. We have chosen to run the CESM model using the initial condition as of September 2023, since this is the earliest time when the sea ice over the Arctic reached the lowest value, a number close to the observed sea ice extent in recent years.

The model has been integrated for 8 consecutive months so far. Several restart files have been prepared. We will use the restart file to integrate the model for 30 years from the current condition. Our preliminary analysis shows that our run is similar to CCSM4's simulation. The average ice concentration for March and August 2023 is 72.1%, and 29.8% in CCSM4, and 71.9% and 36.3% in CESM1, respectively. The sea ice thickness displays a similar pattern and distribution as shown in Figure 8. The average ice thickness is 1.58m in both CCSM4 and CESM1 in March, and 0.80m in CCSM4 and 0.97m in CESM for August. Most of the differences are near the north shore of the Canadian archipelago, and near the east coast of Greenland. We have applied and are being approved for additional disk storage at NCAR super computer. Further model integration and analysis is underway.

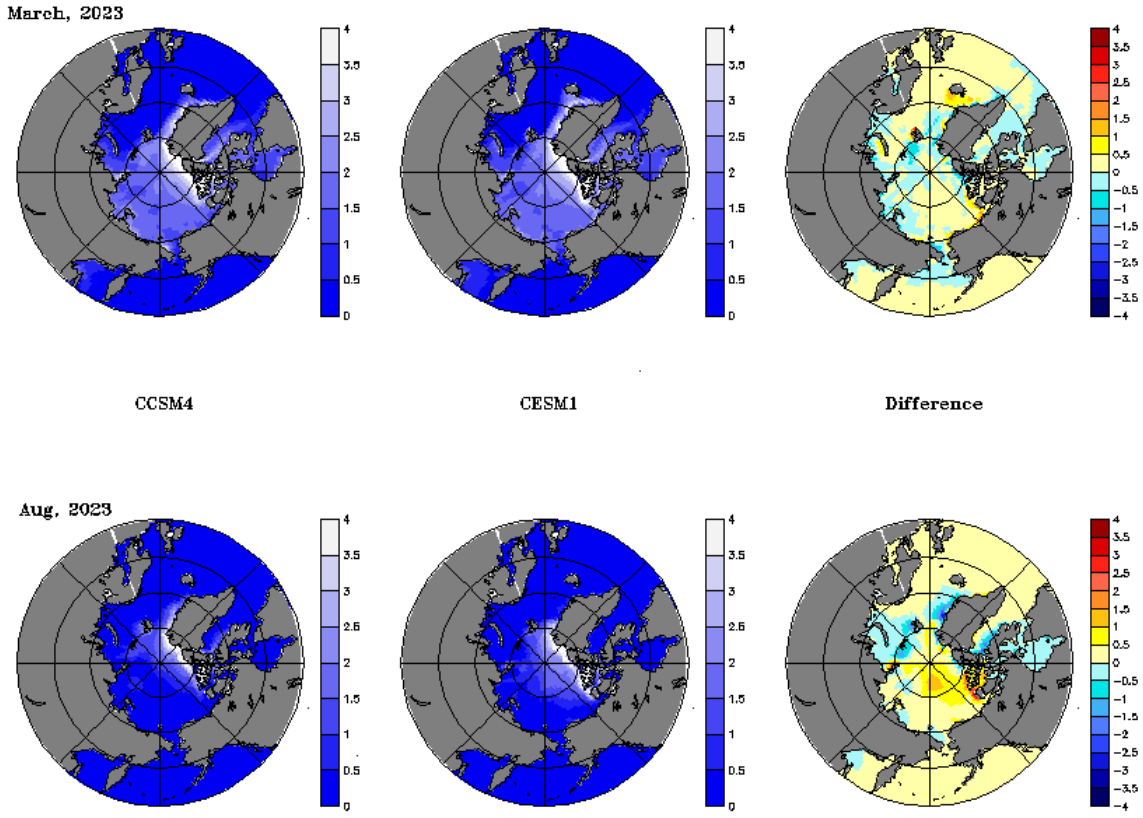

Figure 8. Monthly mean ice thickness over the Arctic as simulated by CCSM4 (left), CESM1 (middle), and the difference between the two models (right). Top panels are for March, and bottom panels are for August.

Significant meetings held or other contacts made

Berchok and Crance have met with Levis Knox (contracting agent) numerous times to discuss the vessel contract for the 2012 field season.

18 January 2012: Berchok hosted "Identifying Arctic sounds" workshop during the Alaska Marine Science Symposium. Attendees include: Catherine Berchok, Jessica Crance, and Stephanie Grassia (AFSC/NMML); Julien Delarue and David Hannay (JASCO Research); Kate Stafford (APL, Univ. of Washington); Josh Jones, Delphine Mathias (Scripps Institution of Oceanography); Susanna Blackwell (Greeneridge Sciences); Melania Guerra (Cornell University); Kalyn MacIntyre (Univ. Washington); Jan

Straley (Univ. Alaska Southeast); and Michael Mahoney, Samantha Schaeffer, and Anneliese Moll (Mt. Edgecumbe High School, Sitka, AK).

27 Feb – 2 Mar 2012: Berchok attended NOPP metadata workshop, Scripps Institution of Oceanography. Learned how to install and use database designed by Marie Roch (San Diego State University, CA). Database will store acoustic metadata and also allow easy access of environmental databases. Group is working towards standardization of the acoustic metadata fields, especially the naming of call types. Attendees included representatives from all NOAA science centers.

5 - 9 March 2012. Spear (zooplankton component) traveled to Seguin, TX to confer with acoustic oceanographer C. Greenlaw on TAPS data processing, including methods appropriate for low signal situations.

14-16 March 2012: Berchok attended SOAR (Synthesis of Arctic Research) meeting in Anchorage, AK. Acoustics team (Catherine Berchok (AFSC/NMML), Chris Clark (Cornell University), Josh Jones (Scripps Institution of Oceanography), Susanna Blackwell (Greeneridge Sciences), Kate Stafford (APL/Univ. of Washington), and Dave Hannay (Jasco Research)) proposed analyzing our combined 'acoustic array', that stretches from Tuktoyaktut in the Canadian Beaufort to the Bering Sea, for noise levels as well as presence of bowhead whale and bearded seal sounds.

14-16 March 2012: Napp attended the SOAR (Synthesis of Arctic Research) meeting in Anchorage, AK and provided comments on CHAOZ zooplankton observations during various discussions. Napp co-lead a synthesis proposal with E. Logerwell (AFSC) to compare and contrast the fish communities and distribution on the Chukchi and Beaufort Sea continental shelves.

14-16 March 2012: Stabeno co-chaired the SOAR (Synthesis of Arctic Research) meeting in Anchorage, AK and discussed with several individuals the physical dynamics on Chukchi Sea.

9 – 13 April 2012: C. Greenlaw (acoustic oceanographer) traveled to Seattle, WA to assist in calibration of our second TAPS-6NG instrument, discuss how to improve the TAPS controller board, and to continue discussions on analysis techniques appropriate for the TAPS instrument data.

Presentations and Publications

Crance, J.L., C.L. Berchok, B. Rone, A. Kennedy, E. Küsel, L. Morse, J. Thompson, and P.J. Clapham. 2012. "Short-term trends in the summer distribution of Cetaceans in the Chukchi Sea". Alaska Marine Science Symposium, 16-20 January 2012. Anchorage, AK.

Napp, J.M., A.H. Spear, and P.J. Stabeno. 2012. "Acoustic detection of zooplankton in the Chukchi Sea". Alaska Marine Science Symposium, 16-20 January 2012. Anchorage, AK.

Napp, J.M. and P.J. Stabeno. 2012. "CHAOZ in the Arctic: Go North Young Scientist!" EcoFOCI Seminar, 10 April 2012. Seattle, WA.

Stabeno, P., C. Berchok, S. Moore, C. Mordy, J. Napp, and S. Salo. 2012. "Chukchi Acoustics, Oceanography, and Zooplankton (CHAOZ): Observations on the Chukchi Sea". Alaska Marine Science Symposium, 16-20 January 2012. Anchorage, AK.

Wang, M., J.E. Overland, P. Stabeno. 2011. "Future climate of the Bering and Chukchi Seas projected by global climate models". Deep Sea Research II. Accepted.