

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

&

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

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 determine the distribution and relative abundance of endangered whales in the Chukchi Sea Planning Area and to relate variation in those parameters to oceanographic conditions, indices of potential prey density, and anthropogenic activities. This annual report covers the period between February 2012 and January 2013.

The major activities during this period consisted of the preparation for and execution of the Chukchi Sea Acoustics, Oceanography, and Zooplankton (CHAOZ) cruise from 8 August through 7 September 2012. The cruise took place on the chartered fishing vessel R/V *Aquila*. A total of seventeen scientists and observers participated on the CHAOZ cruise.

Since the completion of the cruise, all data have been stored, and analyses begun (where possible). In addition, the ocean noise modeling analyses as well as the climate modeling analyses have continued, including data summaries specific to the Distributed Biological Observatory (DBO) sampling conducted during 2010-12 CHAOZ cruises. 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.
9. Contribute to the sampling of two regions of the Distributed Biological Observatory (DBO), as part of the international pilot study ongoing since 2010 (http://www.arctic.noaa.gov/dbo/cruise_data.html)

Cruise activities and summary

The 2012 CHAOZ cruise took place from 8 August through 7 September aboard the R/V *Aquila*. Seventeen scientists participated in the survey. A total of 70 CTD and plankton tow stations were completed, 39 long-term oceanographic and acoustic moorings, 8 ARGOS drifters, and 227 sonobuoys were deployed, and over 1,100 miles were visually surveyed (Figure 1). In addition, 4 ARGOS drifters were deployed from the USCGC HEALY for this project. Please see the attached 2012 CHAOZ cruise report for a full summary of activities and accomplishments made during the cruise.

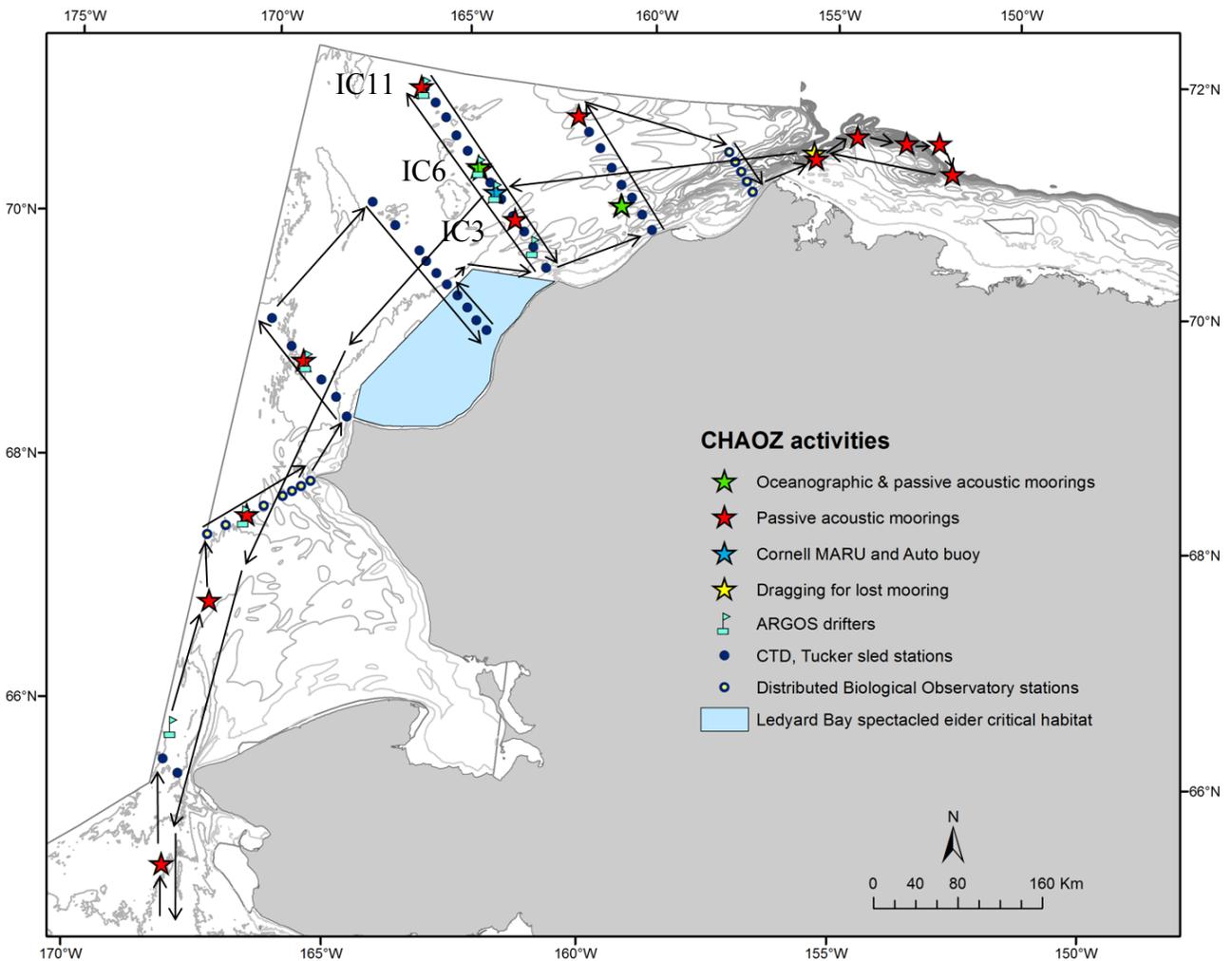


Figure 1. Map showing trackline and activities of the 2012 CHAOZ survey.

ACOUSTICS COMPONENT

Preliminary results

NMML Long-term moorings:

The second year deployments of the long-term passive acoustic recorders were retrieved this year and data analysis has begun. These units recorded on a duty cycle of 85 minutes every 5 hours, at a sampling rate of 16kHz. Table 1 lists the 15 passive acoustic moorings retrieved, and the actual time period when they were recording data. Preliminary analyses of the 2010-2011 units consist of one recorder from each array being analyzed for presence of bowhead, fin, beluga whales, and bearded seals. Results showing bowhead whale, fin whale, bearded seal, and beluga (when available) detections from one recorder from each array are shown in Figures 2-4. Data were analyzed in 30 minute time intervals for the bowhead and fin whales. If a bowhead or fin whale call was detected, the analyst skipped ahead to the next 30 minute bin. If the call was indeterminate, or if no calls were present, the bin was analyzed fully. Beluga and bearded seals were analyzed fully regardless (except in the case of bearded seals from the middle Icy Cape mooring that were also analyzed in 30 minute time intervals). The three recorders analyzed were the A3 mooring within the inshore IC3 cluster (Figure 2), the B3 mooring within the middle IC6 cluster (Figure 3), and C2 mooring within the offshore IC11 cluster (Figure 4).

All moorings have three strong peaks of bowhead call detection during the fall with the majority of animals out of the area by the end of December; however, only the inshore IC3 mooring (A3, Figure 2) shows a strong bowhead presence the following spring. The two strongest peaks of bowhead whale call detection in the spring at A3 correlates with the two peaks in beluga call detection. Beluga presence has been analyzed for the inshore IC3 (A3, Figure 2) and offshore IC11 (C2, Figure 4) moorings. The inshore mooring shows a single fall migration peak and a bimodal peak in beluga presence in spring. We hypothesize that the first spring peak may be caused by animals from the eastern Beaufort stock migrating north, and the second spring peak from the eastern Chukchi stock. In contrast to the high, although sporadic, levels of presence on the inshore mooring, beluga presence on the offshore mooring (C2) was considerably lower. A single weak migration peak was detected in both fall and spring. Despite a reduced presence offshore, belugas are utilizing this area to migrate in both directions. Future analyses of the common calls types within each peak will be undertaken in an attempt to assign beluga stocks to each peak in vocal presence, to aid in the understanding of movement patterns within the region. All plots show a consistent near-year-round bearded seal presence. Fin whales were not detected on any of the moorings.

Analyses on the 2011-2012 units just retrieved have begun. The recorders were redeployed in 2012 as part of the BOEM funded ArcWEST project, therefore we will be able to continue adding to this long term dataset. One recorder was placed at each Icy Cape site in place of the

five- unit array, and several new locations were added. Modifications to existing array localization code will be completed in 2013 by Berchok.

Table 1. Recording period, position, and depth of all long-term passive acoustic recorders deployed off Icy Cape, AK from 2011-2012. The ‘A’ moorings were deployed at inshore IC3, ‘B’ moorings at middle IC6, and ‘C’ moorings at offshore IC11.

Mooring Name	Start date	End date	Latitude	Longitude	Depth (m)
CZ11_AU_A01	9/3/2011	4/22/2012	70.8734667	-163.2211333	44.0
CZ11_AU_A02	9/3/2011	4/22/2012	70.8572333	-163.1183333	43.5
CZ11_AU_A03	9/3/2011	9/7/2012	70.8167667	-163.1361167	43.5
CZ11_AU_A04	9/3/2011	12/11/2011	70.8097667	-163.2478000	43.7
CZ11_AU_A05	9/3/2011	9/30/2012	70.8475500	-163.3094500	43.8
CZ11_AU_B01	8/29/2011	5/8/2012	71.2524167	-164.2744333	43.5
CZ11_AU_B02	8/29/2011	5/3/2012	71.2353000	-164.1929333	43.9
CZ11_AU_B03	8/29/2011	5/19/2012	71.2016333	-164.1979167	44.3
CZ11_AU_B04	8/29/2011	5/24/2012	71.1962667	-164.2944000	45.2
CZ11_AU_B05	8/29/2011	5/4/2012	71.2286000	-164.3439833	44.4
CZ11_AU_C01	8/29/2011	5/29/2012	71.8536500	-165.9983167	43.5
CZ11_AU_C02	8/29/2011	5/14/2012	71.8319000	-165.9005500	42.6
CZ11_AU_C03	8/29/2011	6/5/2012	71.8022500	-165.9272667	42.7
CZ11_AU_C04	8/29/2011	4/6/2012	71.7985833	-166.0287833	43.3
CZ11_AU_C05	8/29/2011	5/9/2012	71.8290333	-166.0714500	43.7

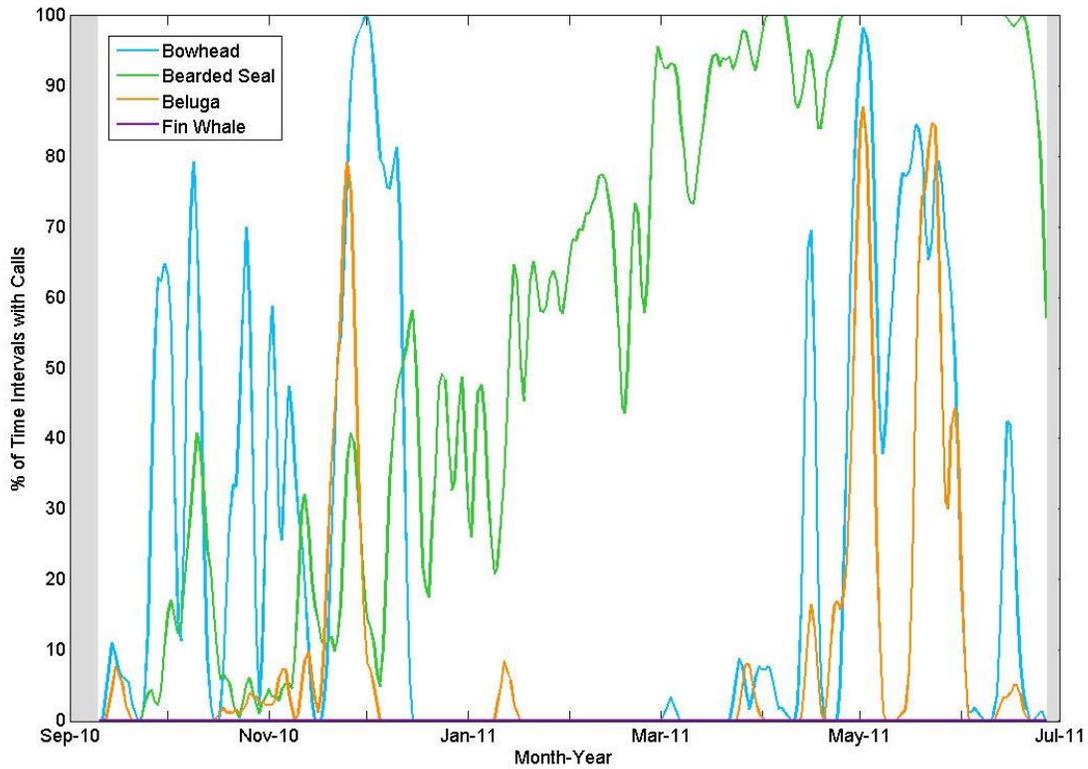


Figure 2. Seasonal acoustic detections of bowhead whales, bearded seals, beluga, and fin whales on 2010 recorder CZ10_AU_A03 at the inshore mooring IC3 off Icy Cape, AK (September 10, 2010 – June 27, 2011). Results are presented as a 3 day moving average of the number of time intervals per day with calls detected.

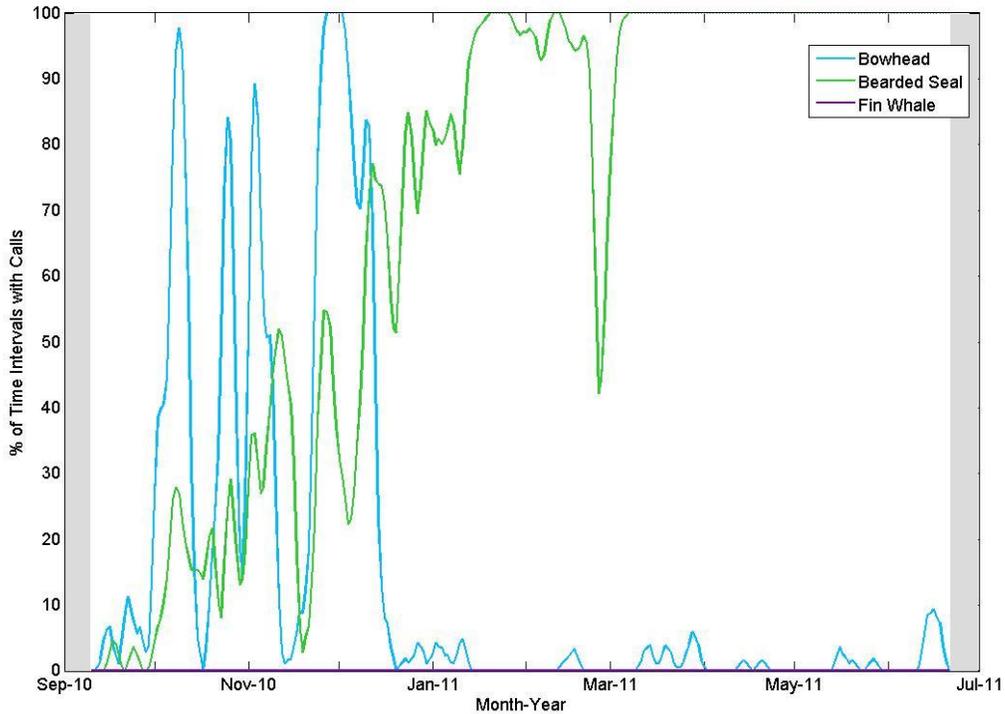


Figure 3. Seasonal acoustic detections of bowhead whales, bearded seals, and fin whales on 2010 recorder CZ10_AU_B03 at the middle mooring IC6 off Icy Cape, AK (September 10, 2010 – June 21, 2011). Results are presented as a 3 day moving average of the number of time intervals per day with calls detected.

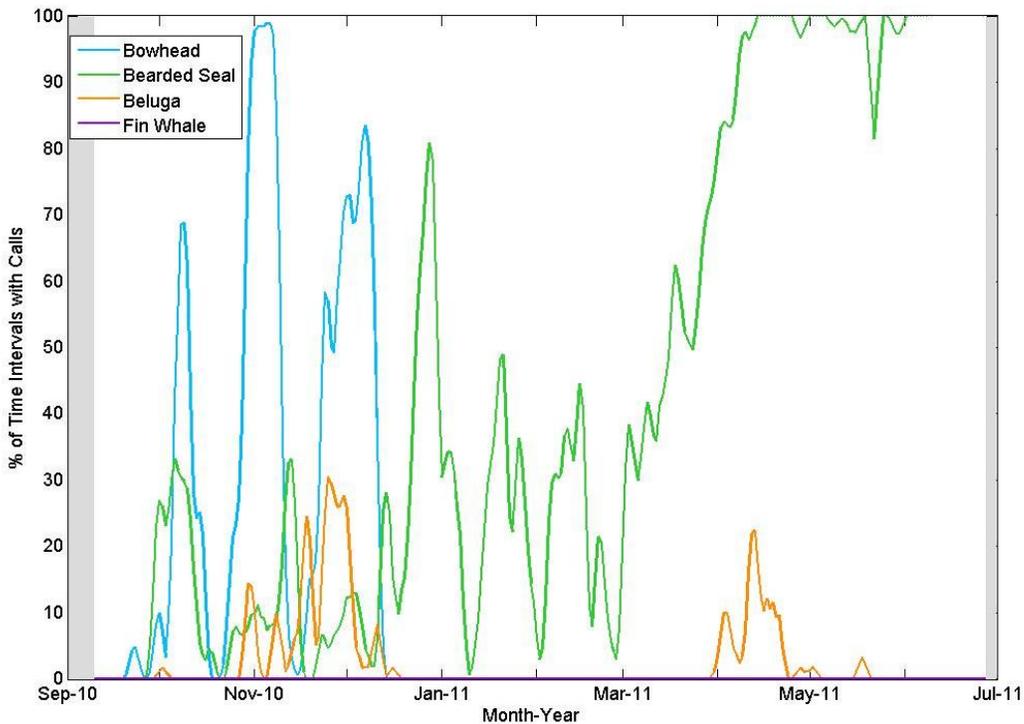


Figure 4. Seasonal acoustic detections of bowhead whales, bearded seals, beluga, and fin whales on 2010 recorder CZ10_AU_C02 at the offshore mooring IC11 off Icy Cape, AK (September 10, 2010 – June 8, 2011). Results are presented as a 3 day moving average of the number of time intervals per day with calls detected.

Sonobuoys:

A total of 227 sonobuoys were deployed during the cruise. A preliminary analysis of species detected was conducted and the results are shown in Figures 5 and 6 for the Chukchi and Bering Seas, respectively. The most commonly detected species in the Chukchi Sea were humpback whales (*Megaptera novaeangliae*) and fin whales (*Balaenoptera physalus*). During the survey, a fin whale was detected 26mi offshore of Barrow Canyon (Figure 5). This is the farthest northeast detection of a fin whale in the Alaskan Chukchi, and a manuscript is being prepared for submission in the spring.

The most common species in the Bering Sea were fin whales (*Balaenoptera physalus*), humpback whales (*Megaptera novaeangliae*), and right whales (*Eubalaena japonica*). Please refer to the cruise report for a more detailed description.

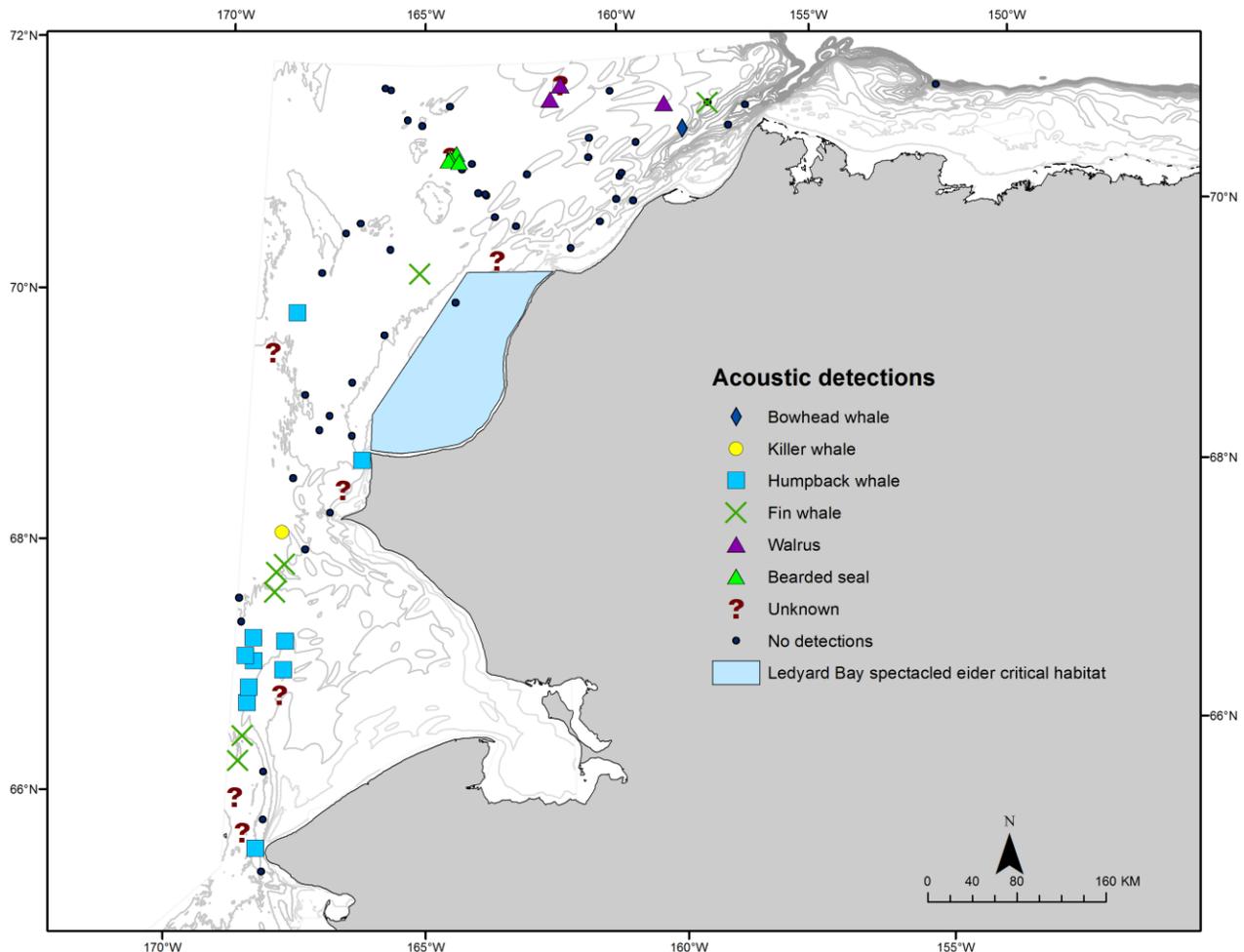


Figure 5. 2012 sonobuoy deployment and acoustic detections in the Chukchi Sea (17 – 31 Aug).

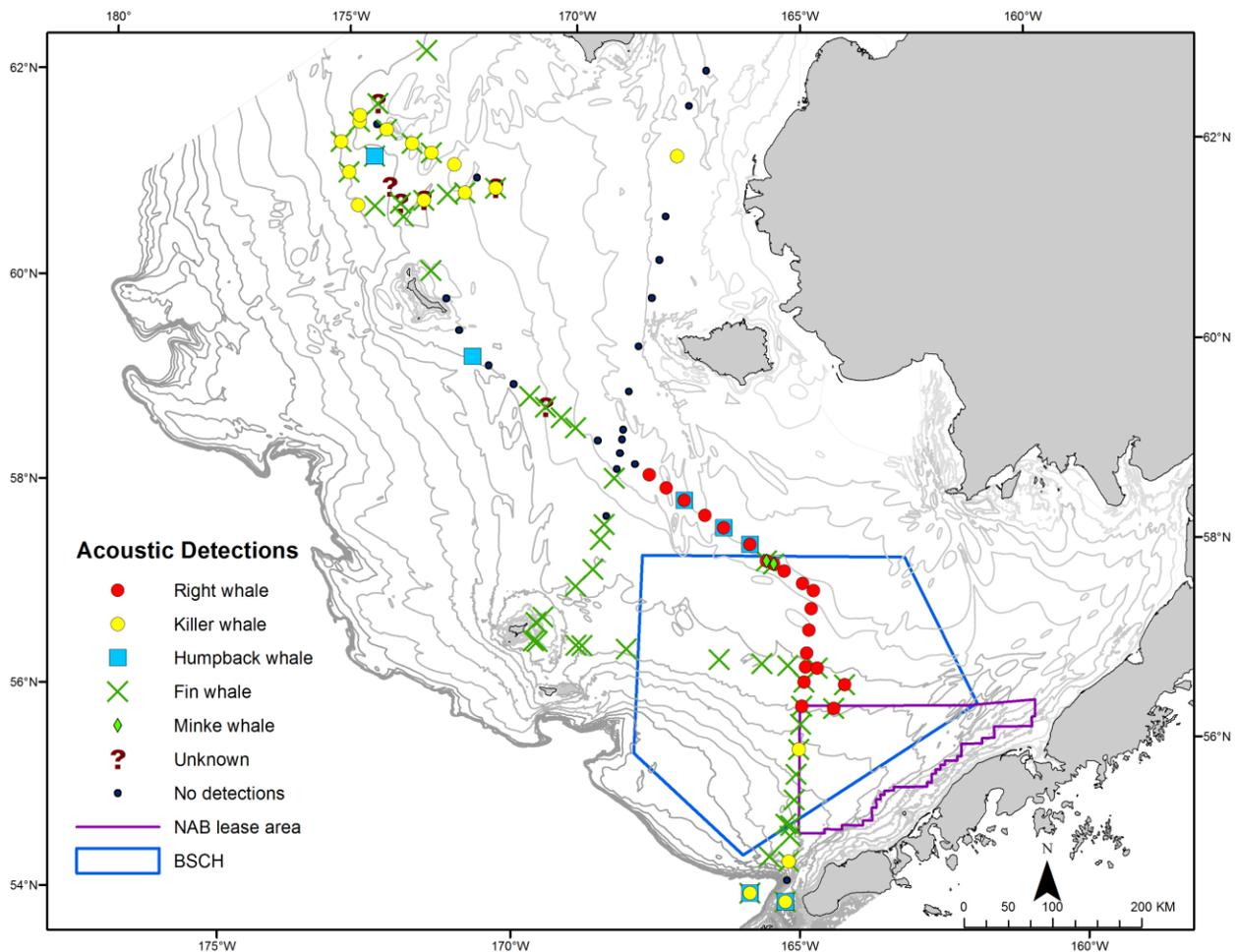


Figure 6. 2012 sonobuoy deployment and acoustic detections in the Bering Sea (8 Aug – 16 Aug & 31 Aug – 7 Sep).

2013 preparations and analysis plans

Data analysis of the recovered 2011-12 long-term moorings has begun. A new version of the in-house Matlab-based SoundChecker program is complete and will allow for simultaneous multi-species analysis of the recorders. The low frequency band includes fin and blue whales. The medium band includes right, bowhead, humpback, gray and minke whales, the gunshot call, walrus, unknown pinnipeds, vessel noise, and seismic airguns. The high frequency band includes beluga, killer and sperm whales, bearded and ribbon seals, the minke ‘boing’ call, and ice.

Preliminary analyses will include analyzing one recorder from each cluster for the presence of bowhead whales, gray whales, fin whales, beluga, and bearded seals. As time allows, additional recorders will be analyzed. When possible, localizations of calling whales will be run to produce a finer scale analysis of whale distribution within the Chukchi and Bering Seas.

As mentioned below, most effort in 2013 will be spent integrating our passive acoustics results with those from the oceanography and zooplankton components.

OCEANOGRAPHIC COMPONENT

Preliminary results

Long-term moorings:

We successfully recovered all oceanographic moorings that were deployed in August 2011. IPS-5 ice profilers were deployed at each of three mooring sites: IC3, IC6, and IC11 (A1, A2, and A3, respectively). Data collection was divided into three time segments or phrases: Phase 01 encompassed fall open water, phase 02 transitioned from open water to winter-spring ice cover, and phase 03 encompassed the summer ice-to-open water transition. The instrument at the inshore IC3 (A1) mooring failed on November 14, 2011 prior to ice arrival, probably due to a battery short, so no ice data are available. Processing from the middle IC6 (A2) mooring will be completed within the next two months. At the offshore IC11 (A3) mooring, data from mid-October 2011 to mid-June 2012 (phase 02) have been processed. Final, single-point corrections to the data set are pending.

Mooring IC11 (A3) is located at 71.82°N and 165.98°W. Ice arrived at the offshore IC11 (A3) area on November 22, 2011, and was present on June 14, 2012 (end of phase 02 data). The deepest keels in 2012 occurred on April 16 (28.7m) and May 2 (26.5m). This is compared to 2010-2011 data where ice arrived on November 2, 2010 and was melted by June 17, 2011, with open water November 22 – December 1, 2010. Deepest keels in 2011 occurred on April 19 (20.14m) and June 8 (19.48m).

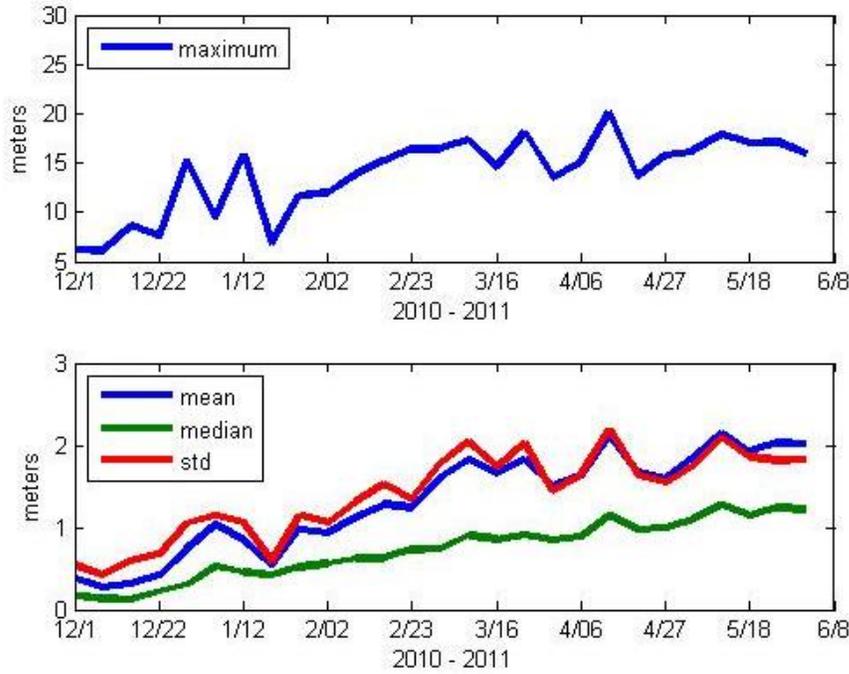
Firmware updates and software compatibility have been an issue with the IPS-5 ice profiler units. We are working with ASL to fix the problems.

Ice thickness and area coverage data from 2010-2011 were used in the interpretation of zooplankton ADCP backscatter data presented at the Alaska Marine Science Symposium (AMSS) meeting in January 2013. These data helped confirm when ice left the region and when ADCP backscatter was attributed to zooplankton and not ice.

All the other instruments from the recovered moorings have been downloaded and processed. Initial inspection suggests that all of them appear to have worked. We are in the process of quality controlling the data from them.

Six moorings were deployed in August 2012 at two mooring sites, IC6 (A2) and off Wainwright (A4). The analysis of data from these moorings will be part of the ArcWEST project.

A.



B.

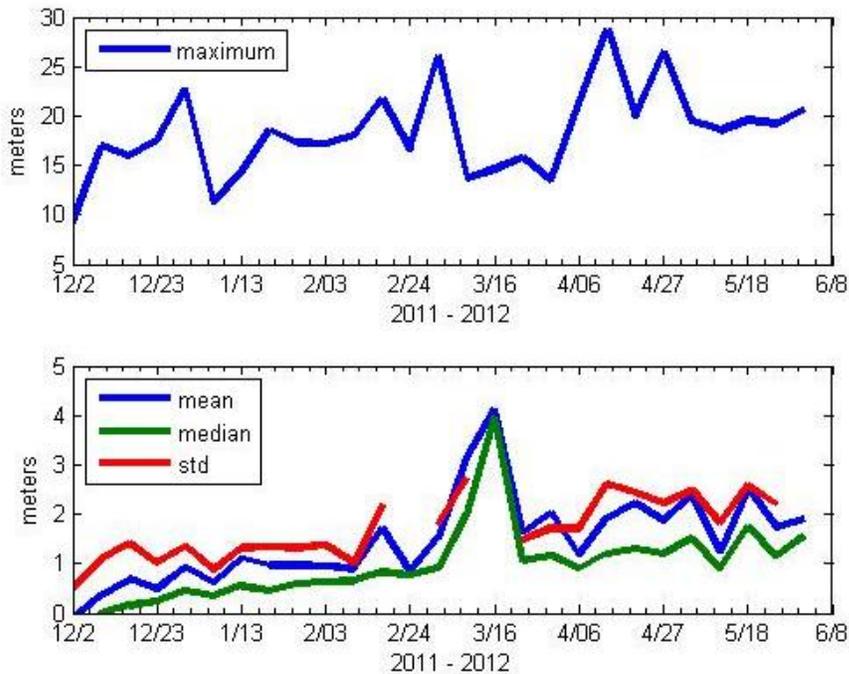
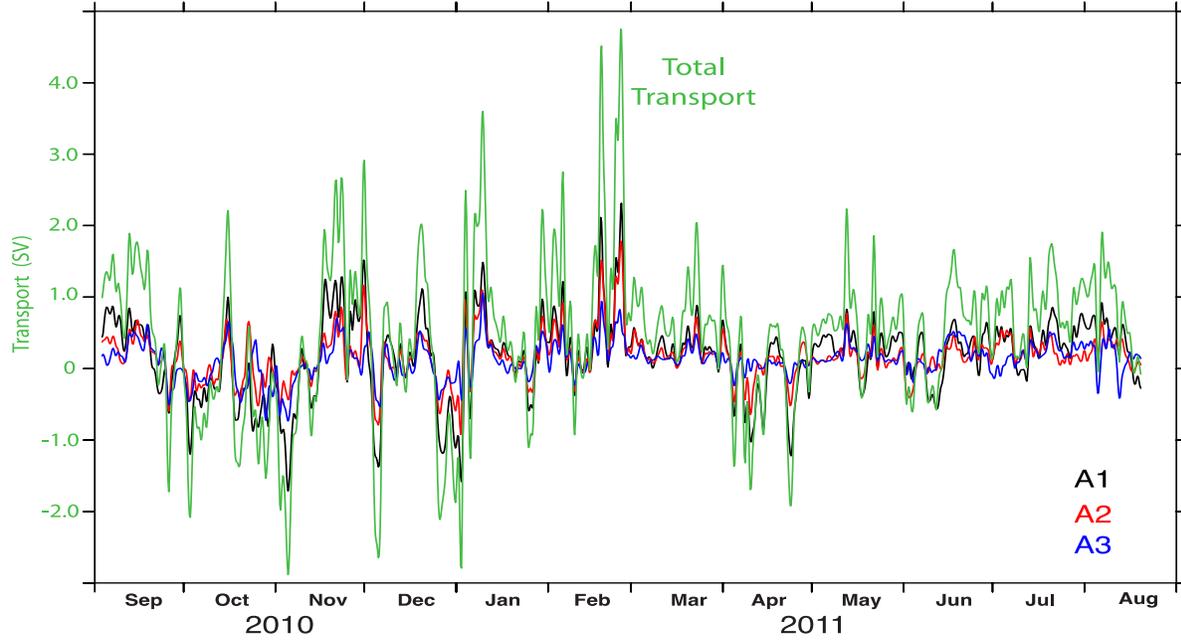


Figure 7. Ice draft data at mooring site IC11 (A3), comparison of central tendencies are shown for two deployment years, A) 2010-2011 and B) 2011-2012, both December to June. Top plots show maximums for ice draft values per week. Bottom plots show mean, median, and standard deviation per week. ASL ISP-5 instruments were used, and data are preliminary.

A.



B.

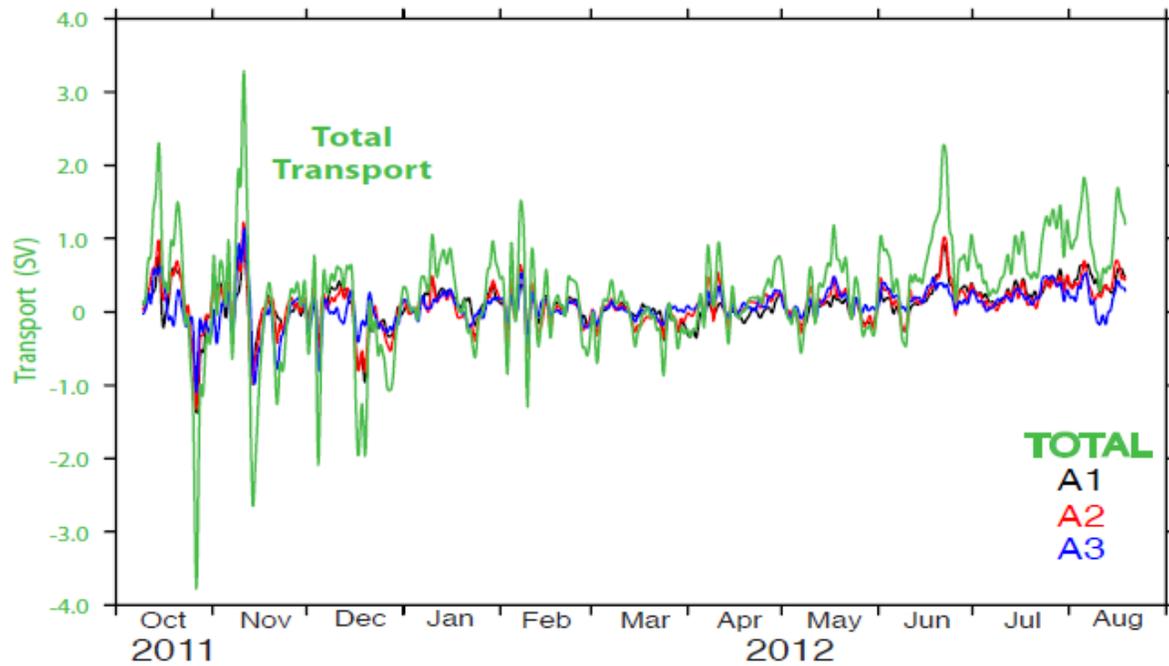


Figure 8. The transport (toward the northeast) at each of the three mooring sites and the total transport (green) for A) 2010-2011, and B) 2011-2012. All measurements are Sverdrups ($10^6 \text{ m}^3 \text{ s}^{-1}$). A1 = IC3, A2 = IC6, A3 = IC11.

Shipboard measurements:

Data were collected at all planned hydrographic sites during the August 2012 cruise except the two farthest offshore of Wainwright. Ice was present offshore of Wainwright, and while the vessel was able to navigate around the ice floes, time constraints prevented us from completing the Wainwright line. Temperature, salinity, nutrients, PAR, oxygen and chlorophyll fluorescence from the hydrographic lines have all been processed and are available for use. We have contributed our data to the DBO.

Satellite-tracked drifters:

A total of twelve satellite tracked drifters (drogued at 30 m) were deployed in August, eight by the R/V *Aquila*, and four by the USCGC HEALY. They were deployed both in the northern Bering Sea and in the Chukchi Sea. A video of drifter movement and ice was shown during our presentation at the AMSS meeting (January 2013). The movie can also be found at <http://www.pmel.noaa.gov/foci/visualizations/drifter/chuk2012.html> All drifters were caught in the advancing ice in November and December.

Satellite Remote Sensing:

Images from satellites 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, including the active acoustics.

2013 plans

In the coming year our effort will be placed on completing analysis of all mooring, drifter, satellite, and hydrographic data and then synthesizing these data with the other components of the project (mammals, zooplankton, and climate). For example, examining oceanographic conditions during the times when marine mammal vocalizations are detected in each subregion; examining oceanographic conditions during the times when zooplankton volume backscatter is high; documenting cross-shelf and inter-annual variability in measured variables; examining oceanographic conditions and vocalizations in polynyas and during the spring and fall transitions; and working to understand how loss of sea ice affects upper ocean processes.

ZOOPLANKTON COMPONENT

Zooplankton Acoustics

We recovered all three TAPS instruments in August, (2) TAPS-8 and (1) TAPS6-NG and collected partial time series of zooplankton backscatter due to different issues with the instruments. One TAPS8 leaked and needs extra attention to recover the data; we will work on that instrument in early 2013. The other TAPS8 instrument worked, but the signal to noise ratio of the instrument is poor due to its old age (1980s). The new TAPS6-NG worked until January, but a programming bug meant that we have data only for August, September, and January. The programming mistake was discovered after the instruments were recovered and has been fixed. We expect that the current TAPS6-NG deployed at site 2 in August 2012 will yield data for all months except October – December (those with a two digit month). During the year we began work with two contractors to update and improve the TAPS6-NG controller board to: 1) draw less power when the instrument was asleep, and 2) greatly expand data storage capacity so that we can save the individual echo amplitudes. That work yielded a set of technical specifications and a proposed design.

We have been working with the data from both years to establish a set of best practices for TAPS data processing. This includes determination of instrument noise, and culling data points that do not meet either the volume scattering assumption or have low signal to noise ratio. We have built a better Matlab user interface as well. In the spring we will begin to investigate the influence of sound reverberation in the water column when ice is present. We continue to discuss and work on the appropriate scattering models for the inverse solutions. Some of the scientific literature suggests that micro-scale turbulence in the water column is a non-biological source of sound scattering that must be accounted for in the models.

To supplement the TAPS data we have also begun to analyze the ADCP 2011-2012 data for patterns in zooplankton scattering. The ADCP data cannot tell us the size of the scatterers, and changes in echo intensities at single frequencies can be due to either a change in the size of the dominant scatterers or changes in the abundance of the scatterers. However, the patterns in sound scattering measured by the ADCP show interesting patterns and we have ADCP instruments in more locations than we have TAPS. A time series of ADCP backscatter was presented during our AMSS oral presentation.

Preserved Zooplankton Samples

All preserved zooplankton samples from the August 2012 cruise were sent to Poland for processing and arrived early January 2013. We anticipate that the processing of these samples will be complete by May 2013. The Recruitment Processes Program is in the middle of creating a new Oracle database to replace our older Access database. If the data entry module is finished

in January, then we will be able to get Poland to also enter the CHAOZ 2012 zooplankton data into the appropriate data tables. If the data entry module is delivered later than this, then we may need to enter the data ourselves which would delay access to these data.

Data from the 2010 and 2011 samples have been verified and uploaded to our old database. Some of these data will be used in the oral presentation at AMSS. A preliminary look at the data revealed several interesting observations: 1) euphausiids were in the region in both years; 2) the vast majority of the euphausiids were early juvenile stages (furcilia); 3) adult euphausiids were seen in 2011, but not 2010; 4) in 2011 there was an intrusion of arctic basin water onto the shelf, as evidenced by the presence of the arctic copepod, *Calanus hyperboreus*. *C. hyperboreus* was not observed over the shelf in 2010. Thus this taxon can serve as a marker or indicator of recent on shelf flux.

2013 Plans

We will focus on analysis of TAPS, ADCP, and zooplankton net data in 2013. The objective is to bring as much of the material as possible into a form that can be used for peer-reviewed publication and our final report.

We continue to work to improve the TAPS6-NG to make it a reliable and easy to use instrument. We will correct the programming errors that resulted in lost data during months with two digits (months 10, 11, and 12) and will implement the code to make dedicated noise measurements that was inadvertently left out. In addition, we will complete the work with our contractor to design, test and produce an improved controller card. This card will then be available to use during our ArcWEST and any subsequent BOEM-supported projects.

Other Activities: Napp gave an oral presentation at the AMSS meeting to bring together some of the CHAOZ physical and biological information. He and L. Logerwell (AFSC) plan to lead a Synthesis of Arctic Research (SOAR) project to synthesize what we know about the small pelagic fishes of the Chukchi region. The first step will be to organize a workshop in Seattle in the spring of 2013 and bring all those with data and knowledge of this subject together to organize the manuscript and make writing assignments.

OCEAN NOISE AND REAL-TIME PASSIVE ACOUSTIC MONITORING

Auto-Detection Buoy System (AB)

The AB monitoring system was deployed and began actively transmitting from the Chukchi Sea on 09 Aug 2012. Unfortunately, the initial recovery attempt on 21-22 Oct 2012 by WHOI on board the USCGC HEALY was unsuccessful due the high sea-state. Shortly thereafter, WHOI detected from the Xeos tracker that the AB was adrift. The AB continued to function properly,

and even continued to report some interesting biological detections during this time (Figure 9), indicating that the AB stretch hose, sphere and EM chain and hydrophone remained connected. On 09 Nov 2012, with the logistical help of Dr. Michael Macrander and the Shell Exploration & Production Company, the buoy system was successfully recovered, including the mooring and anchor (Figure 10). The AB was eventually delivered to Seward, AK. To date (07 Jan 2013) the AB continues to transmit periodical health and status reports from a location onshore at Seward, AK. WHOI plans to travel to Seward to recover their system and our electronics in the near future. We eagerly await the return of the onboard flashcard for analysis of the complete record of acoustic data.

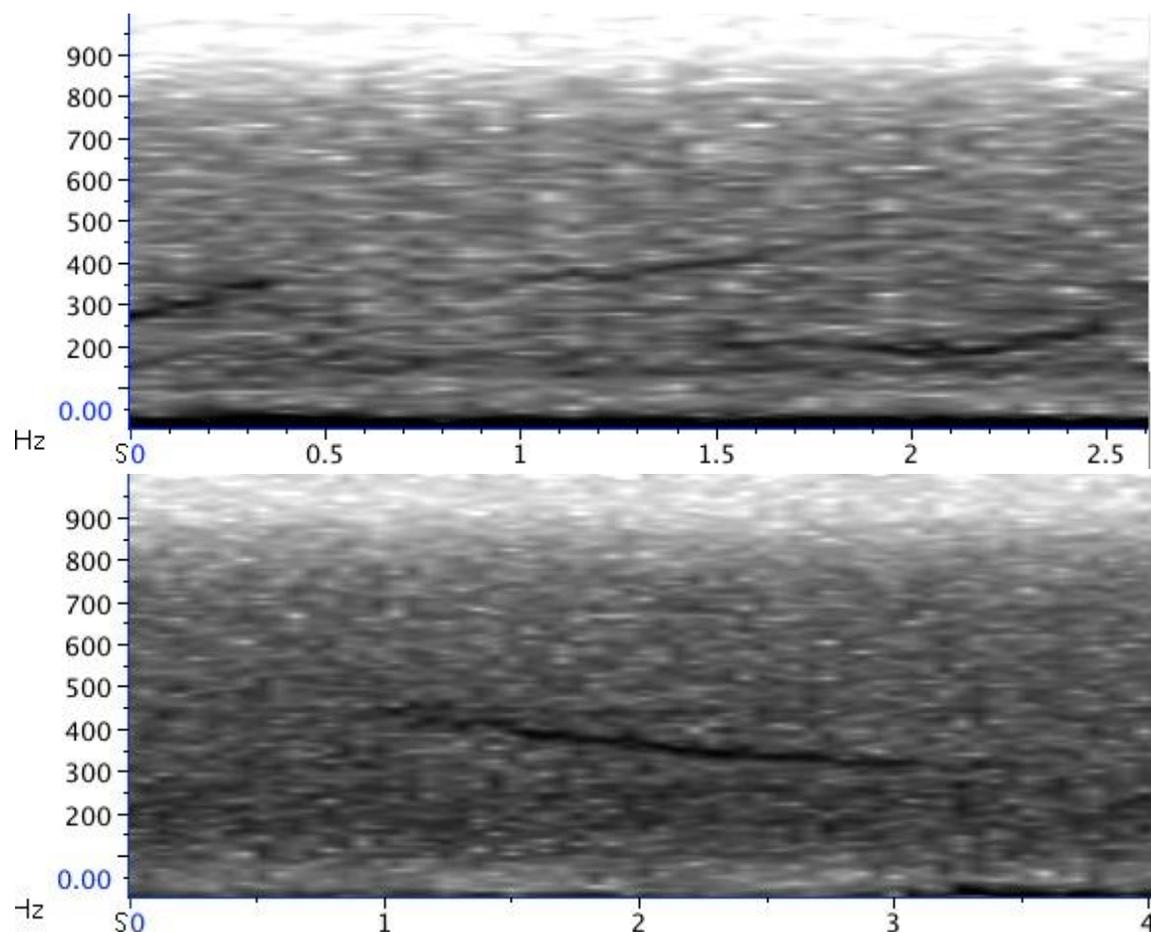


Figure 9. Samples of tonal signals of interest (believed to be of biological origin) detected by the AB system on 06 November 2012, near the end of its deployment.



Figure 10. Recovery of AB system by Shell Exploration and Production Co. personnel on 09 November 2012.

Marine Autonomous Recording Unit (MARU)

At the end of the previous quarter, the hard drive containing the acoustic data recorded by the second consecutive CHAOZ MARU was received at BRP. The data were successfully extracted, stored and prepared for analysis. These data began on 09/01/2011 and recorded continuously until 08/29/2012 at a sampling rate of 2kHz. This particular MARU was deployed at latitude $71^{\circ}01.637$ and longitude $-163^{\circ}43.797$ in 43m water depth.

Using BRP's custom-developed tool (Ponirakis *et al.*, in prep), various noise analyses were applied on the 2011-2012 data, analogous to those previously performed on the 2010-2011 acoustic record. Ambient noise metrics such as linear (Figures 11a and 12a) and $1/3^{\text{rd}}$ octave frequency band (Figures 11b and 12b) spectrograms were computed at various integration timescales: 1hr and 6hr in the case of year-long spectrograms (Figure 11) and 1 min in the case of daily spectrograms (Figure 12). This was done in order to visualize and distinguish the signatures of various noise sources occurring in different timescales.

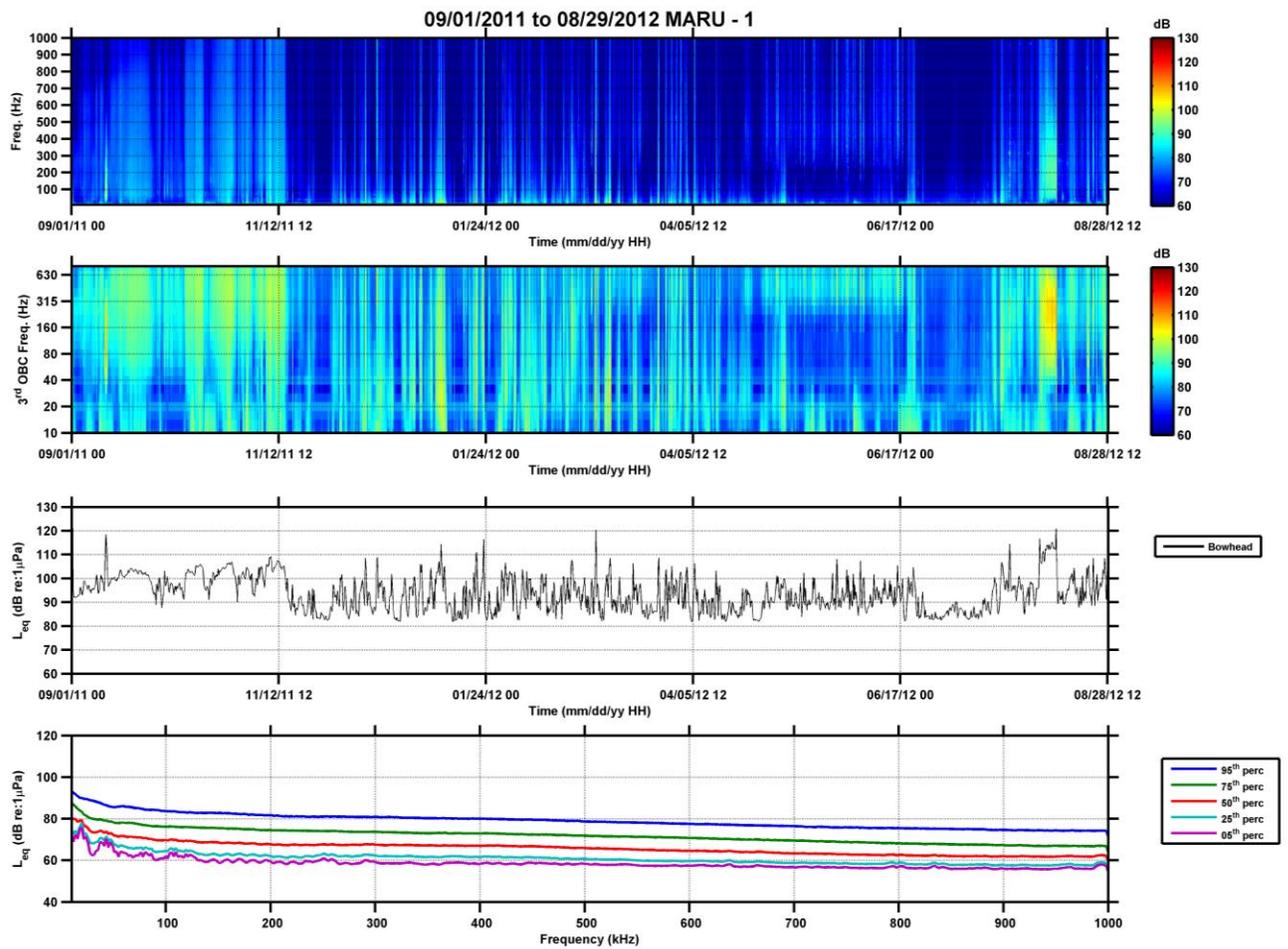


Figure 11. Deployment-long output of the Noise Analysis tool for 2011-2012 data: a) Linear frequency spectrogram; b) 1/3 octave frequency band spectrogram; c) Sound Equivalent Level (L_{eq}) in the bowhead whale octave-band frequency range (71-708Hz); d) L_{eq} percentile distribution

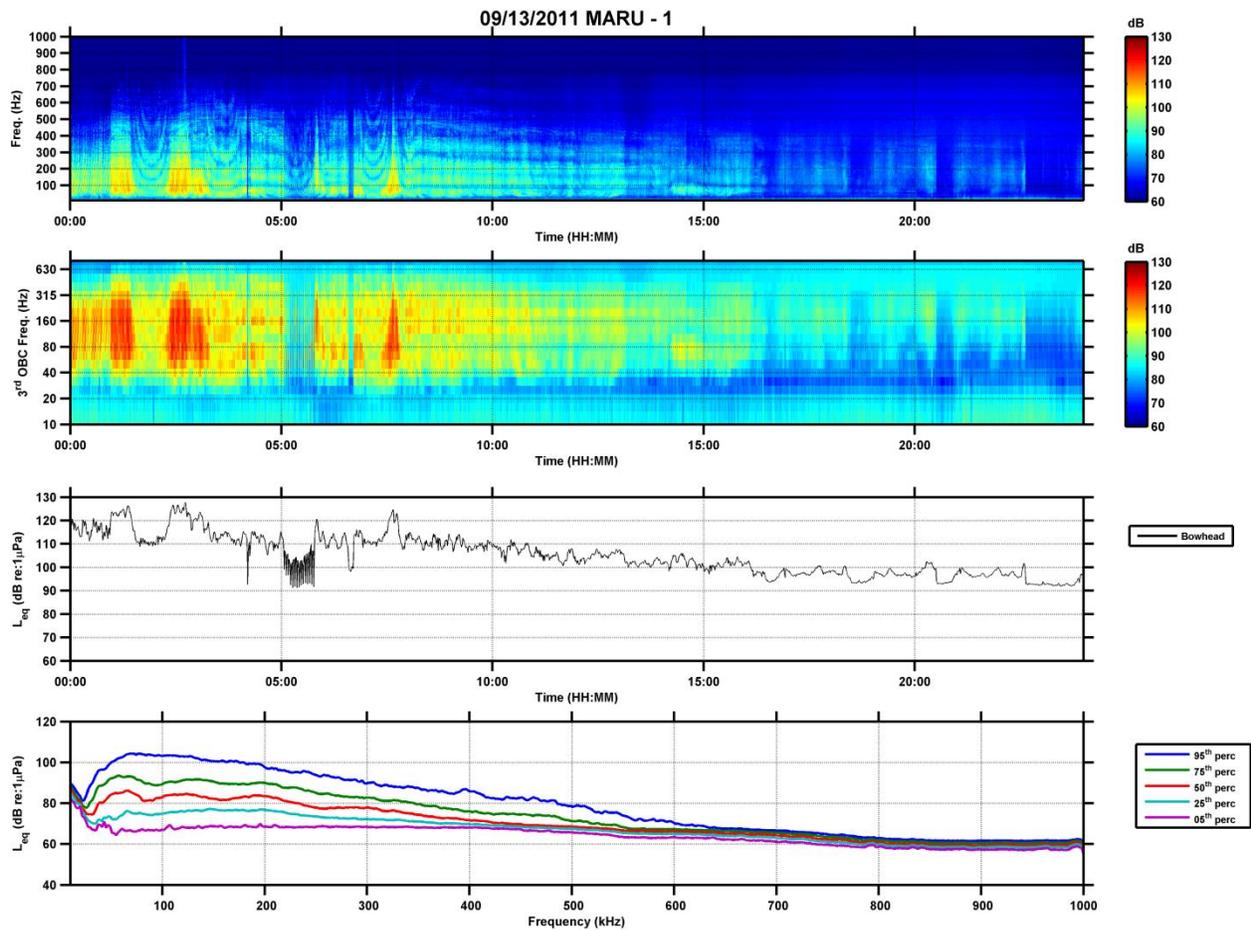


Figure 12. Example of one day-long output of the Noise Analysis tool for 09/13/2011: a) Linear frequency spectrogram; b) 1/3 octave frequency band spectrogram; c) Sound Equivalent Level (L_{eq}) in the bowhead whale octave-band frequency range (71-708Hz); d) L_{eq} percentile distribution

One such example of identifying noise sources through the spectrogram can be seen on 09/13/2011, a day with especially intense energy in the frequencies below 350Hz (Figure 12). When reviewing the data in more detail using the software application XBAT (Figure 13), it is observed that multiple seismic airgun surveys (shooting at different intervals) are occurring within the detection range of the MARU. From the day-long spectrogram, we can determine that the main airgun activity decreases between 05:00 and 05:30, a period that corresponds to a ramp-up (*i.e.*, mitigation-gun) procedure, and thus the overall cumulative energy put into the acoustic environment decreases.

By detecting and tallying these seismic signatures, it was found that in the 2010-2011 acoustic record, 53 of the 353 days (15%) contained these anthropogenic sources, especially in the months of August and September.

The next step will be to estimate what the background ambient levels would have been in the absence of seismics in order to quantify the impact of the disturbance. For this, we will look at times before/after the seismic survey and model the contribution of other natural noise sources, like wind.

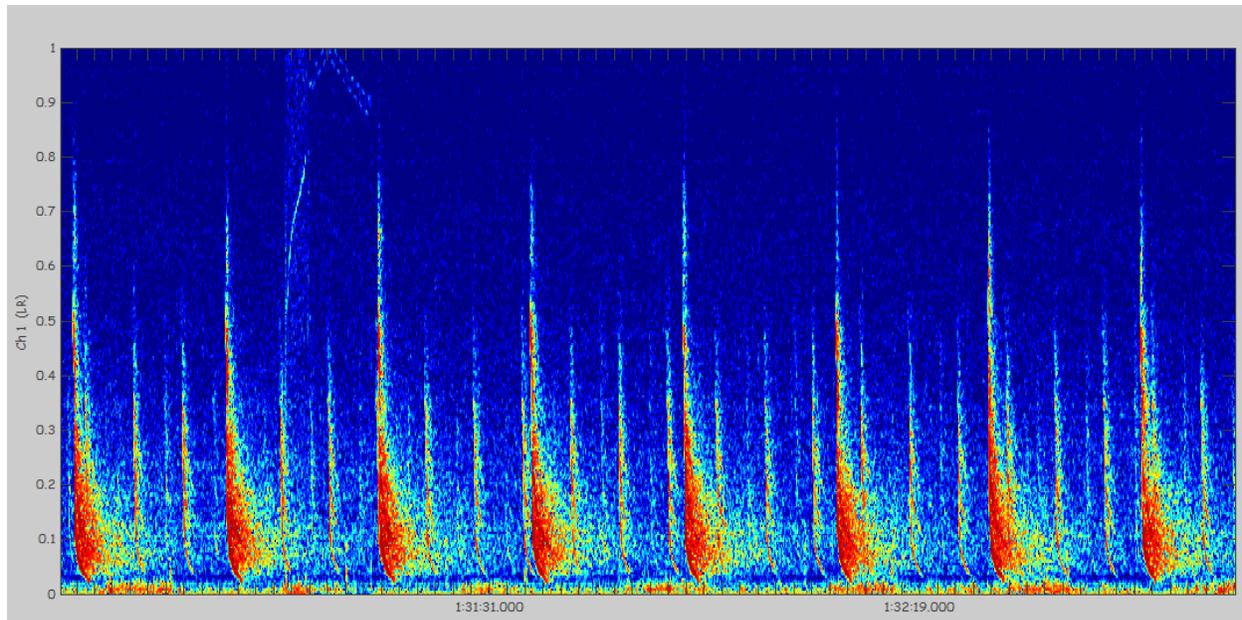


Figure 13. Zoom-in spectrogram into 9/13/2011 at approximately 01:31ADT. Multiple seismic airgun surveys are occurring within the MARU's detection range.

CLIMATE MODELING COMPONENT

We have successfully completed three simulation runs, each consisting of 30 years of simulation using CESM1.0 configuration (CAM2 for atmospheric component, CLM2 for the land surface component, CICE for sea ice model, and POP2 for ocean component). These four model components are joined via the coupler, CPL. The runs were initialized with low sea ice coverage under RCP6.0 emissions scenario, and the outputs were compared with the original CCSM4 runs. We also compared model results (currents, temperature, salinity and sea ice thickness) at the Chukchi Sea Icy Cape mooring sites (IC3, IC6 and IC11) with observations. The CESM simulated seasonal cycle of ocean temperature is in agreement with observations, although during ice free months the simulated ocean temperature at 40m depth is higher than that observed at the moorings. The simulated ice thickness is within the range of observations, but the model only simulated a single peak in the salinity profile, whereas observations depicted twin peaks at the middle and offshore mooring sites IC6 and IC11. A poster summarizing these results was presented by Drs. Wang and Cheng at the CESM annual workshop in June 2012. A manuscript about future climate projections by IPCC AR4 models over the Bering the Chukchi Seas was published in *Deep-Sea Research II* in 2012. (Wang *et al.* 2012). Dr. Wang and Dr. Overland published another paper using the updated CMIP5 model outputs in GRL entitled "A sea ice free summer Arctic within 30 years: An update from CMIP5 models".

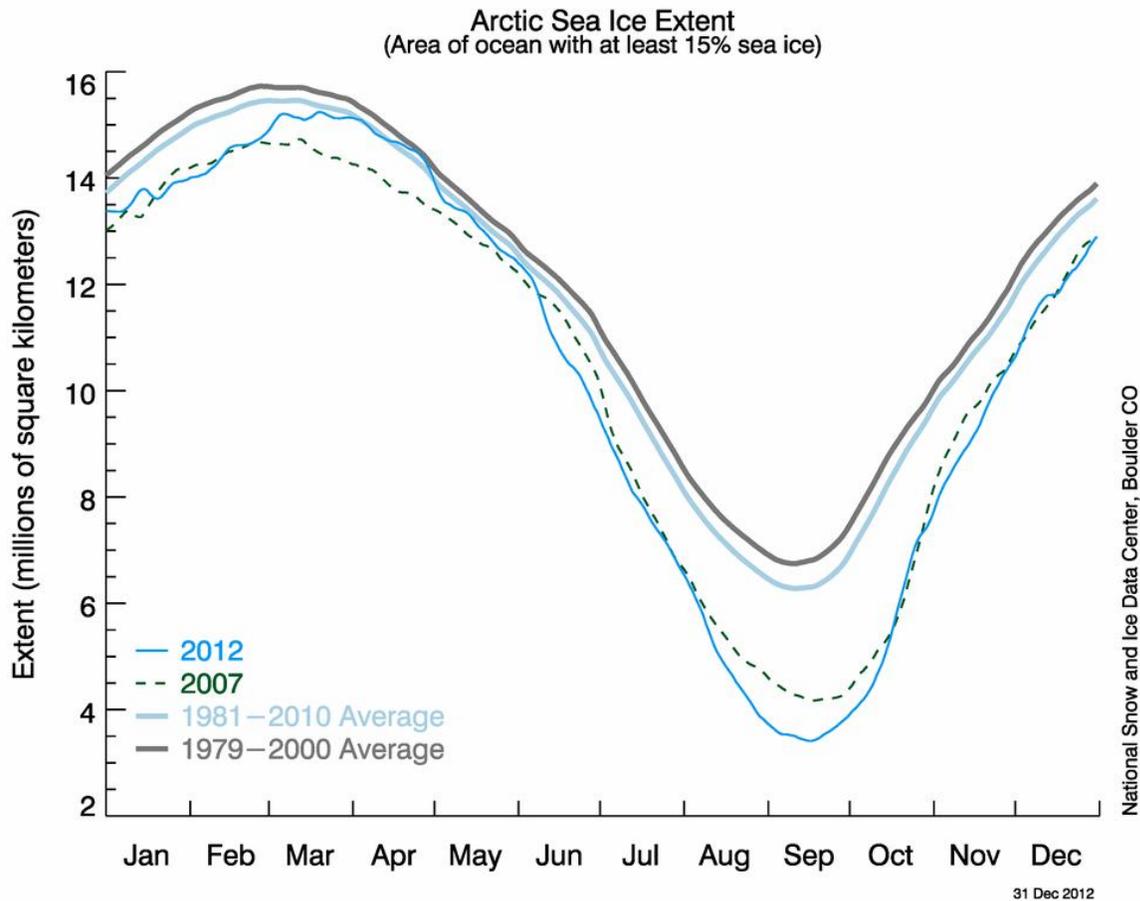


Figure 14. Annual Arctic sea ice extent average from NSIDC comparing 2012 (solid bright blue line) with the previous low (2007, dashed green line) as well as the past few decades (solid light blue and gray lines).

CHAOZ CONTRIBUTION TO DBO PILOT STUDY

The CHAOZ project has contributed to biophysical sampling in regions 1, 3, 4, and 5 of the Distributed Biological Observatory (DBO), during the pilot study years 2010-2012 (for details see <http://www.arctic.noaa.gov/dbo/index.html>). Region 1 is the area southwest of St. Lawrence Island in the Bering Sea, and although not part of our CHAOZ study area, it was an area we surveyed during our transit to the CHAOZ study area. Region 3 corresponds to the CHAOZ Point Hope line, Region 4 to the CHAOZ Icy Cape line, and Region 5 corresponds to our Barrow Canyon transect. In anticipation of the upcoming DBO Data workshop, provisional analyses of inter-annual variability in biophysics are underway. Specifically, annual measures of temperature, salinity, sea ice seasonality and thickness, chlorophyll, nutrients, and zooplankton occurrence, and marine mammal call indices during the CHAOZ cruises will be summarized and

contributed to the broader international data set in support of the plan for full implementation of the DBO anticipated over the next 3-5 years.

Sonobuoys and visual observations

Each year during the field season, sonobuoys are deployed to conduct short-term fine-scale passive acoustic monitoring for marine mammals. Visual surveys are also conducted during daylight hours. The results of three years of data collected for DBO Regions 1, 3, 4, and 5 are presented in Figures 15-19. Our cruise did not survey in Region 2, so no data are presented for that region. The two most common species detected for Regions 1 and 3 were fin and humpback whales, though minke, gray, and killer whales were also detected. The two most common species detected for Regions 4 and 5 were bowhead and gray, although minke whales and walrus were also detected.

Region 3 (Figure 17) had the greatest species diversity, with five species detected: gray, fin, humpback, killer, and minke whales. Region 4 (Figure 18) had the least species diversity, with only three species detected (gray and fin whales, and walrus). This region also had the least number of acoustic or visual detections.

An interannual comparison shows that 2012 had the most acoustic and visual detections overall, although 2011 had a large number of visual detections in Region 1 (Figure 16) that consisted primarily of fin and humpback whales, with one minke whale present. Region 1 was not surveyed in 2010, so no data are present for that year. All years detected six species, though the species were not always the same from year to year. The same six species were detected in both 2010 and 2011: fin, humpback, bowhead, gray, and minke whales, and walrus. The six species detected in 2012 were fin, humpback, bowhead, gray, and killer whales, and walrus.

There were two unusual acoustic detections of fin whales during the DBO pilot study. In 2010, a fin whale was detected on the western edge of Region 4, off Icy Cape (red star, Figure 18). In 2012, a fin whale was acoustically detected 26 miles off Peard Bay in Region 5, between Wainwright and Barrow (blue star, Figure 19). This detection represents the farthest northeastern acoustic detection of fin whales in the Alaskan Chukchi Sea.

While usually the visual and acoustic results correlate nicely and show similar species detected, there are instances where one species is visually detected, but is not vocalizing, and vice versa. For example, in Region 5 in 2011, a gray whale was acoustically but not visually detected, whereas bowhead whales were visually but not acoustically detected.

Acoustics – long-term recorders

NMML has been deploying long-term (year-long) passive acoustic recorder moorings in various locations throughout the Bering, Beaufort, and Chukchi Seas since 2006, 2007, and 2010 respectively. Figure 20 shows the locations of all moorings deployed since the start of the DBO pilot study effort in 2010. A summary of recordings obtained on representative moorings in each region during the 2010-2012 DBO pilot study can be found in Table 2. Currently these recordings are being analyzed for a brief presentation at the upcoming DBO workshop in Seattle (Feb 27-Mar 1, 2013). Recorders were deployed in all regions in the fall of 2012, and so additional data should be available for the final pilot study year (2012) in those regions after the moorings are retrieved in the fall of 2013.

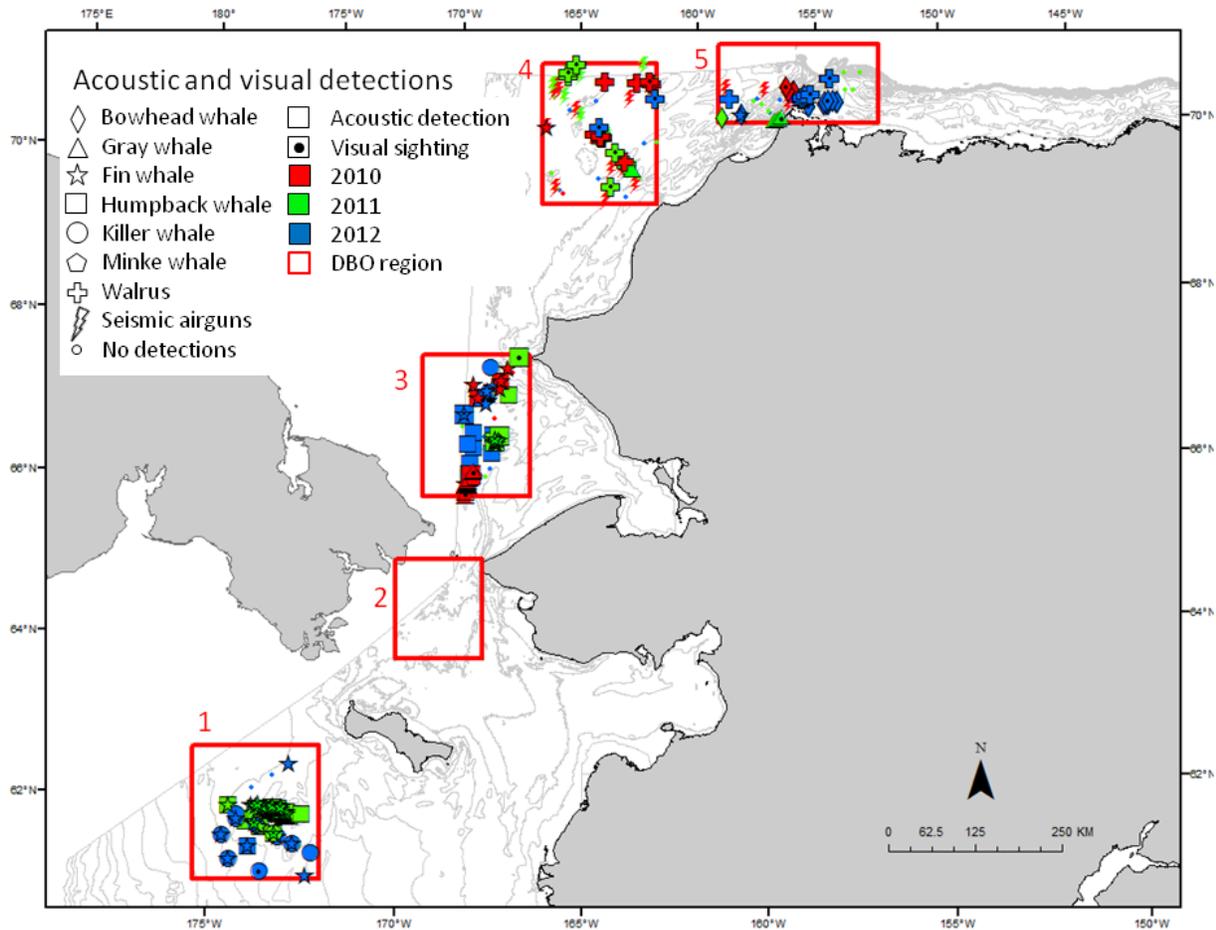


Figure 15. Overview map showing sonobuoy and visual detections in all DBO regions for 2010 – 2012.

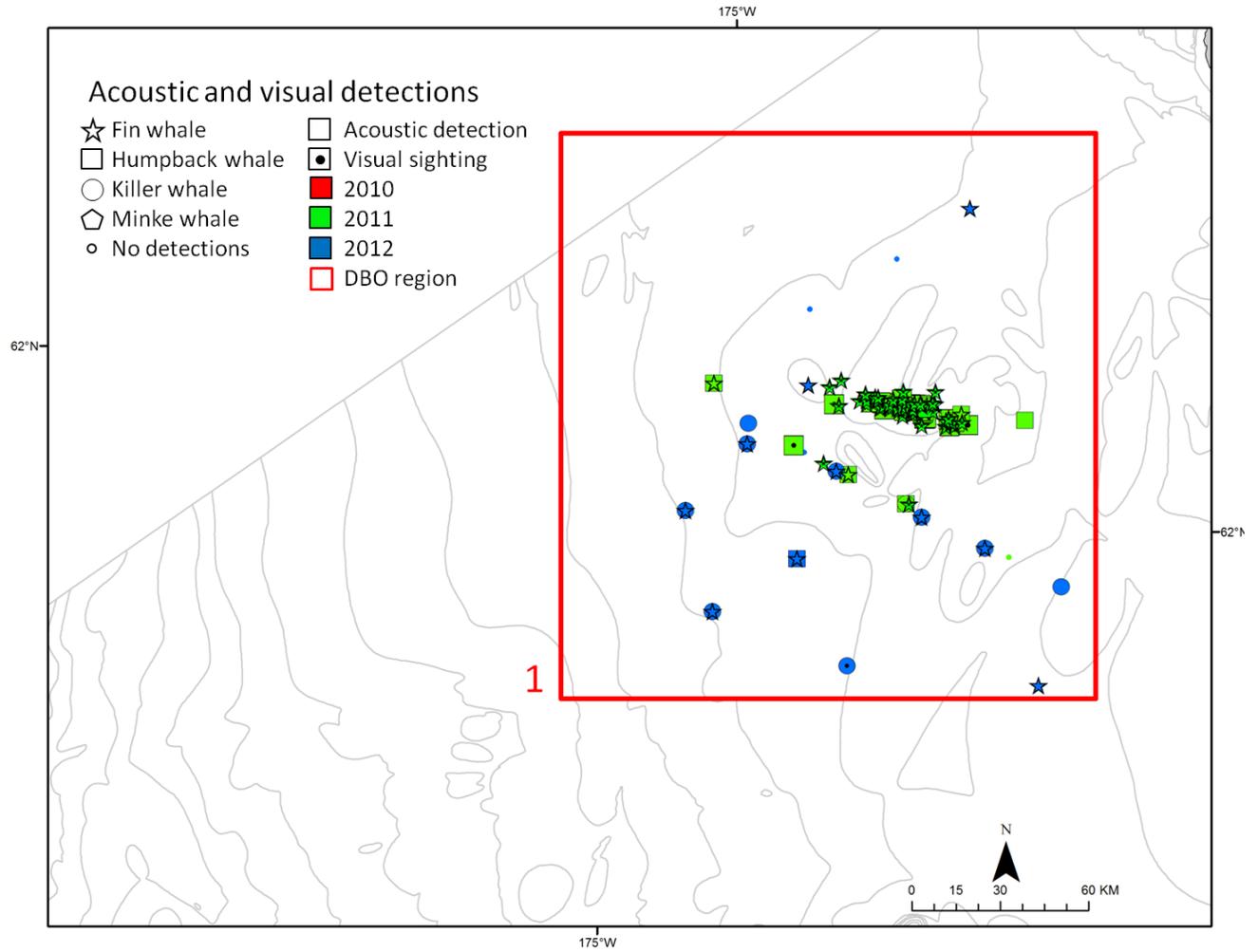


Figure 16. Map showing sonobuoy and visual detections in DBO Region 1 for 2010 – 2012.

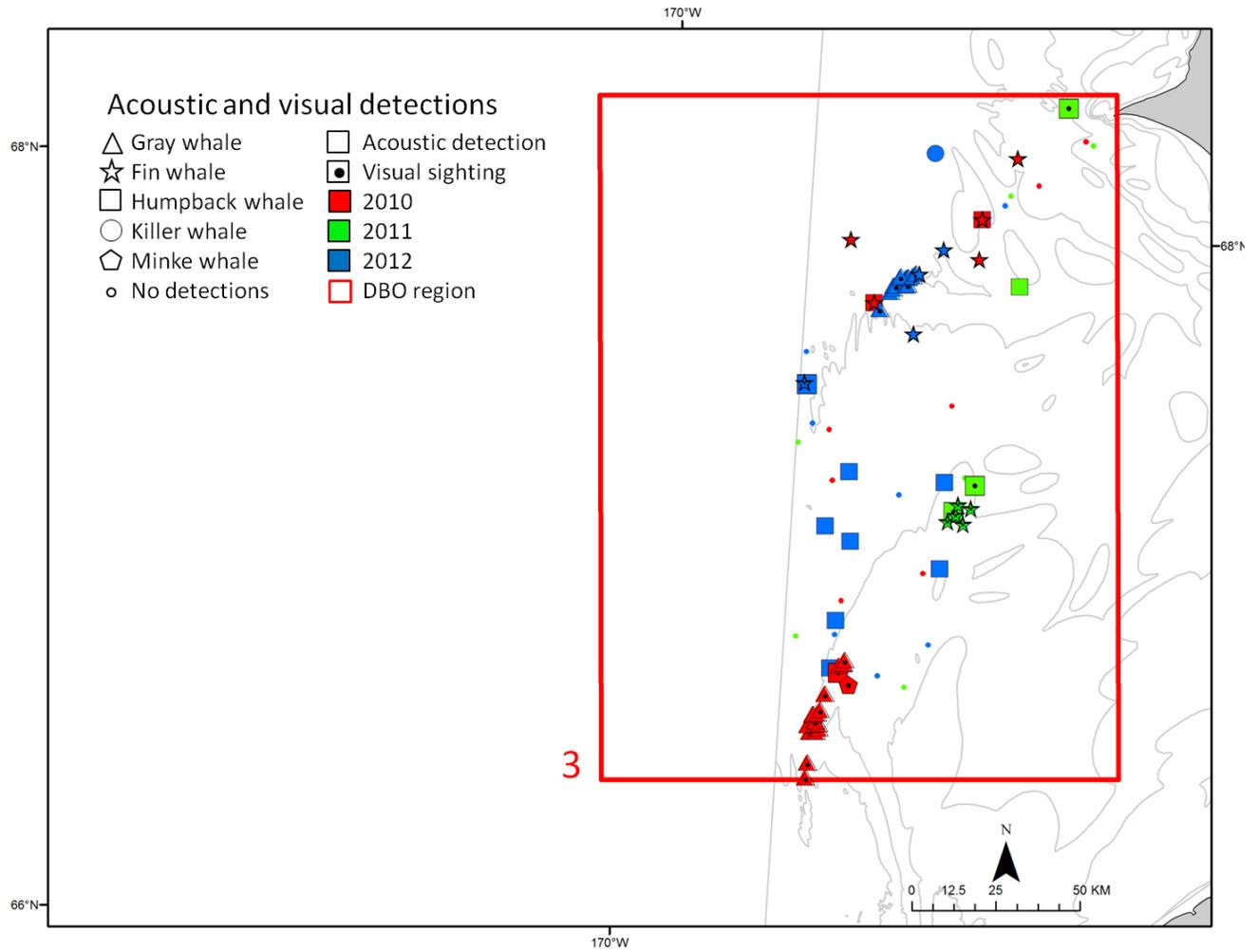


Figure 17. Map showing sonobuoy and visual detections in DBO Region 3 for 2010 – 2012.

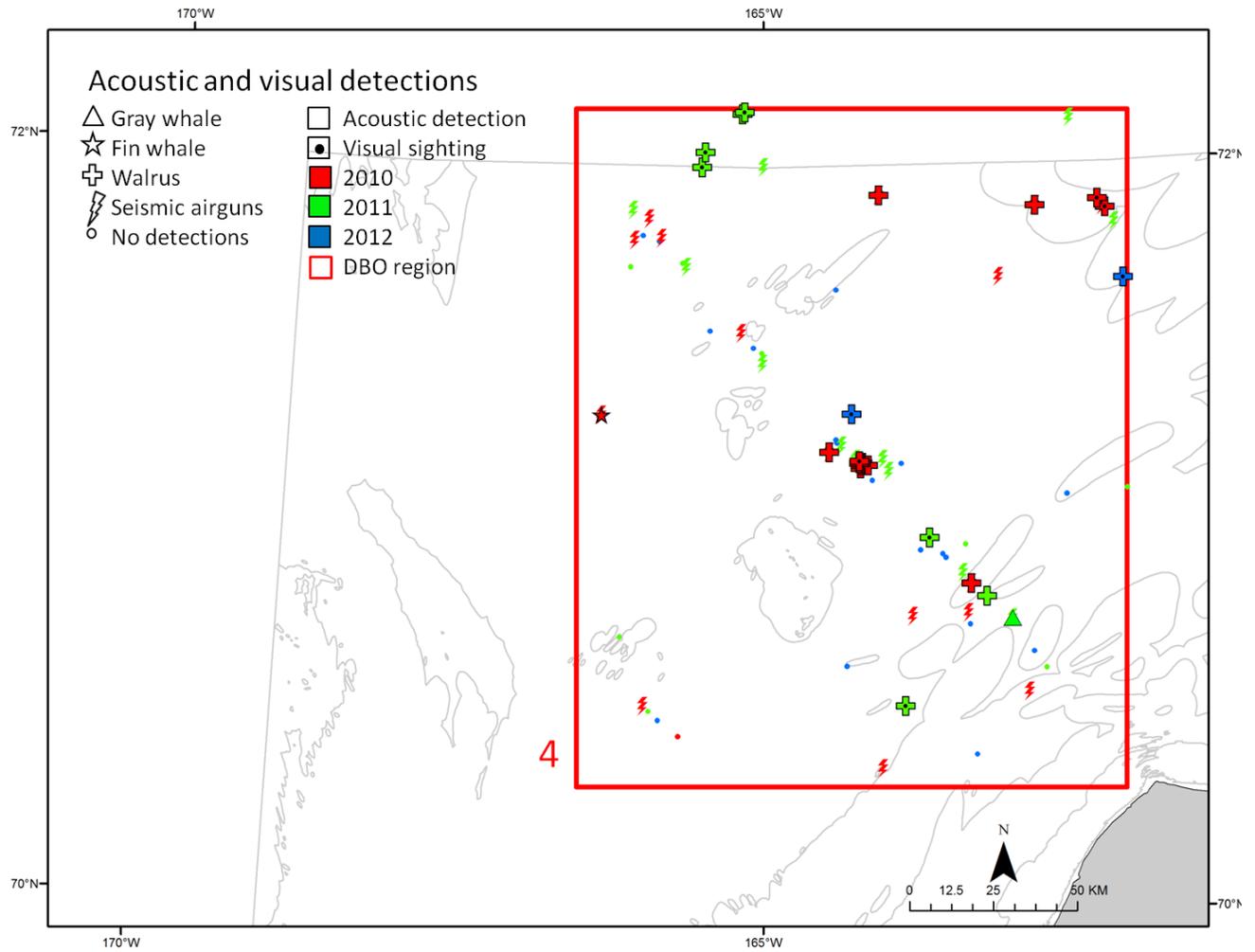


Figure 18. Map showing sonobuoy and visual detections in DBO Region 4 for 2010 – 2012.

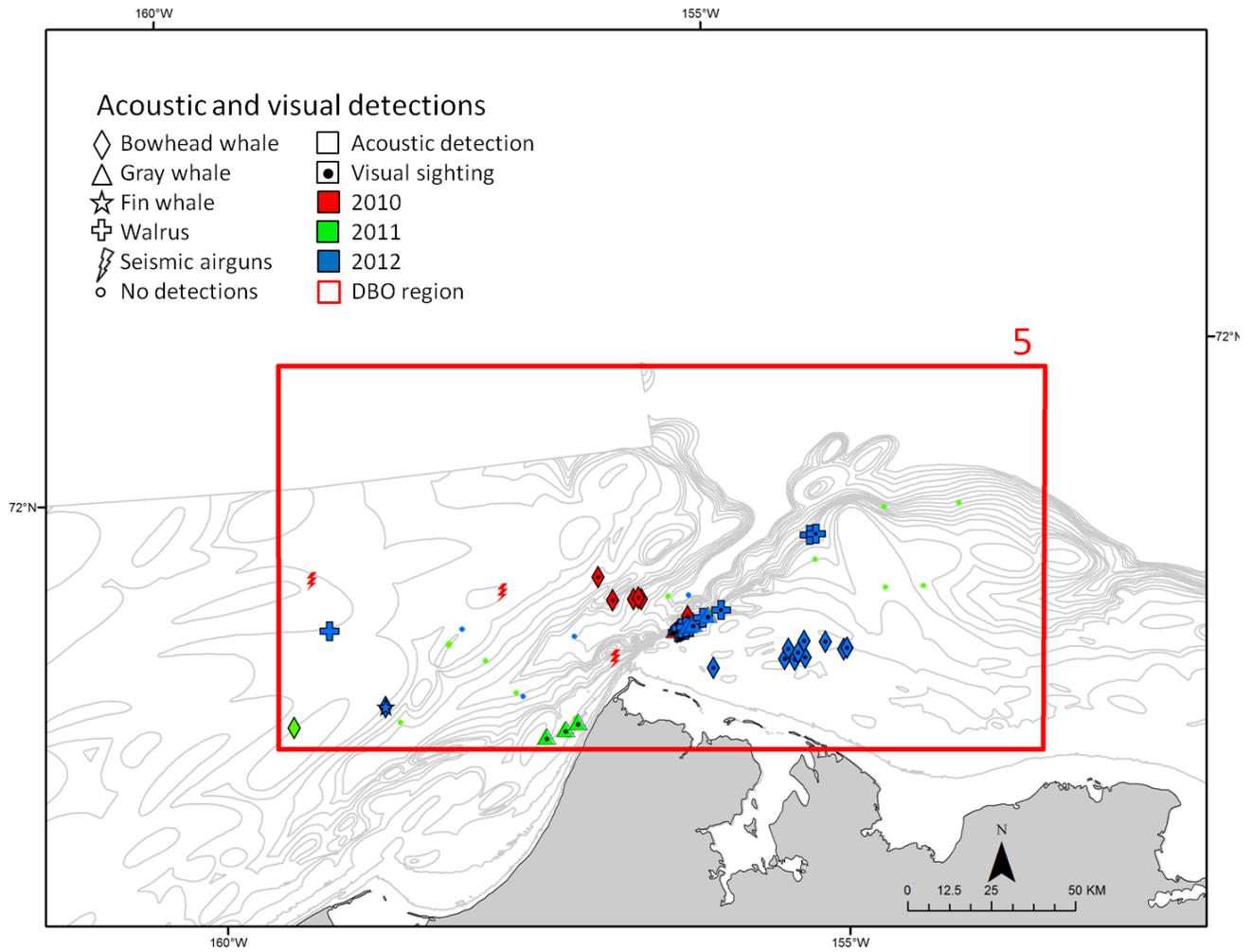


Figure 19. Map showing sonobuoy and visual detections in DBO Region 5 for 2010 – 2012.

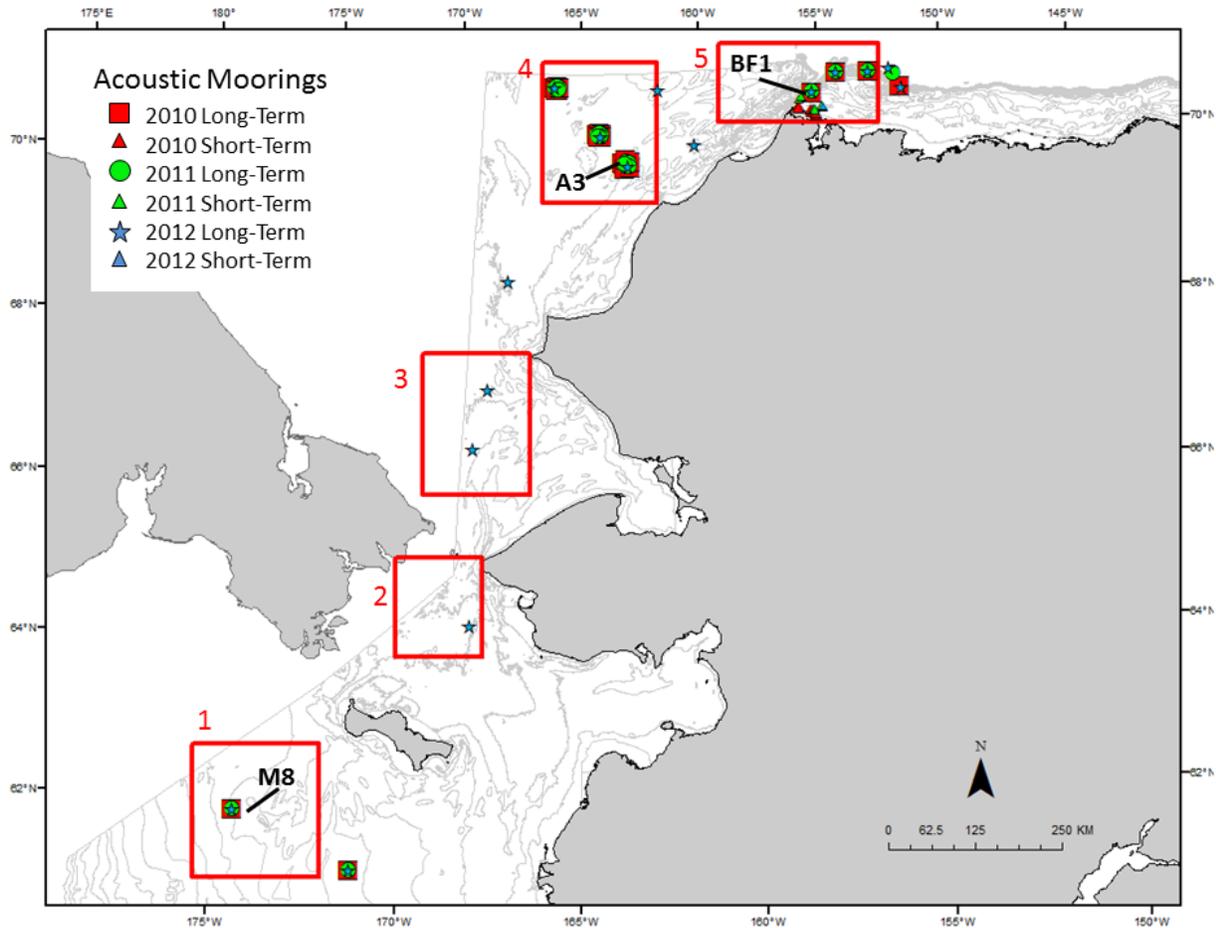


Figure 20. Passive acoustic recorder mooring locations in all DBO Regions for 2010 – 2012. Note that recorders deployed in 2012 will not be retrieved until fall of 2013. Recordings obtained from moorings M8, A3, and BF1 are summarized in Table 2.

Table 2. Long-term passive acoustic recordings obtained during the DBO pilot study 2010-2012.

DBO region	Mooring	2010												2011												2012											
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
1	M8																																				
4	A3																																				
5	BF1																																				

Significant meetings held or other contacts made

18 January 2012: Berchok hosted an “Identifying Arctic Sounds” passive acoustic workshop at the Alaska Marine Science Symposium in Anchorage. Attendees included: 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). Each attendee played sound clips of unknown sources and attendees debated their source.

27 February – 2 March 2012: Berchok attended NOPP metadata workshop at 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, Napp, and Stabeno 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 Tuktoyaktuk in the Canadian Beaufort to the Bering Sea, for noise levels as well as presence of bowhead whale and bearded seal sounds. Napp 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. Stabeno co-chaired the SOAR meeting and discussed with several individuals the physical dynamics on Chukchi Sea.

9-13 April 2012: Napp, Ben Bloss, David Strauss, and Adam Spear hosted Charles Greenlaw of Oceantronics. TAPS6-NG Unit B was calibrated at the HTI calibration barge and discussions on data processed were held. After Mr. Greenlaw's visit, Bloss, Strausz, and Napp calibrated TAPS6-NG Unit C on their own.

2-4 May 2012: Crance and Stephanie Grassia travel to Cornell University (Ithaca, NY) to meet with Chris Clark and members of the Bioacoustics Research Program (BRP).

22-24 May 2012: Moore participated in NOAA CetSound Workshop @ Washington DC; CHAOZ acoustic data highlighted as source for cetacean seasonal occurrence records, as CetMap software develops (<http://cetsound.noaa.gov/index.html>).

11-22 June 2012: Moore participated in the IWC Scientific Committee meeting; CHAOZ work re. bowhead whale seasonal movements & acoustic environment included in discussion of two sub-committees.

18-21 June 2012: Wang and Wei Chang participated in and presented at the 2012 Community Earth System Model (CESM) annual workshop in Breckenridge, CO.

9-25 August 2012: Moore joined the BOEM-supported *Hanna Shoal Ecosystem Study* cruise aboard the USCGC HEALY. In addition to providing a marine mammal watch, Moore interacted with PIs of the Hanna Shoal study (e.g., Dunton, Grebmeier, Ashjian, Cooper, Weingartner) with regard to science questions and operations relevant to the CHAOZ project.

6-8 November 2012: Berchok attended the SOAR (Synthesis of Arctic Research) passive acoustic group meeting in Ithaca, NY. Attendees also included Chris Clark (Cornell University), Josh Jones (Scripps Institution of Oceanography), Kate Stafford (APL/Univ. of Washington), and Dave Hannay (JASCO Research)). Prior to the meeting, Cornell staff ran noise analyses on most of our data. We compared results and outlined a draft paper (and created rough figures) that will combine our collective 'acoustic array', that stretches from Tuktoyaktut in the Canadian Beaufort to the Bering Sea for noise levels as well as presence of bowhead whale sounds.

Presentations and papers

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.

Garland, E.C., C.L. Berchok, and M. Castellote. 2012. "Acoustic monitoring of belugas (*Delphinapterus leucas*) in the eastern Chukchi Sea". 164th Meeting of the Acoustical Society of America, 22-26 October 2012. Kansas City, MO.

Moore, S.E. 2012. Science Lecture aboard the USCGC HEALY entitled "Marine Mammals in the 'New Normal' Pacific Arctic", where sampling protocols and mammal distributions from the CHAOZ cruises were highlighted. August 15, 2012.

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.J., C.L. Berchok, S.E. Moore, C. Mordy, J.M. 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.

Stabeno, P.J. and J.M. Napp. 2012. "Observations in the Chukchi Sea". Oral presentation for Pacific Marine Environmental Laboratory (PMEL) seminar series, April 10, 2012.

Stabeno, P.J. and J.E. Overland. 2012. "The New Normal in U. S. Arctic". Presented to the NOAA Senior Res. Council. July 19, 2012. Seattle, WA.

Wang, M., J.E. Overland, and P.J. Stabeno. 2012. "Future climate of the Bering and Chukchi Seas projected by global climate models". *Deep-Sea Research II*, 65-70: 46-57.

Wang, M. and J.E. Overland. 2012. "A sea ice free summer Arctic within 30 years: an update from CMIP5 models". *Geophysical Research Letters* 39, L18501, doi:10.1029/2012GL052868.

Wang, M., W. Cheng, J.E. Overland, and P.J. Stabeno. 2012. "Chukchi Sea climate variability seen from CESM". Poster presentation for Community Earth System Model (CESM) annual workshop. Breckenridge, CO, June 18-21, 2012.