Wildlife Special Publication, ADF&G/DWC/WSP-2011-1

Chukchi Sea Acoustics Workshop

Final Report for Coastal Impact Assistance Program
Project Title: Hydro-acoustic Monitoring of Ambient Noise and Marine Mammals in the Chukchi Sea

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Photo by Patrick Kelley, USCG.

November 2011

Alaska Department of Fish and Game Division of Wildlife Conservation

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Cover Photo: A High-frequency Acoustic Recording Package (HARP) is recovered aboard the USCG Vessel Healy in the eastern Chukchi Sea following a year-long deployment. *Photo by Patrick Kelley.*

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Introduction and Background

Monitoring the levels of both natural (i.e., 'ambient') and anthropogenic sources of noise in the marine waters of Alaska is needed to establish a baseline to determine possible impacts of noise on marine mammals. Further, substantial changes in the marine ecosystem of the Chukchi Sea are anticipated due to climate change, which could alter acoustic propagation and noise levels due to the thinning and reduction of sea ice. Thus, changes in natural noise sources, combined with an increase in anthropogenic noise sources due to oil and gas activity and vessel traffic, are occurring in the Chukchi Sea. Establishing a long-term record of underwater noise from increased anthropogenic activities before the distribution and abundance of marine mammals shift in response to changing sea ice conditions is crucial to the development of effective mitigation measures.

A grant was awarded to the Alaska Department of Fish & Game (ADF&G), Division of Wildlife Conservation, through the Coastal Impact Assistance Program (CIAP) for a projected titled "*Hydro-acoustic Monitoring of Ambient Noise and Marine Mammals in the Chukchi Sea*". The first objective of the project was to develop a strategy for hydro-acoustic monitoring in the Chukchi Sea, based on a cooperative approach among key stakeholders. Specifically, a workshop was convened to develop a strategy for hydro-acoustic monitoring in the Chukchi Sea, with participants from the oil and gas industry, Alaska Native marine mammal organizations, the North Slope Borough, the State of Alaska, National Oceanic and Atmospheric Administration (NOAA) Fisheries, the academic and private research communities, and Minerals Management Service (MMS; beginning in 2010, called Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE)).

The Chukchi Sea Acoustics Workshop (CSAW) was held February 9–10, 2009, with the following purpose: ***Briefly review acoustic monitoring studies in the Alaskan Arctic and determine priority research objectives for acoustic monitoring of natural and anthropogenic underwater noise in the Chukchi Sea from a marine ecosystem and marine mammal perspective.***

This report represents the proceedings of CSAW and includes a compendium of recommendations from the CSAW and a workshop entitled *Acoustic Ecology of Arctic Marine Mammals*, held in advance of the 18th Biennial Conference on the Biology of Marine mammals in October 2009.

Overall, this report includes the following: a synthesis of the discussions held at the CSAW workshop; recommendations that were derived from discussions at both workshops (pages 10–13); a review of the primary acoustic signal parameters for western Arctic marine mammals, ambient noise, and anthropogenic noise (Appendix 1; page 14); and workshop Agendas and Attendees (Appendices 3–5; pages 27–32). The minutes from CSAW are available by request.

Synthesis of CSAW Workshop Presentations and Discussions

CONCERNS ABOUT UNDERWATER NOISE

From a Federal regulatory perspective, NOAA Fisheries must meet the requirements of the Marine Mammal Protection Act (MMPA), the Endangered Species Act (ESA), and the Fish and Wildlife Conservation Act. Following these requirements, NOAA Fisheries has the authority to grant "incidental takes" of marine mammals, including takes that result from harassment by noise. Further, NOAA Fisheries must ensure that (1) only a negligible impact on a small number of marine mammals occurs, and (2) any adverse impact on the availability of marine mammals for subsistence can be mitigated.

The interests of NOAA Fisheries regarding acoustics include how acoustics needs to be considered in the designation of critical habitat under the ESA, and the noise levels experienced by marine mammals from both anthropogenic and ambient sources. Further, NOAA Fisheries is interested in determining how to assess cumulative impacts of noise and obtaining additional information to refine the criteria for noise exposure to determine incidental takes.

From the perspective of Alaska Native subsistence users, traditionally there has been an awareness of the potential negative impact of noise on the success of hunting marine mammals and thus hunters are taught to minimize noise when they hunt. Hunters also listen to the ice and the ocean to determine the relative safety of the conditions for hunting, and they also listen to marine mammal sounds. Hunters have observed changes in the distribution, abundance, and migration of marine mammals associated with anthropogenic noise. They are concerned about the impact of noise in the local areas where they hunt, as well as how the noise that marine mammals experience in areas far away may influence migration patterns. Hunters believe there should be long-term monitoring because the impacts of noise may not be observed right away and may increase over time.

From the perspective of The North Slope Borough (NSB), information from subsistence hunters relative to learning about bowhead whales and their responses to noise is very important. The controversy about the size of the bowhead whale population in the late 1970s, and possible reductions in the subsistence quota, led to the use of passive acoustic monitoring that resulted in a more accurate population count. Subsequently, the value of acoustic monitoring was recognized and utilized by the oil and gas industry in both the Beaufort and Chukchi seas; e.g., Northstar. The results of acoustic monitoring has helped understand the impacts of industry activities on marine mammals, especially bowheads, and should continue as a source of information needed to mitigate impacts from industrial sound for marine mammals and North Slope communities. The NSB believes that acoustic monitoring should be used to improve our understanding of (1) the general distribution and relative abundance of marine mammals; (2) how ambient noise levels may change with increased activity, changes in sea ice, and climate change; and (3) how industrial sounds may influence marine mammals from both an ecological and subsistence use perspective. Further, both acoustic and visual monitoring is needed, due to the lack of detection of marine mammals when they aren't vocalizing.

NATURAL & ANTHROPOGENIC UNDERWATER NOISE IN THE ALASKA ARCTIC

A very brief background to acoustics pertinent to the Arctic was presented, noting available sources of information; e.g., Richardson 1995. The difference between physical acoustics and the use of passive acoustic monitoring (PAM), a mechanism to conduct ecological research, was acknowledged, along with the importance of using standardized acoustic units to understand and interpret noise levels derived from different experiments, instruments, and or sources. Mention was made of published ambient noise levels vs. frequency and sea state (i.e., Wenz and Knudsen curves; see Richardson et al. 1995).

PASSIVE ACOUSTIC MONITORING IN THE ALASKAN ARCTIC 1980S–2006

A broad overview of acoustic studies conducted during the 1980s, 1990s, and early 2000s was presented. From 1979–1987, Minerals Management Service/Naval Ocean Systems Center (MMS/NOSC) conducted spring and fall aerial surveys in the Alaskan Beaufort, Chukchi, and northern Bering seas during which sonobuoys (AN/SSQ 41A or B, or 57A) were deployed. Acoustic data, up to 10 kHz, were recorded to tape via radio link and calls from bowhead whales and other marine mammals were recorded. Bowhead calls in spring and fall seasons were categorized to 'type' by simultaneously listening to and viewing spectrograms of the data. Subsequently, call counts by category (simple-FM; complex-AM) were presented in annual NOSC reports (e.g., Ljungblad et al. 1988; NTIS No. PB88-245584/A), with a provisional call repertoires published in Ljungblad et al. (1982), Clark and Johnson (1984), and Würsig and Clark (1993).

Additionally, bowhead daily call rates were estimated from sonobuoys modified for extended transmission and moored 5 km north of Barter Island in fall 1986; 7,152 calls were recorded over a 37-day period. In fall 1987, sonobuoys were routinely dropped near Barrow; 531 calls were recorded over a 34-day period. Three periods of peak calling were identified each year, corresponding with daily sighting rates from aerial surveys (Moore et al. 1989).

From 1984–1988, an acoustic census using 3–4 hydrophones deployed along an ice lead was conducted in tandem with a visual census from ice-based sites near Barrow, resulting in continuous hardcopy spectrograms from two audio channels (see Clark and Ellison 1989 and 2000). The analysis of the data emphasized the location of calls and the creation of call tracks, which were subsequently linked to visual surveys results to estimate population abundance. It was noted that call data linked to visual observations of the number and behavior of migrating bowheads from this study could yield important insights for interpreting data from long-term autonomous acoustic monitoring data for which concurrent visual observations are not obtained.

A spring migration study was conducted from 1989–1991 and 1994, in which helicopters were used to establish camps on the ice from which sound measurements were obtained and playback experiments were performed using dipping hydrophones and transducers.
For the 2003–2004 overwinter period, Acoustic Recording Packages (ARPs) were deployed off Barrow and Wainwright in conjunction with an oceanographic cruise, from which gray whale and bowhead whale calls were detected (Stafford et al. 2007, Moore et al. 2010).

By 2008, over 100 acoustic recorders of different capabilities were deployed throughout the Chukchi and Beaufort (Canadian and Alaska) seas, and many were deployed for the 2008–2009 overwinter period. Current mooring deployments and scientific surveys have recently been brought together by the Alaska Ocean Observing System at: http://dev.axiomalaska.com/AOOSdev/maps/arctic_assets.html?v=5.0.

RECORDERS IN THE CHUKCHI & WESTERN BEAUFORT SINCE 2006

Beginning in fall 2006, two High-Frequency Acoustic Recording Packages (HARPs; 32 kHz sampling rate) were deployed north–northwest of Barrow in the Chukchi Sea for year-round deployments. For 2006–2007 the HARPs were programmed for continuous recording, whereas for 2007–2008 they were programmed with a duty cycle of 7 min on/off. The primary objectives of the study are to obtain a long-term acoustic record on the offshore seasonal distribution of marine mammals and ambient sound levels, prior to likely increases in sound due to increased vessel activity and other anthropogenic sounds. It was noted that calibrated hydrophones obtain received sound pressure levels rather than the relative levels from hydrophones that are not calibrated.

During 2008–2009, AURALs (Autonomous Underwater Recorder for Acoustic Listening) were deployed as part of the National Ocean Partnership Program that was examining the episodic upwelling of zooplankton and biophysical linkages to bowheads and other marine mammals. Passive acoustic data were co-located with daily profiles of temperature, salinity, turbidity, chlorophyll, Colored Dissolved Organic Matter, and sea ice deformation. These data will be used to examine east–west differences in migratory timing of bowhead whale migration between the Bering and eastern Beaufort Seas via the western Beaufort.

The Bowhead Feeding Ecology Study (BowFEST) began in 2007 (also known as Arctic Ice Monitoring (AIM) for 2008–2009) and hydrophones (Aural M-2) have since been deployed as part of an interdisciplinary feeding study. Hydrophones were placed in triads to localize calling whales with a sample rate of 8192 Hz and a duty cycle of 9 min on/21 min off. Bowhead prey was sampled in late summer and the influence of wind on prey concentration is being examined. Additionally, short-term deployments are targeted spatially with visual surveys, and bowhead distribution is being examined relative to ice conditions. During the discussion of this project, it was noted that automatic detection was typically used for bowheads and bearded seals, and that the detection of the calls is relatively easy whereas classification is more difficult; thus, a combination of looking and listening to calls is needed. Analyses will include power spectral density for noise levels, automatic detection for call counts, energy detection, and correlation with broadband data to examine how wind influences noise levels. Importantly, the analytical approach will depend on the hypothesis being tested, and discussions during this workshop should explore the key questions of interest throughout the region.

INDUSTRY RECORDERS IN THE CHUKCHI & WESTERN BEAUFORT SINCE 2006

A broad overview was presented of the ~3 decades of acoustic studies conducted by Greeneridge, JASCO, LGL, and Cornell in conjunction with oil and gas activities. Most of the earlier studies were associated with Kuvulum drilling and ice management, Hammerhead drilling and ice management, and seismic activities in the late 1990s. Since 2000, there has been a consistent use of acoustics for monitoring associated with activities of BP (Northstar), Shell, CPAI, Pioneer, and Eni, with the goals of establishing baseline sound conditions and gaining an understanding of (1) sound propagation of industry activities (i.e., vessel, seismic, drilling), (2) responses of marine mammals (migration, vocalization, distribution, subsistence) to those activities, and (3) the overall distribution of marine mammals.

Specific aspects of the studies included sound source verification (SSV), which was conducted during operations to assist in the development of mitigation parameters. SSV was typically conducted at the beginning of each year's activities to identify shut down zones. Additionally, correlations between sound levels and specific activities were assessed on an annual basis, and the range of noise levels and their variation was determined. Acoustic recorders were targeted at some specific sites (e.g., BP Northstar, CPAI/Shell Chukchi prospects, and Pioneer/Eni) and spread out over broad areas in other regions (e.g., Shell/CPAI Chukchi in 06–07). It was noted that seismic activity showed some different propagation characteristics in the Beaufort vs. the Chukchi, 2006 was a difficult year due to ice conditions whereas in 2007 extensive seismic activity was conducted under better ice conditions, substantial problems with acoustic devices limited data collection in 2008. For the 2006–07 overwinter period, 5 acoustic recorders were deployed in the Chukchi with 7 recorders for 2007–08.

An overview of the acoustic monitoring at Northstar was presented, which began with measuring underwater sounds associated with construction and operation as part of the required mitigation during the construction of the Northstar Island by BP. Subsequently, beginning in 2001, DASAR arrays were deployed to triangulate bowhead calls, with DASARs deployed 5 km apart based on a detection distance of ~30 km. Measurements were conducted in the 10–450 Hz band; most industrial sounds are within this band. Bowhead calls were all below 500 Hz, wind speed affected ambient sound levels, and DASARs near Northstar Island did not detect many airgun events because the water depth was only 10 m near the island. Acoustic deployments by Shell in the Beaufort and Chukchi seas were briefly reviewed, with a focus on results for bowhead whales. Discussion points included the lower calling rates during seismic airgun activity compared to the pre and post-seismic periods, as well as the possible impact of airgun activity on feeding behavior—noting the likely spatial and temporal variation in concentrations of bowhead food, and that the detection of bowhead calls is influenced by wind, current, and ice conditions.

A presentation was made of some preliminary results of walrus calls during 2007 in the Chukchi Sea, which generated substantial discussion. Walruses were detected (automatic detection with human validation) at all recorders in early July, with substantial numbers of calls near Hannah Shoal in late July and early August. Each individual type of vocalization (e.g., one 'knock', or 'bell', or 'grunt') was tallied as one count, and then the total number of counts was calculated, which does not represent an index to abundance; no concurrent visual surveys were conducted. The spatial-temporal distribution of acoustic detections appeared correlated with ice conditions and walruses did not appear to show a response to seismic activity; the marine mammal observers (MMOs) on-board seismic vessels did not report responses by walrus yet the relative number of walruses appeared greater prior to the survey. It was noted that subsistence hunters observed a distribution of walruses similar to the acoustics data.

During 2007–2008, Shell acquired seismic data in the Beaufort Sea and ocean-bottom cable shooting took place in 2008 (conducted by ENI). A large number of bowhead calls were detected in mid-September 2007, with a decrease in detections near seismic activity possibly due to (1) masking from either high winds or reverberation from the seismic activities, or (2) a reduction in bowheads calling in the presence of active seismic exploration. High winds were recorded during the period of seismic operations, which could have masked some calls; when seismic shut down for bad weather call rate increased. It was noted that to deal with masking from wind is addressed by only using detections from within 10 km of the nearest DASAR even though calls are detected at greater distances.

Typically, oceanographic data have not been collected concurrent with acoustics studies, although temperature is obtained with the AURAL recorders. In the Bering Sea, recorders have been integrated with long-term moorings deployed by the Pacific Marine Environmental Laboratory (PMEL), with provisional assessment of fin whale calling and oceanographic parameters provided in Stafford et al. (2010). Ideally, CTDs should be deployed with acoustic instruments to track changes in oceanographic conditions and correlations with marine mammals.

BASELINE INFORMATION

An open discussion among workshop participants focused on what type of acoustic data exists from previous studies that could potentially be considered "baseline", and additionally, how can this baseline information help develop future study designs and objectives; the following is a list of the main points made during this discussion:

1. Determining which "standard data" are needed for each measurement should be pursued; e.g., sampling rate, absolute levels.

2. There is common interest in reaching an agreement on a sampling protocol, which would then help promote the sharing of data among different projects.

3. The question of how duty cycle affects available data, and data sharing, needs to be addressed; perhaps 5-minute sampling of every hour would be a good way to compare data.

4. There is common interest in developing a good automatic detection program, particularly for bowhead calls, that would be shared among those involved in acoustic research. Different training data will be required for different locations and environments, and the need to distinguish between using a common algorithm and using the same parameters for the algorithm. To date, however, the complexity of the bowhead whale repertoire has made this nearly impossible.

5. A substantial amount of data exists that have not been examined or analyzed, particularly for less common events; e.g., ice seals, presence of fin whales.

6. There is common interest in all marine mammals, recognizing the importance of bowheads for subsistence and from an historical perspective.

7. The key questions, objectives, hypotheses should be listed, from which an overall framework and priorities can be established. Further, we should collectively ask questions from the broader ecology scale to finer scale behavioral issues. For example, can we obtain a general understanding of how acoustics influences bowhead migration to asking further questions like "*Does this type of activity cause migration deflection?*" As data and information are summarized, this approach will help determine which analyses to pursue, which questions can be answered, and the focus of future studies as both environmental and anthropogenic conditions change.

8. Are the seismic data useful to ascertain "hot spots" or certain acoustic zones that are more reflective? From a management perspective, knowledge of how propagation characteristics vary spatially would help determine whether some areas are more critical than others, resulting in more accurate permitting.

9. An approach that examines the overall noise budget to assess the broader "soundscape" is used on the east coast of the U.S., and that approach should be considered for the Arctic.

10. In the last few years there has been substantial progress related to deflection of bowhead migration, but are we at the point of diminishing returns because we are not able to answer the question?

11. We are seeing how impulsive sounds affect behavior, and thus we need finer resolution studies to interpret these observations in a broader ecological context. Specifically, moorings should obtain both oceanographic and acoustic data to address ecological questions rather than one particular acoustic question, and the inclusion of interested oceanographers would add to the database of knowledge. Further discussion on the topic of the integration of oceanographic and acoustic parameters included the following:

    A. An interest in adding oceanographic data to acoustic studies because of the differences between the Chukchi and Beaufort, as far as bathymetry, currents, etc.

    B. The question was asked if ocean acidification changes acoustic parameters, and it was noted that acidity affects sound attenuation in high frequencies (high kHz), but not in the frequencies typically associated for most marine mammals or seismic activities due to the "relaxation process".

12. Recognition of the importance of assessing how ice affects sound propagation in the Arctic environment and monitoring changes in sea ice, both thickness and extent. It was noted that the Navy did a substantial amount of research on ice during the 1950s, 1960s, and 1970s and a published report is available.

13. In addition to information on sounds from marine mammals or industry activities, information is needed on overall ambient levels and how conditions affect those levels.

14. Industry clearly has the monitoring responsibility to understand implications of their activity on marine mammals. Yet, does that responsibility also include obtaining general baseline information, and do these issues affect the permitting process?

15. The need for coordination with subsistence users was agreed upon, particularly in regards to timing research activities in a manner that minimizes disturbance to marine mammals, especially during migration.

16. In addition to the contributions listed above, the rest of the baseline discussion involved the idea of data sharing, as summarized here:

    There was a common interest in developing an agreement with specific guidelines for the sharing of raw data, to take advantage of the opportunity represented in the large amount of data collected from so many acoustic recorders. In particular, industry has obtained a substantial amount of data, including data specific to when and where seismic activities have been conducted, which is important to assess relationships with marine mammals and ambient sounds. Data sharing would:

    A. Promote the analysis of the extensive amount of data already collected; i.e., 'data mining'
    B. Encourage new approaches to examine data in different ways, or address questions that have not been looked at through previous studies or previously available data
    C. Help answer some of the important questions we have identified
    D. Help determine when funds should be spent on new deployments vs. additional analyses of existing data.

    Further, there was interest in establishing a collective database, or at least a 'directory', with the following attributes:

    E. The raw data that were collected, or a sample for verification.
    F. Are the data available to be shared: Yes or No?
    G. The analyses that have been completed, based on agreed upon standards, or at least documentation of how the analyses were conducted.
    H. The output and results of the analyses, and any summaries, products, reports, publications.

17. When asked if industry would be open to share raw data files for others to analyze, there was support for the general idea, yet mention was made of legal issues, complexities, and costs. Further, there would most likely need to be a list of

qualifications for individuals requesting data, statement of purpose, etc., as part of the data agreement. It was noted that the International Whaling Commission (IWC) has an established data sharing agreement, that required extensive and difficult discussions, but it was completed. Finally, the suggestion was made that perhaps AOOS or NPRB could be the 'home' of the shared collective database.

Priority Recommendations for Future Acoustic Research

Following the presentations and discussions described above, workshop participants held an open discussion to determine what they believe are the priority recommendations for future acoustic research. This discussion resulted in the following recommendations:

COOPERATION AND COLLABORATION AMONG ALL STAKEHOLDERS: SCIENTISTS, SUBSISTENCE USERS, ALASKA NATIVE HUNTERS, INDUSTRY, CONSULTANTS

1. Foster and maintain communication across groups and disciplines to share and develop ideas.
2. Keep all stakeholders informed as new research projects are proposed and seek input in the development of project objectives and methods.
3. Explore the potential for collaborative partnerships in the development of scientific research studies.
4. Research studies must minimize disturbances to marine mammals and impacts on subsistence hunting.

MANAGEMENT AND CONSERVATION—POLICY

1. Devote greater attention on broader scale issues that have not received sufficient attention; i.e., potential impacts on habitat, whether marine mammals are vacating large areas, and cumulative impacts.
2. Complete a synthesis of available information that can be used to develop mitigation strategies designed to meet legal obligations to minimize impact on marine mammals during industry operations.

EXPERIMENTAL DESIGN OF NEW ACOUSTIC STUDIES

1. Develop a strategy for long-term acoustic monitoring; i.e., years or decades rather than months. Implementation of the strategy is needed to understand seasonal and annual changes in the acoustic environment due to climate change, regime shifts, increased vessel traffic, and other anthropogenic factors.
2. Ensure ambient acoustic environment is being measured adequately to assess seasonal and annual variation.
3. Seek collaboration and coordination among projects, prior to deployments. For example, large-scale studies conducted by industry with smaller-scale studies to expand overall effort, optimize spatial distribution of recorders, avoid overlap, take advantage of vessel support, etc.
4. Obtain directional acoustic data when possible, with an emphasis on developing localization capabilities.
5. Obtain information on marine mammals (e.g., relative distribution and abundance) prior to oil and gas activities.

INTEGRATE OCEANOGRAPHIC AND ACOUSTIC RESEARCH

1. Seek collaboration with oceanographers.
2. Promote a broader ecosystem perspective that integrates oceanography, marine mammal ecology, and ecosystem dynamics.
3. Explore the potential to obtain oceanographic information concurrently with acoustic information from the same moorings; oceanographers may be willing to share instruments. Obtaining oceanographic information may help assess which areas are more productive (i.e., prey species) and hence important to marine mammals.
4. Characterize habitats used by marine mammals and examine interactions of anthropogenic noise and habitat use by marine mammals.

LINK MARINE MAMMAL BEHAVIOR AND ACOUSTICS

1. Conduct ‘fine-scale’ studies to document concurrent marine mammal behavior and acoustics, in particular acoustic response of marine mammals to anthropogenic noise.
2. Explore potential use of tags that record marine mammal dive behavior data concurrently with acoustics; i.e. D-tags or similar technology.
3. Link behavior and noise exposure to vocalization to assess which factors may prompt a marine mammal to make a certain type of call.
4. Determine the sound levels received by marine mammals.
5. Examine how the calling behavior of marine mammals varies with the source of the sound stimulus; e.g., seismic, vessels.
6. Explore feasibility of ‘play-back’ studies designed to record responses of marine mammals to known sources, levels, and locations of sound.
7. Determine if results are available from ‘play-back’ studies that were conducted in the 1980s and 1990s, and if they provide insights on possible future studies.
8. Extrapolate fine-scale studies to broad-scale understanding and applications, when possible.

DATA ACQUISITION, ARCHIVING, ANALYSES, AND MINING

1. Determine the important attributes required to document how data are reported.
2. Establish guidelines (i.e., standards) for how data should be analyzed.
3. Create a meta-database that includes the following:
    a) The type of data collected.
    b) The type of analyses that have been completed, and whether the analyses did, or did not, follow the guidelines.
    c) The output and summary products available from the analyses.
    d) Availability of the raw data, or a sample of the raw data.
4. Determine what additional questions, ‘big’ and ‘small’, should be pursued with data previously obtained.
5. Determine feasibility of developing software recognition/classification programs that would be utilized across studies.
6. Explore application of modeling work conducted by Chris Clark to the Arctic. Specifically, model noise exposure and masking affects from the perspective of the

acoustic ecology of marine mammals (i.e., time, space, frequency) to conduct a more comprehensive assessment of potential acoustic impacts on communication range.
7. Develop catalogs of marine mammal calls based on previously recorded acoustic data.
8. Determine how duty cycle affects data.
9. Determine how ambient sound levels should be reported across studies.
10. Determine how anthropogenic sounds should be characterized.

CLIMATE CHANGE

1. Consider how changes due to climate change should be examined\documented through acoustics research.

INTEGRATION OF SCIENTIFIC AND TRADITIONAL KNOWLEDGE

1. Ensure the integration of scientific and traditional knowledge is accomplished in a manner that involves the participation and support of both scientists and subsistence users.
2. Broadly distribute the integrated knowledge among the scientific community and Alaska Native communities, particularly subsistence hunters.

RECOMMENDATIONS SPECIFIC TO BOWHEADS

1. The community of Point Barrow relies on bowhead whales for subsistence and is concerned that human activity may "deflect" whales offshore from the spring and fall hunting areas; several other communities hunt bowheads for subsistence. Thus, information is needed to determine if whales are deflected from Barrow and other communities. Concern was also expressed about impacts from changing ice and more open water, and how sound may be changing due to those environmental changes; Cross Sound was suggested as an additional area to consider.
2. Assess what additional changes/impacts on whale behavior may occur in response to the sounds that cause deflection.

RECOMMENDED SUMMARY INFORMATION TO BE PROVIDED FOR ALL ACOUSTIC RELATED PROJECTS

Data Collection

1. Point of contact for the project
2. Project objectives (*Note: include all objectives; e.g.,* primarily objective may be to record whale calls, yet detection of airguns could be secondary objective)
3. Deployment Start & End dates (Note: for projects with multiple deployments, include start and end dates for each deployment)
4. Number and type(s) of recorder(s)
5. Type of mooring(s)
6. Location(s) of recorder(s); if > 1 recorder, deployed independently or in array?
7. Depth(s) of recorder(s) (Note: include both the depth of the water column and the depth of recorder in the water column)
8. Name of vessel used to deploy recorder(s)
9. Directional capability
10. Sample rate
11. Type of quantization used
12. Duty cycle
13. Were recorders calibrated? If so, when and how?
14. Passband gain (system sensitivity)
15. Filtering Applied?
16. Self-noise?
17. Overload level
18. Dynamic range
19. Data format (.wav, .bin, etc.)

Data Processing

1. How much data was recorded during deployment for each instrument?
2. How were data analyzed; i.e., 100% detectors or some eyeballing
3. QA/QC on data?
4. Detectors used by species
5. How were results reported; e.g., analysis bandwidth, PDFs, or lofargrams
6. Counts?
7. Energy?
8. Results?

Appendix 1: A review of the primary acoustic signal parameters for western Arctic marine mammals, ambient noise, and anthropogenic noise.

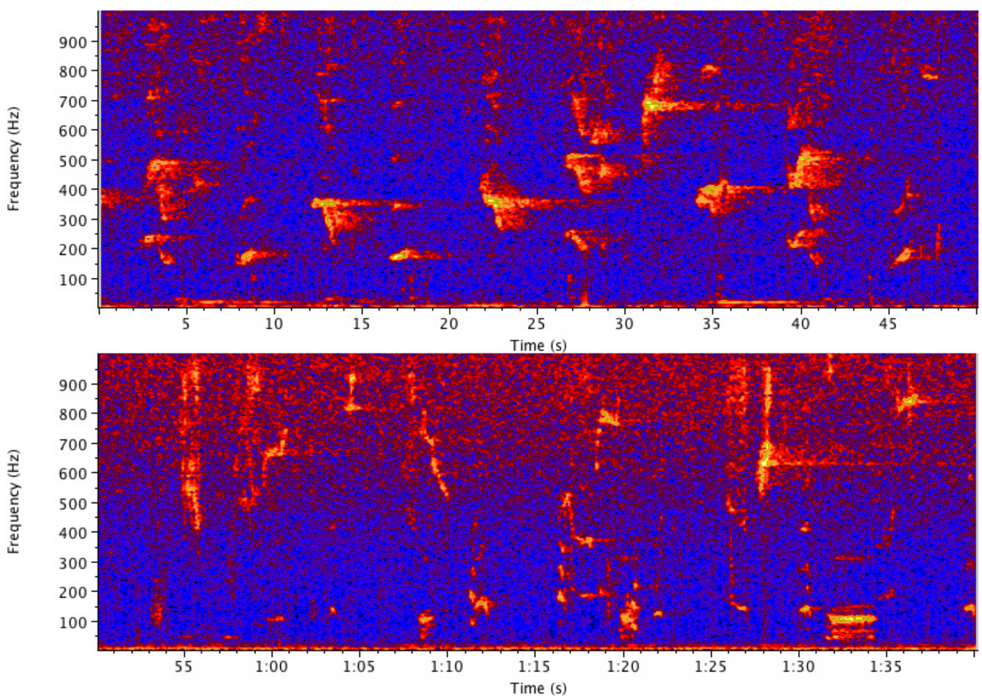
WESTERN ARCTIC MARINE MAMMALS

NOTE: Much of the information below is extracted from Richardson et al. 1995 Marine Mammals and Noise. Additional references are included in Appendix 2: References.

Cetaceans

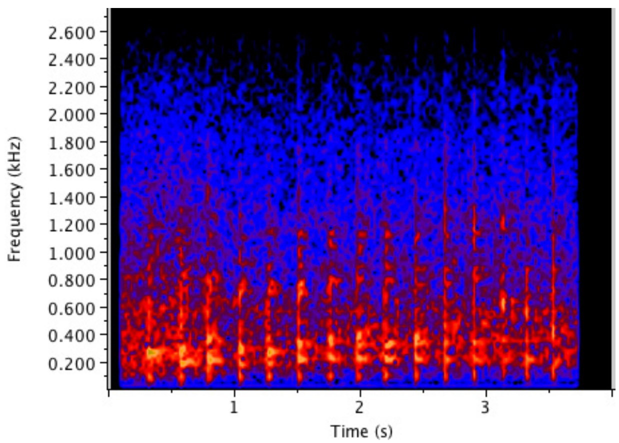
Bowhead whale (Balaena mysticetus)

- Simple up and down calls to complex "song"
- 20 Hz to > 6 kHz, each unit usually ~1 s long
- Certain sounds may be confused with bearded seal, humpback whales
- Repertoire differs with behavioral state (migration v. 'song') and season
- Subsistence species



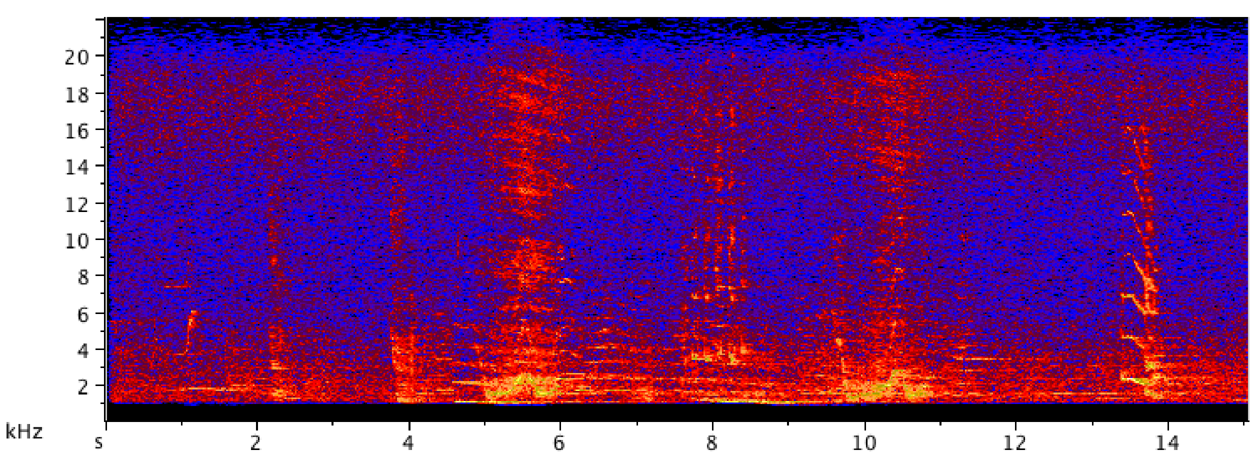
Gray whale (Eschrichtius robustus)

- Pulses, moans
- calls 20–2000 Hz
- SL 185
- Can be confounded by walrus, air guns
- Repertoire incompletely described
- Unknown if seasonal changes or behavioral changes in sound production



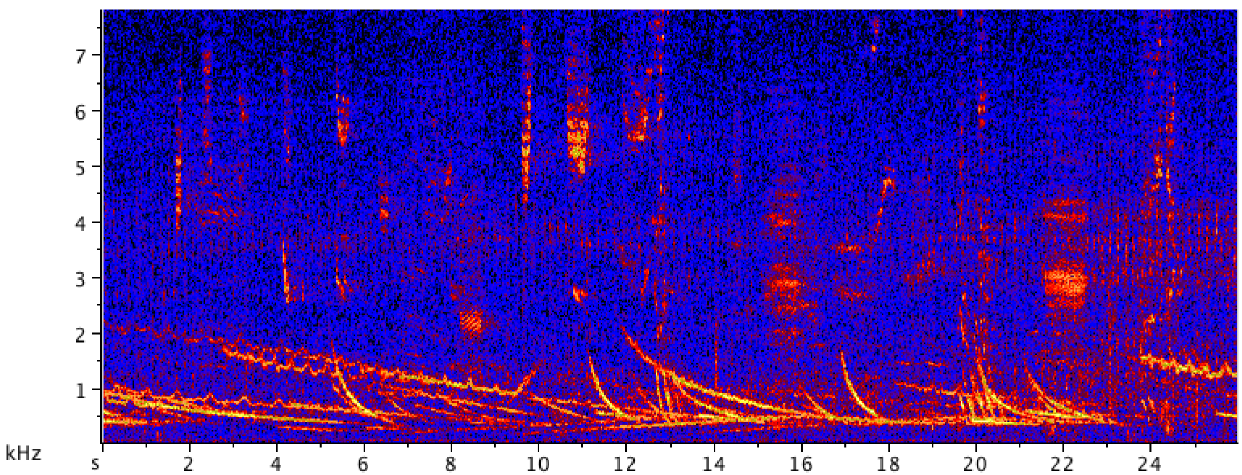
Beluga whales (Delphinapterus leucas)

- Whistles and pulsive calls
- 500 Hz– >20 kHz
- SL unknown?
- Echolocation 40–120 kHz
- Repertoire from wild animals poorly described
- Subsistence species



Narwhals (Monodon monoceros)

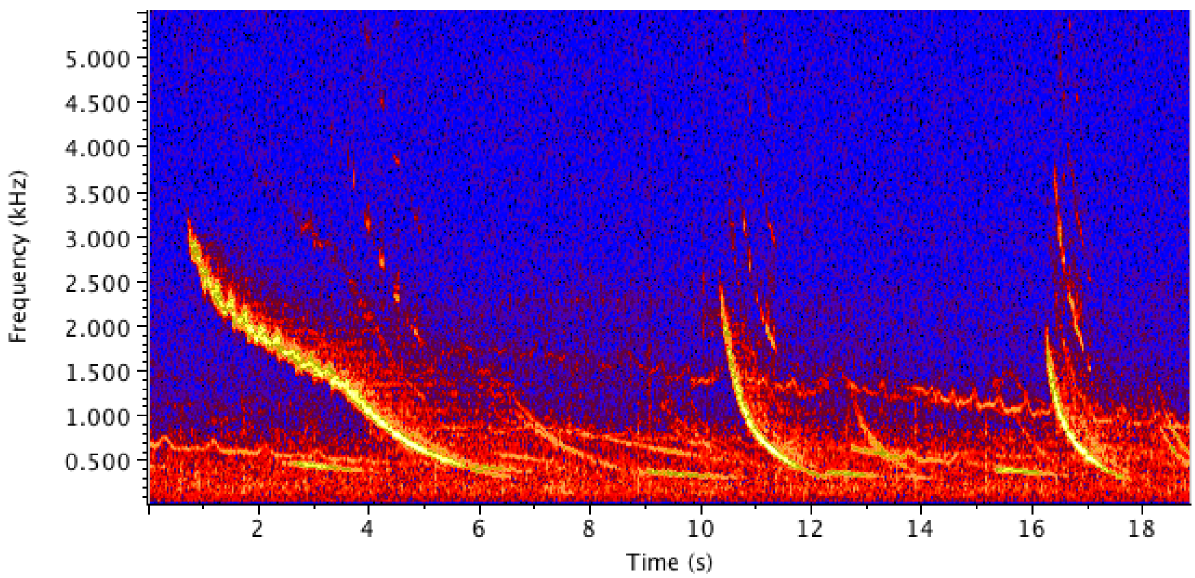
- Whistles and pulsive calls
- 300 Hz to 20 kHz
- SL unknown
- Echolocation to 120 kHz
- Documented but rare visitor to western Arctic
- Might be confused with beluga



<u>Pinnipeds</u>

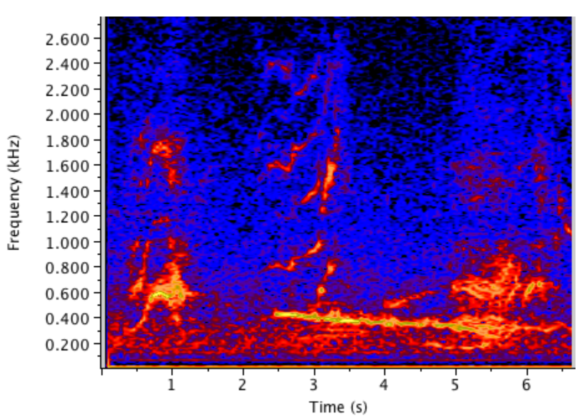
Bearded seals (Erignathus barbatus)

- Sounds variable, long trills can be 10–15 s long
- 20 Hz to 6 kHz
- SL 178 (dB re 1uPa@1m)
- Best-studied arctic pinniped
- Behavior varies with behavioral state, season
- Can be confused with bowhead, ribbon seals
- Contribute overwhelmingly to AN in spring
- Subsistence species



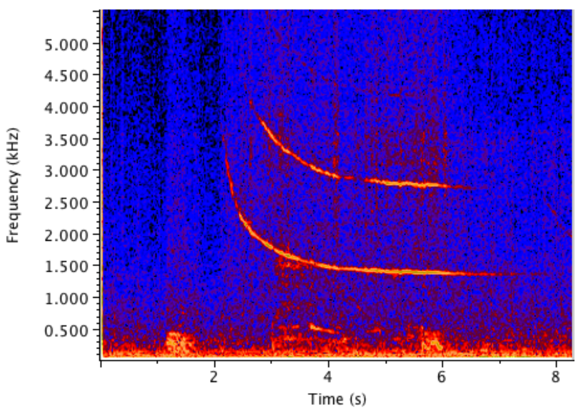
Ringed seals (Phoca hispida)

- Yelps, barks, whistles, lots of variation reported
- <5 kHz
- SL 95–130 dB (re 1uPa@1m)
- Subsistence species



Ribbon seals (Phoca fasciata)

- Repertoire Poorly known
- calls to 7 kHz
- SL 160 dB re 1uPa@1m
- Sound production likely varies with behavioral state and season
- Might be confused with bearded and ringed seals, bowhead
- Subsistence species



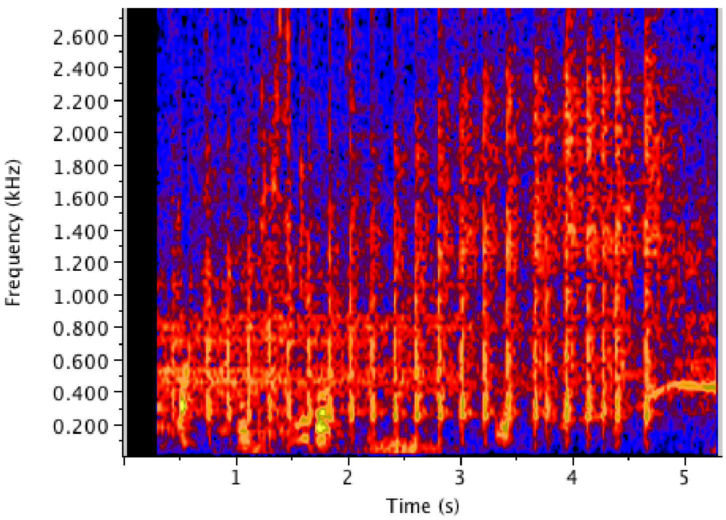
Spotted seals (Phoca largha)

- Yelps, barks, whistles, lots of variation reported
- <5 kHz
- SL 95–130 dB (re 1uPa@1m)
- Subsistence species

Fissipeds

Walrus (Odobenus rosmarus)

- Knocks, bells, rasps, grunts
- 400 to 1200 Hz
- SL unknown
- Repertoire poorly documented
- May be confused with gray whales
- Subsistence species



AMBIENT NOISE

1. Frequency range of interest.
2. Sound pressure spectral density levels (SPSDLs) in dB re 1 uPa^{**2}/Hz, nominal 1-Hz frequency cell spacing, window lengths of 10 or more seconds.
3. For the Fourier transforms, use 1-s transform length, Blackman-Harris window, 50% overlap, average the transform magnitudes.
4. Graph SPSDLs with a log frequency scale.
5. Compute SPSDL at intervals appropriate for the ambient noise being measured, perhaps every hour.
6. Sum over the spectral densities to determine a band level of the ambient noise for that measurement time.
7. Relate to hourly wind speed if appropriate.
8. Over a period of time (several days or weeks), compute statistical spectra by sorting the magnitudes of each frequency cell and constructing a minimum SPSDL, a 5th-percentile, and 25th-percentile, a 50th-percentile (median), a 75th-percentile, a 95th-percentile, and a maximum.
9. Compute the same percentiles for the broadband level of the ambient noise over that period of time.

ANTHROPOGENIC NOISE

1. For relatively continuous sounds like vessels, drilling activities, machinery, use the same general analysis process for db (RMS) as is described above for ambient noise.
2. For intermittent, transient sounds like airgun pulses, follow the Malme procedure to determine the following:
    a. Instantaneous peak pressure
    b. Peak-to-peak pressure
    c. Duration
    d. Sound Pressure Level (SPL) in dB re 1 uPa
    e. Sound Exposure Level (SEL) in dB re 1 uPa**2-s.
    NOTE: Don't forget to remove the contribution of the background sound to these measures.
3. Measure the received level vs. distance. Use distances that are roughly multiples of 1, 2 and 5, like 200, 500, 1000, 2000, 5000, and 10,000 m because the spreading loss in decibels will be roughly linear with log(distance). Graph the received levels against log (distance), and consider computing the kurtosis.

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Appendix 3: Chukchi Sea Acoustics Workshop Agenda

CHUKCHI SEA ACOUSTICS WORKSHOP
9 & 10 February 2009, Anchorage Alaska
Conoco-Phillips Building
AGENDA

Purpose of Workshop: *Briefly review acoustic monitoring studies in the Alaskan Arctic and determine priority research objectives for acoustic monitoring of natural and anthropogenic underwater noise in the Chukchi Sea from a marine ecosystem and marine mammal perspective.*

Day 1: Background – where do things stand now?

8:30 Welcome, Introductions, and Workshop Background & Goals (Bob Small)

9:30 Concerns about Underwater Noise

1. NOAA/NMFS (Brad Smith); *Regulatory issues relative to 'take' under the MMPA and cumulative impacts*
2. Alaska Native Organizations & North Slope Borough (ANO reps & Robert Suydam)

10:00 Natural and Anthropogenic Underwater Noise in the AK Arctic (Charles Greene)

10:30 BREAK

10:45 Passive Acoustic Monitoring in the Alaskan Arctic, 1980s–2006 (Sue Moore); *A brief overview of the different types of instruments used and the data they collect*

11:15 Recorders in the Chukchi & Western Beaufort Sea, since 2006: BOWFEST, NOPP, & SIO (Kate Stafford); *Primary objectives of and the general background information on the studies.*

12:00 LUNCH

1:30 Industry Recorders in the Chukchi & Western Beaufort, since 2006: Shell, Conoco-Phillips, and BP (Michael Macrander); *Primary objectives of and the general background information on the studies.*

2:15 What is our Baseline? *A general/brief summary of bandwidth, sampling rate, duty cycle, etc. from past recorder deployments and the available data will distributed at the workshop*

1. What baseline data exists from previous studies?

2. What can be learned from previous recorder deployments in the Chukchi Sea; what worked, what didn't, noise from moorings, etc.
3. How can this baseline help in development of future (2010–2015) plans?

Day 2: <u>Determine priority objectives for future monitoring</u>

8:30 Summary of Day 1 (<u>Sue Moore</u>)

9:00 Review the primary signal parameters (e.g.., frequency, loudness, duration) of interest for the following (<u>Kate Stafford & Charles Greene</u>)
1. Marine mammals
2. Ambient noise
3. Anthropogenic noise

9:40 Identify those aspects of the acoustic environment that may be impacted by climate change and determine how we monitor those impacts (<u>Sue Moore</u>)

10:00 What spatial, temporal, and sampling factors should be considered in acoustic studies?
1. What can the different instruments do, and not do?
2. What do we need to learn?; e.g., tracking the presence of marine mammals relative to ambient and anthropogenic noise
3. How does the choice of sample rate and duty cycle affect recordings of the primary signal parameters of interest?

10:45 BREAK

11:00 What factors need to be considered in how acoustic data are collected and subsequently analyzed, especially in regard to potential collaborations to summarize and compare/contrast across different studies?

1. Have analytical techniques been consistent; e.g., identifying bowhead whales
2. How do we measure and document ambient noise?
3. How are automated detection systems being utilized among studies?
4. Is the process for summarizing and reporting data consistent?
5. What metadata do we need?

What specific challenges need additional attention/awareness?

1. Problems with Chukchi deployments; e.g., bio-fouling, problems inherent in shallow moorings, noise from mooring equipment, etc. ☐ What has worked and what hasn't
2. Others?

LUNCH ~12:30

Integrate information discussed during the workshop to ***<u>determine priority objectives</u>*** for future monitoring. Factors that need to be considered include the following:

1. What additional analyses/archiving of data previously collected should be pursued, especially in relation to the baseline of ambient noise?
2. Broad vs. fine scale
3. Long-term monitoring vs. short-term studies
4. How do we assess cumulative impacts; e.g., across multiple basins, state and international borders, and years?
5. Integration of changes in climate, increased vessel traffic

Appendix 4: Participants of the Chukchi Sea Acoustics Workshop

Catherine Berchok
Harry Brower
Russ Charif
Dale Funk
Willie Goodwin
Charles Greene
Dave Hannay
Merlin Koonooka
Michael Macrander
Chuck Monnett
Sue Moore
Steve Okkonen
Caryn Rea
Ethan Roth
Bob Small
Brad Smith
Kate Stafford
Robert Suydam
Sheyna Wisdom
Jim Wilder

Appendix 5: Agenda of the Acoustic Ecology of Arctic Marine Mammals workshop, held in advance of the 18th Biennial Conference on the Biology of Marine mammals in October 2009.

Arctic Acoustics workshop schedule

08:30–09:00: Registration
09:00–09:15: Introduction

09:15–11:15

Identifying species, seasonal and geographic patterns in sound production

Denise Risch
Vocalizations in male bearded seals: evidence of geographic variation across the Arctic

Isabelle Charrier
Acoustic communication in Atlantic walrus

Ian Stirling
Antiquarian recordings of underwater seal calls and thoughts about future research on seal vocalizations

Jack Terhune
What do ringed seals gain from vocalizing in late summer?

Susannah Blackwell
Bowhead whale migratory acoustic behavior

Julien Delarue
Acoustic detections of fin whales in the Alaskan Chukchi Sea

Kate Stafford for Manolo Castellote
Behavioral context of click behaviors in captive and wild beluga whales

Kate Stafford
Pack ice narwhal recordings and how do you tell a narwhal from a beluga?

Discussion panel:

How are we identifying species?
What do we know about seasonal and geographic changes in vocal behavior?

11:15–12:30
Tools

Aaron Thode
Ambient noise levels and mechanisms in Arctic waters

Jack Terhune
Localization accuracy problems using small hydrophone arrays under ice

Kate Stafford
Instrumentation for arctic recording

Dave Mellinger
Automatic detection software

Discussion panel:
Best tool for the job?
Taking ambient noise levels into consideration?

LUNCH on your own 12:30–13:45

14:00–16:00

Sofie van Parijs
Effects of changing ice cover on bearded seal acoustic ecology

Michael Macrander
Chukchi walrus

Elly Chmelnitsky
Acoustic monitoring of cetaceans in the eastern Arctic:belugas, killer whales, narwhal, and bowheads

Yvan Simard –
Recent observations with AURALs in Canadian Arctic and Hudson Bay

Sue Moore
Passive acoustic data and Arctic observing systems

Chris Clark
Acoustic Ecology of the Alaskan Arctic; Whales, Ice and Men

Discussion panel:
Going beyond who's where and when: Broader applications of acoustic data to address Arctic issues: climate change, anthropogenic noise, etc.
Integrating acoustic data into Arctic observing systems

16:00–17:00
meet and greet – informal discussion aimed at fostering collaborations, data exchange