Baseline Hearing Measurements in Alaskan Belugas

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LONG-TERM GOALS

Due to the opening of the Northwest Passage and interest in Arctic resources, naval activities (amongst others) and ocean noise are increasing in northerly beluga waters. Through data acquired in a capture-release project, this work examines the frequencies and sound levels to which wild belugas are sensitive. A standard audiogram is being determined from the wild samples, noting the variation between animals and the audiogram of maximal sensitivity. This will be compared to available hearing data from captive belugas, evaluating any differences and potentially combining the two data sets. The hearing curves will be appraised relative to demographic and health-related meta-data from the animals from which the measurements were made. Through these data analyses we seek to: 1) define the natural and baseline hearing abilities and variability in belugas, 2) place the results in the context of potential ecological influences and that of anthropogenic noise, and 3) evaluate the validity of captive-based hearing data in relation to wild animals.

OBJECTIVES

Evaluate the audiograms of temporarily captured wild belugas from Bristol Bay, substantially increasing the sample size and consequent knowledge of how this protected species naturally detects and utilizes sound.

1a) Identify a standard beluga audiogram and evoked potential waveform, and their variances, and examine the individual audiograms relative to demographic and health-related meta-data.

1b) Compare these audiograms with published audiograms and new data from captive experiments to evaluate the fidelity of summing captive and wild beluga hearing data and establish a baseline comparison for captive auditory research. Also place the beluga audiogram variability in the context of other measured odontocetes populations.

APPROACH

Baseline audiograms in wild belugas were measured in coordination with a planned capture-release field project in Bristol Bay, AK. The project was run by the National Marine Mammal Laboratory of the Alaska Fisheries Science Center (NMFS Marine mammal research permit #14245), Alaska Department of Fish and Game, the Georgia Aquarium and the Alaska Sealife Center. The work involved temporarily capturing 9 beluga whales during September 1-13, 2012. Hearing abilities were measured for 7 restrained animals using auditory evoked potential (AEP) methods (Fig 1). Representatives from NMML, ADF&G, Georgia Aquarium and others were simultaneously acquiring additional physical health measurements (e.g., blood chemistry, stress measures), genetic samples, ultrasound images and fitting the animals with satellite tags.

The audiograms were collected using a custom-built AEP system and software which is well established for physiological hearing tests (Mooney et al. 2008) including field measures (Mooney et al. 2009; Mooney et al. 2011a). Attaching the suction-cup electrodes for beluga AEPs requires careful placement because their skin may be wrinkled and belugas have the ability to move their head/neck, both of which can dislodge electrodes. Auditory sensitivity was measured in octaves and half-octaves from 1-180 kHz (1, 2, 3, 4, 5.6, 8, 11.2, 16, 22.5, 32, 45, 54, 80, 100 128, 150, 180 kHz) using SAM tone stimuli (except for 1-3 kHz which used 6 cycle tone pips). Sounds were presented using a suction-cup jawphone placed on the rostrum tip of the lower jaw. In belugas and other odontocetes, this region produces maximal AEP amplitudes compared to other parts of the head preferential (Mooney et al. 2008; Mooney et al. 2011b). For AEP hearing tests, this transducer placement is preferential to the typical pan bone region, likely because it allows sound to propagate equally to both ears, avoiding potential complications which could occur from auditory deficits in only one ear. Hearing thresholds were determined statistically using linear regression methods (Supin et al. 2001; Nachtigall et al. 2007).

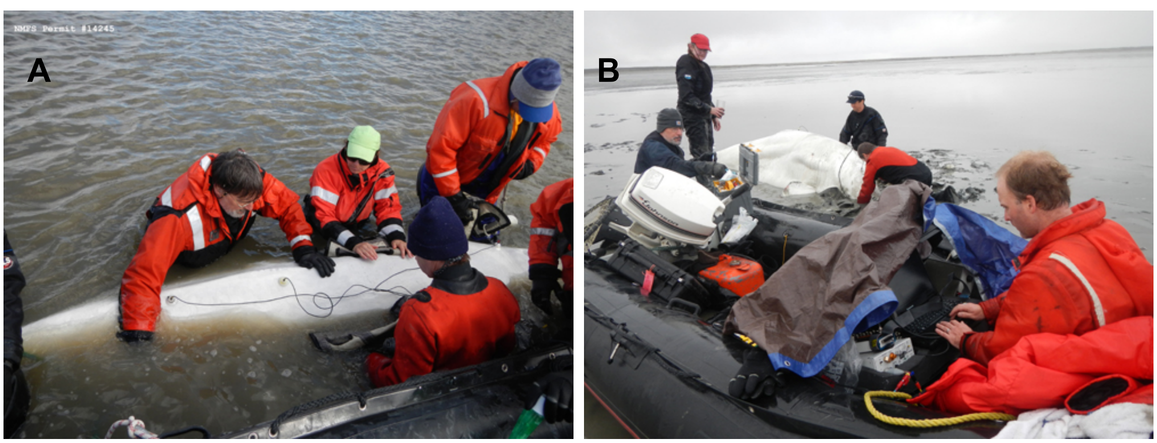

Figure 1.(A) A wild Bristol bay beluga temporarily restrained while hearing sampling is conducted. (B) The portable AEP equipment in use collecting hearing data on a temporily restrained beluga. (Photos take under NMFS permit # 14245).

WORK COMPLETED

Field work was based from Dillingham, AK and coducted in Bristol Bay where a population of approx. 2000 belugas reside and pass through. We were stationed in AK, from September 3-12, 2012. Of these days, four were poor weather conditions in which we could not go out. We ventured out in search of animals on six days: September 6, 8, 9,10,11,12. Seven animals were caught on these days (and 2 additional animals prior to our arrival in Dilingham), thus averaging more than one animal per day (Table 1). Audiograms were collected on 7 belugas (all animals available for testing) using AEP methods (Fig 1). "Full audiograms," consisting of at least 7 frequencies ranging from 4-128 kHz, were tested on all animals. For one animal, lower frequencies of 1-4 kHz was also examined using tone pips.

The data collection was very successful. The goal of this project was measurements from 6 animals; thus, with 7 animas we exceeded this target. We are extremely pleased that full audiograms were recorded from all animals. This will provide substantial support for the analyses proposed for this work. These are the first audiograms of wild belugas and the first population evaluation of hearing in an odontocete species other than bottlenose dolphin (*Tursiops truncatus*). Seven full audiograms increases the current beluga publised audiogram sample size by 233% and provides the only hearing data for wild belugas. We expect these data will greatly enhance our knowledge of beluga hearing and wild odontocetes in general. Baseline audiograms (7-10 frequecies) were collected in as little as 35 min (Table 1; these times include pauses in the data collection as other health measures were made). More detailed measures were recorded when addition time was avialable. The mean time from AEP data collection start-to-finish was 48 min, and the mean number of frequencies assessed was 11. Additional samples collected on the animals included blood for: hematology, serum chemistry, hormone studies (stress and reproductive) and disease screening (immunology, bacteriology and virology) for both blood and skin samples (lesions). Other samples included: fecal analysis, blubber thickness and energetics analysis, respiratory tract disease and stress analysis (breath sampling), and satellite tagging. Collecting low-noise, high quality hearing data, and the overall productivity substantially advances and supports AEP methodoligies as field-applicable.

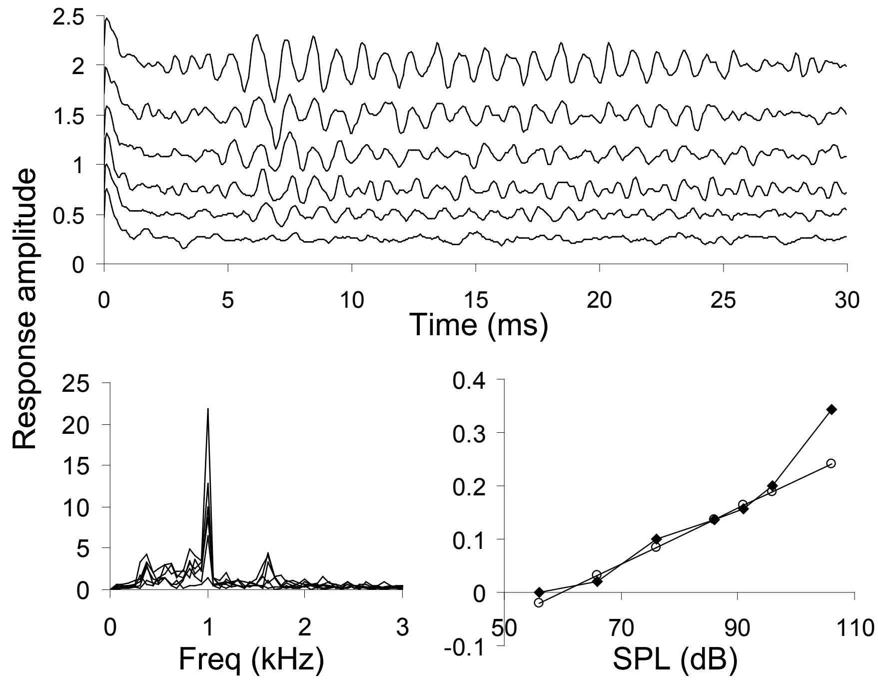

Figure 2. Upper plot: AEP waves and succeeding EFR to amplitude modulated tone stimuli presented at the rostrum tip of the lower jaw for the frequency 54 kHz. Lower left panel: Fourier transform of the envelope following responses showing a peak in the stimulus frequency of modulation of 1 kHz. Lower right panel: Plot of the peak value of each Fourier spectra at the 1 kHz modulation frequency (line with solid circles) for each SPL presented and best fit regression (line with open circles) used to determine the threshold at 54 kHz. The threshold identified above is at 60 dB re: 1 µPa rms.

RESULTS

The focus of this project is the off-line analyses (Figure 2) of these audiograms including comparisons within the wild animals and to captive beluga data (Figure 3). These assessments are under way. Four full audiograms have been constructed from the data. They are plotted together and relative to the audiograms of published captive belugas. All audiograms will be plotted indiviually as well as with a mean audiogram ± SD and quartile ranges. The goal is to determine the "best" hearing senstivity in multiple ways including through: (i) the most senstive audiogram overall (and at low, mid and high frequencies), (ii) the mean audiogram, and (iii) the overall variance of hearing as well as differences assoicated with age, sex and health condition. From these data we will evaluate potential differences within this Bristol Bay population. It will allow comparisons to the known hearing abilities of the few captive belugas studied and the populations of captive bottlenosed dolphins examined. It will also allow us to estimate hearing abilities for wild belugas in other popuations which are at greater risk for chronic effects of anthropogenic noise exposure and other stressors, including the endangered Cook Inlet population.

Intial AEP reponses were very clear and distinct from the background noise, and showed typical, identifiable trends including a delay (approx. 5 ms) from stimulus onset to start of the reponses (Figure 2). Envelope following responses (EFR), or auditory steady-state reponses (ASSR), decreased in response amplitude with decreasing stimulus intensity. A portion of each record was fast-Fourier transformed and the values at 1 kHz (the stimulus modulation rate) was plotted relative to its respective, generating, sound pressure level. A best-fit linear regression was then used to determine the threshold.

All animals showed “good” hearing (Figure 3). Sensitivites were as low at 45 dB SPL and reponses were found up to 100 kHz in all animals and up to 150 kHz in 3 animals. Most had a high frequency cut-off of 128 kHz. These hearing abilities are excellent compared to many other odontocetes, including captive beluga whales (Figure 3B). Upcoming analyses include comprehensively comparing these wild beluga audiograms and addressing potential deviations to the concurrent health measures also recorded. Overall, we are excited about the success of this project (clear, field-based AEP results on 7, wild, belugas – all animals avalable for testing) and plan to rapidly analyze and submit the results.

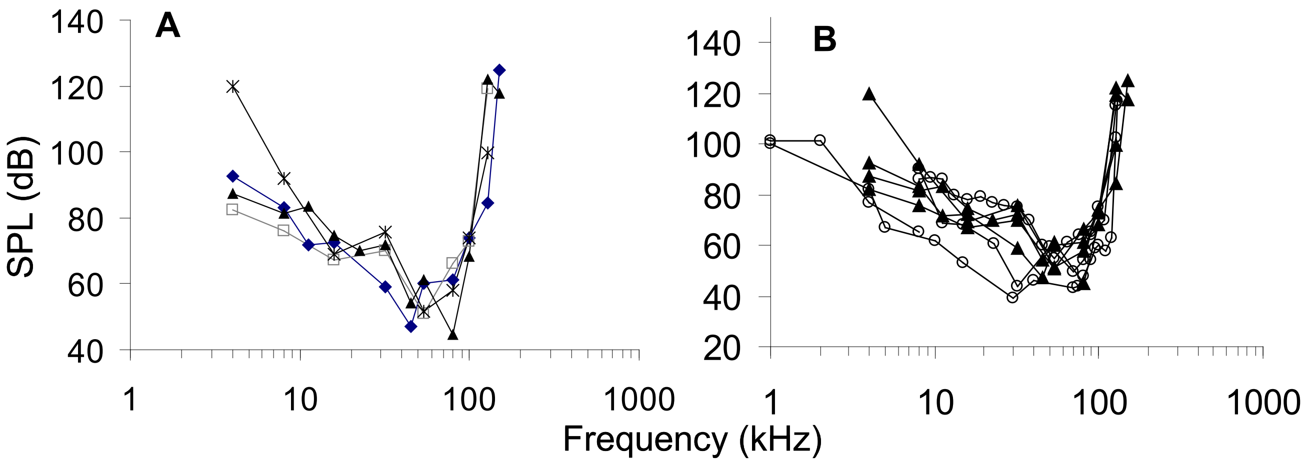

Figure 3. A: Completed audiogram of four belugas captured in Bristol Bay, AK. B: Available audiograms from these four wild animals shown in A (black triangles) and four captive beluga studies (open circles).

Table 1. Beluga whales obtained for health assessments, sampling, and tagging in Bristol Bay, AK (Sept 2012). Measures shown include audiogram duration, and number of frequencies tested.

Animal ID Number	Date	Sex	Age class	Length (cm)	Axillary girth (cm)	Handling time (min)	Audio. dur. (min)	Freq range (no. tested)
DLBB12-03	9/8/2012	F	Subadult	272.5	68	77	48	4-150 (11)
DLBB12-04	9/8/2012	M	Adult	350	84	86	52	4-150 (9)
DLBB12-05	9/9/2012	F	Adult	300	190	80	39	4-150 (12)
DLBB12-06	9/11/2012	F	Adult	375	250	83	35	4-128 (8)
DLBB12-07	9/12/2012	M	Adult	390	245	115	43	4-128 (7)
DLBB12-08	9/12/2012	F		310	192.5	83	44	4-180 (14)
DLBB12-09	9/12/2012	F	Adult	390	267.5	114	77	1-150 (17)

IMPACT/APPLICATIONS

Scientific significance: The proposed work will provide needed data on the hearing abilities of wild Arctic belugas. This information will improve our understanding of the natural, baseline hearing abilities, and natural auditory variation. These data will be compared to those from captive animals offering an assessment of the validity of captive auditory research, substantially increasing our knowledge of beluga hearing, and initiating a preliminary estimate of beluga audiogram demographics based on coordinated physical health measurements. There are currently no measures of hearing for wild beluga whales and few data from healthy representatives of most odontocete species, suggesting these data will be intrinsically valuable to evaluating beluga whale hearing and comparatively important to understand hearing in wild odontocetes. Results may be applied to impacted and declining populations such as the endangered Cook Inlet belugas. Additionally, the success of these field hearing tests highlight the progress that can be gained in short periods of time using AEP procedures. This supports additional AEP applications to other populations of cetaceans including stranded animals and additional safe capture-release operations.

Naval significance: Due to the opening of the Northwest Passage and interest in Arctic resources, naval activities (amongst others) are increasing in northerly beluga waters. This will raise interactions between naval practices and this protected species. Identifying the frequencies which belugas are most sensitive is important to minimizing operational disturbances. Information gained will address odontocete population hearing diversity, means of mitigating potential sonar-induced impacts, supporting encounter avoidance and assessing future effects.

RELATED PROJECTS

1) Beluga tagging Health Assessment- NMML/Georgia Aquarium. Collaborators: Alaska Department of Fish and Game, Alaska Sealife Center, Bristol Bay Native Association, Alaska Pacific Univeristy.

Beluga captures were made for this health assessment project. The hearing study presented here was incorporated as part of the health status for the first time this season.

2) Satellite-linked depth-recording LIMPET tag testing in Bristol Bay Belugas – Alaska Sealife Center.

Five temporarily restrained belugas for the health assessment project were instrumented with LIMPET tags with a pneumatic gun to test the viability of this tagging method and the duration of the tag transmission.

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PUBLICATIONS

Baseline hearing measurements in Alaskan belugas. M Castellote, TA Mooney, R Hobbs, L. Quakenbush, C. Goertz, E. Gaglione. In preparation.

HONORS/AWARDS/PRIZES

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