First description of beluga hearing in the wild

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BACKGROUND

Belugas (*Delphinapterus leucas*) have been identified as Arctic ecosystem sentinels because they are broadly dispersed, high trophic feeders and are likely to be negatively impacted by climate change. They are highly dependent on hearing and underwater sound to enact key biological activities such as forage for prey, communicate with conspecifics and navigate. Therefore, understanding how noise might affect their sensory ecology is a priority to encourage their survival and address the broader potential acoustic impacts within the Arctic. Ocean noise levels are increasing in the Arctic due to an increase in human activities, which are related to the interests in Arctic resources and the opening of the Northwest Passage. This is of concern because several beluga populations are endangered and considered strategic stocks. Their hearing sensitivities are unknown. The work presented here describes for the first time how wild belugas hear.

OBJECTIVE

This objective is part of a multidisciplinary project (Bristol Bay Beluga Health Assessment Study). See posters by Andrews et al., Goertz et al. and Keogh et al. for other project results.

To describe the hearing sensitivity of temporarily restrained Bristol Bay belugas using auditory evoked potential (AEP) techniques for the range 4-180 kHz in the shortest time possible.

METHODS

1) Solitary belugas were captured using a 300-ft. long net, 15-ft deep with 21 in. mesh deployed from an 18 ft. aluminum skiff with a 70 hp outboard assisted by an additional two to four support boats. Animals were restrained with a combination of a tail rope, head hoop net, and a modified canvass sling.
2) Sinusoidally amplitude modulated (SAM) tone-bursts were presented at 4, 8, 11.2, 16, 22.5, 32, 45, 54, 80, 100, 110, 128, 140, 150, and 180 kHz through a jawphone placed in the lower jaw near the rostrum tip. AEP responses were collected from gold, surface electrode sensors embedded in silicone suction-cups (Figure 1).
3) Envelope following responses (EFR) were Fast Fourier transformed (FFT) to obtain frequency peak values for each stimulus at different intensities. Based on FFT-EFR results, hearing thresholds were estimated for each frequency by regression analysis.

RESULTS

Audiograms were obtained on average in 45 minutes. However, AEP collection was often paused to adjust animal position or relocate it to follow the tide, or while another sample type was obtained. Thus, lower duration of 36-38 min is a good indication of how fast the procedure occurred in these particular environmental and contextual conditions. All audiograms had a general U-shape typical of mammals and odontocetes with a steeper slope at the high frequency cut-offs, and a more gradual increase in thresholds a the lower range of hearing. The two males (belugas #2 and #5) appeared to have upper hearing limits of 128 kHz, and both had higher thresholds at this frequency than females (Figure 2). Substantial differences were obtained between audiograms reflecting the natural hearing variability for this species. Differences were as high as 45 dB (Figure 3B & 3C). Beluga #7 had the "best" overall hearing. Best average hearing was from 22.5 to 80 kHz with 59-60 dB thresholds (Figure 3A). Best absolute hearing was at 80 kHz with a 43.8 dB threshold.

Figure 1: (A) Beluga #1 during AEP collection. The suction-cup sensors are visible and attached to the animal. (B) Beluga #7 for which the tide receded too rapidly and left the animal and the inflatable boat stranded for several hrs. The AEP equipment is being operated in the inflatable and the whale is behind the inflatable.

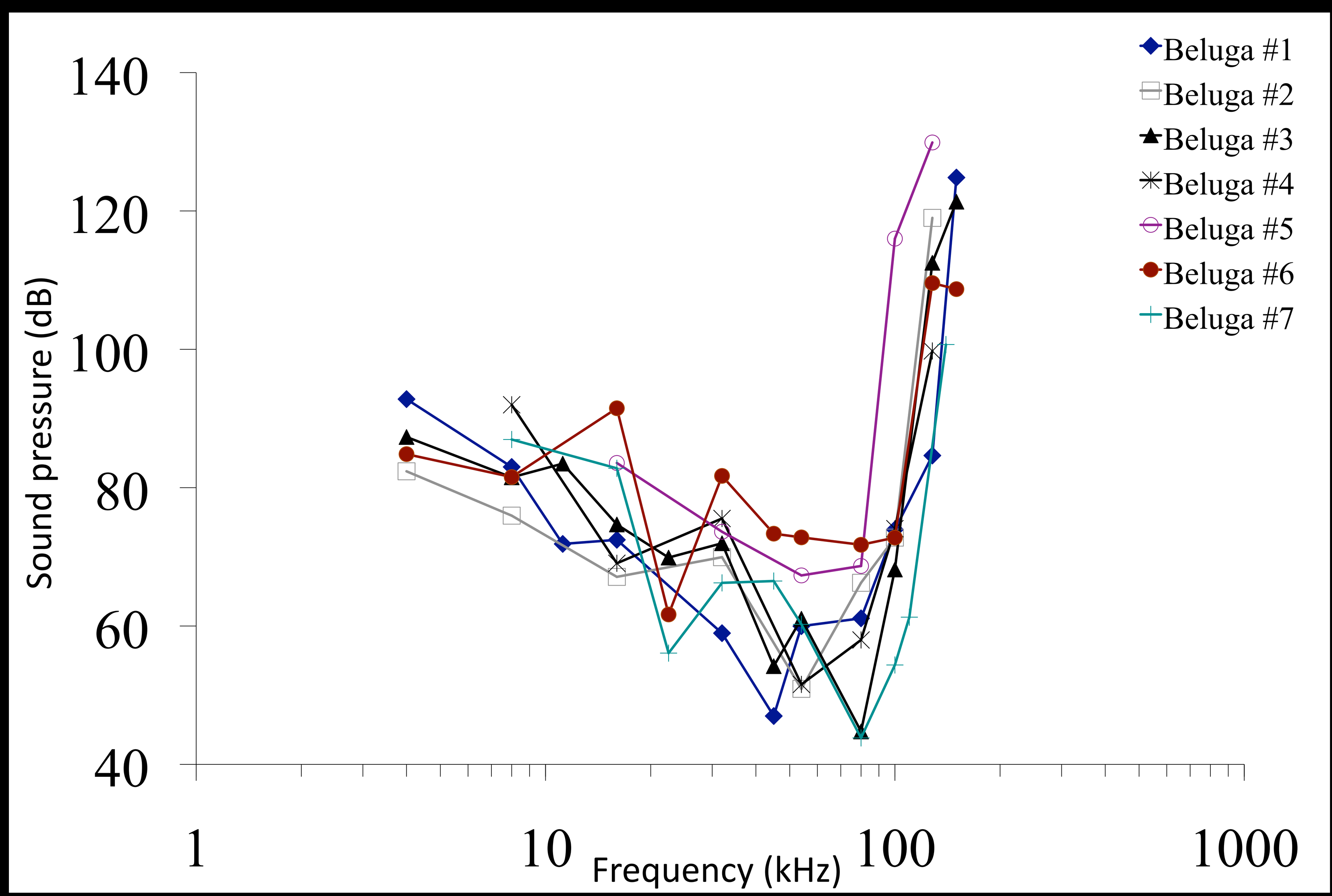

Figure 2: AEP audiograms of all seven wild belugas. (Sound pressure levels are in dB re 1 μPa).

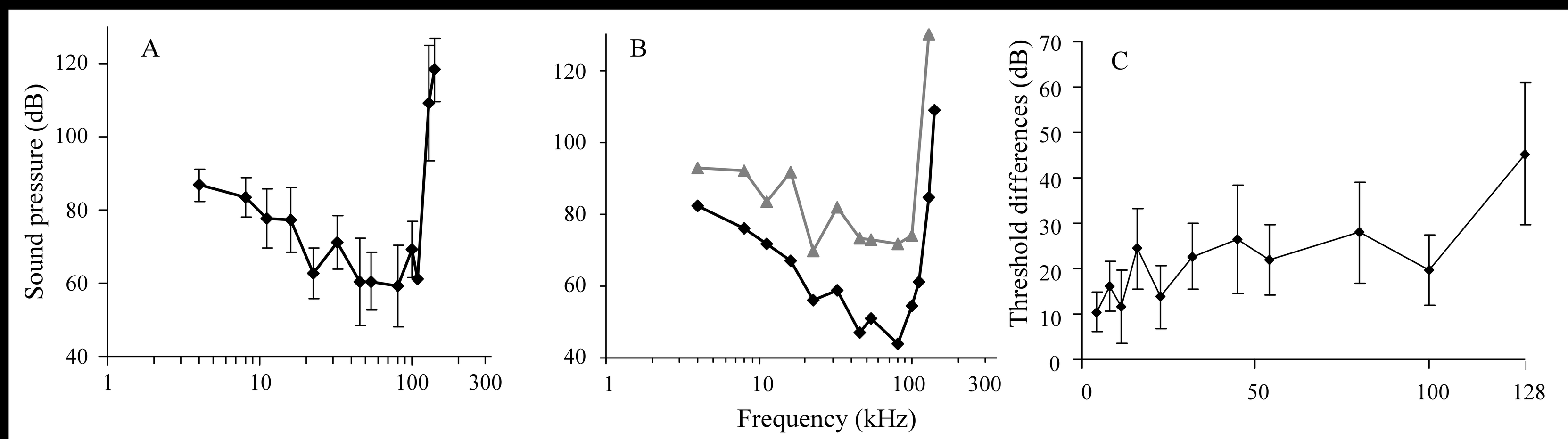

Figure 3: (A) The mean audiogram ± s.d. values. (B) Composite audiograms constructed by plotting the thresholds of maximal (black, diamonds) and minimal sensitivity (grey triangles). (C) The difference between maximal and minimum thresholds plotted with the s.d. (Sound pressure levels are in dB re 1 μPa).

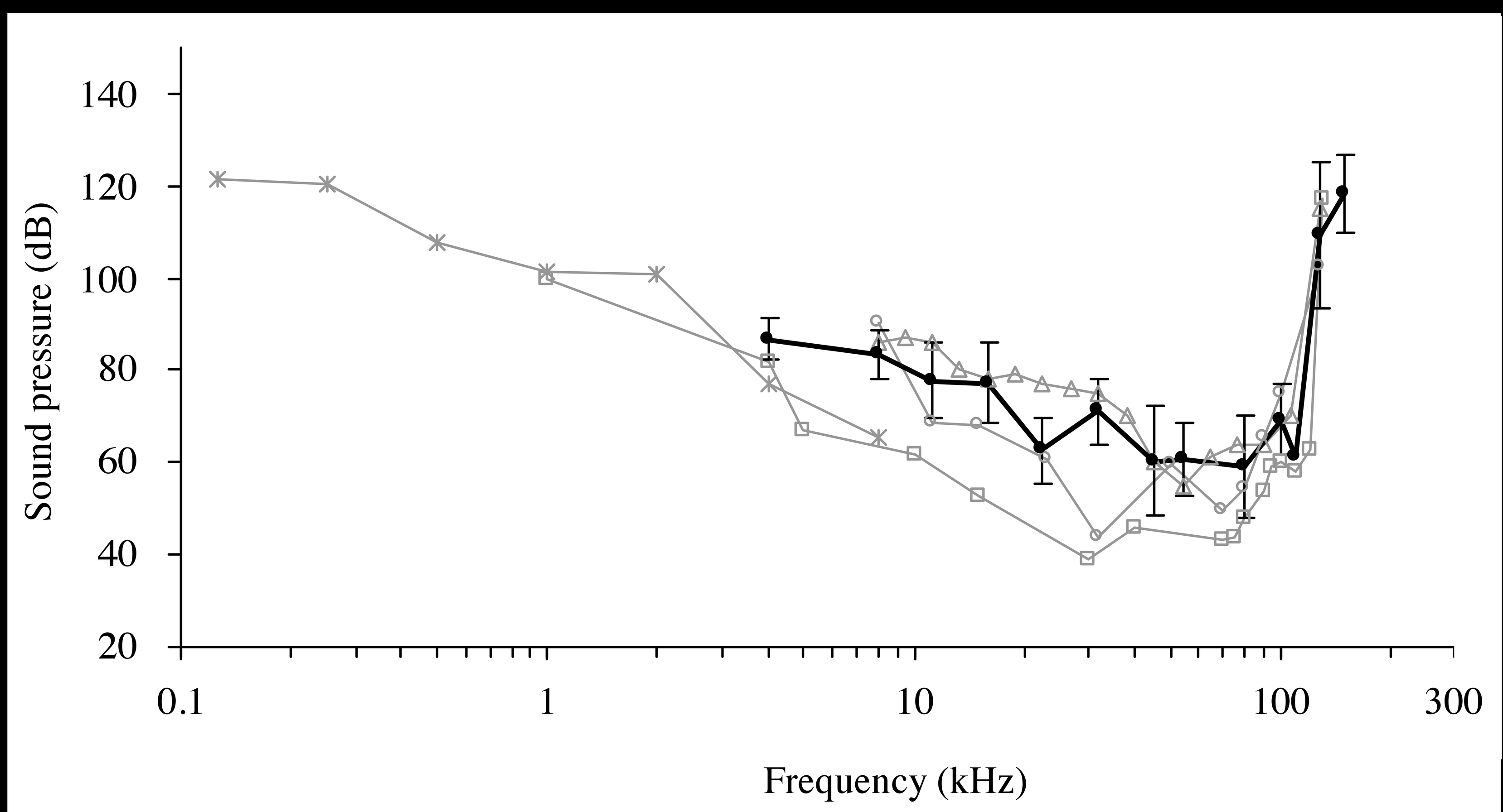

Figure 4: Mean wild beluga audiogram ± s.d. (black, circles) compared to the audiograms (grey, open symbols) from captive belugas: (White et al., 1978)-squares, (Awbrey et al., 1988)-stars, (Mooney et al., 2008)-circles, (Klishin et al., 2000)-triangles.

DISCUSSION

The shape of the mean audiogram is similar to descriptions from other odontocetes as well as captive belugas (Figure 3A & 4). In general, the hearing variability documented in captive belugas falls within the results collected in Bristol Bay. These results prove the validity of hearing studies in captive animals and ground-truth our baseline hearing knowledge for this species.

However, for several frequencies tested in Bristol Bay belugas, best hearing thresholds are well below the previously documented captive beluga hearing (e.g. 8, 22.5, 45, 80 kHz) even if there is a good general agreement. These results call for caution when variability in hearing data is not considered, in particular for management decisions (e.g. thresholds for anthropogenic noise disruption or injury).

The greatest differences in hearing abilities occurred at the high end of the auditory range (Figure 3C) in accordance with age-related haring loss. No evidence of hearing deficit was observed in low frequencies, where anthropogenic noise is prevalent.

Collecting AEP responses in temporarily restrained belugas proved to be a feasible and fast procedure. In view of the expected changes in the Arctic acoustic environment, expanding our knowledge on beluga hearing is of central importance for an appropriate conservation management framework. The impact of anthropogenic noise has been identified as a serious threat potentially impeding the recovery of the Cook Inlet beluga population (National Marine Fisheries Service, 2008). In the contrary, the Bristol Bay beluga population is a healthy population (National Marine Fisheries Service, 2008). Their acoustic environment is also very different; all the chronic anthropogenic sources typically found in Cook Inlet beluga habitat are essentially absent in Bristol Bay habitat. This suggests that Bristol Bay belugas are a valuable asset to evaluate baseline hearing and health measures for comparison to effected populations, such as Cook Inlet belugas.

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