# Anthropogenic noise sources and sound production of beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska

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## Abstract

Beluga whales (*Delphinapterus leucas*) in Cook Inlet, Alaska are geographically and genetically isolated from other Alaskan beluga populations, and were listed as endangered in 2008. One potential threat to the recovery of the population is anthropogenic noise, which may disrupt communication and normal behaviors throughout the population's limited range. In order to evaluate this potential problem, knowledge of anthropogenic noise sources and levels, and in-depth understanding of the animals' acoustic behavior is necessary. This project used a single boat-based hydrophone system to evaluate noise levels at several locations in Cook Inlet on 6 days from August 2-14, 2007. Belugas were encountered on two days during this period, at the Port of Anchorage and near the mouth of the Little Susitna River, and recorded vocalizations were analyzed to develop a preliminary catalog of the whales' vocal repertoire. Beluga vocalizations were measured and categorized into whistles, high-frequency whistles, and pulsed/noisy sounds. Most recorded vocalizations were similar to call types found in other beluga populations. Vocalization frequencies ranged from 0.381 kHz to 24 kHz (the limit of our recordings), with most energy at frequencies above 2 kHz. Recorded noise sources included ships at and around the Port of Anchorage, commercial and military airplane over-flights, and tidal flow. Broadband and 1/3-octave band levels were evaluated for all anthropogenic and natural noise sources. Vessel noise levels were highest below 0.5 kHz, but frequencies ranged to greater than 8 kHz at the Port of Anchorage. Based on the overlap in frequency between beluga vocalizations and noise, anthropogenic sound can potentially interfere with beluga communication close to transiting and docked vessels in Cook Inlet.

## Methods

• Recorded underwater sounds with a calibrated ITC 6050C hydrophone and digital recording system. Recording platform: Avon inflatable boat owned by NMFS. Sampling frequency: 48 kHz, 16 bit.

• 13.7 hours of recordings made opportunistically on 6 days between 2 and 14 August 2007. Belugas were sighted and recorded on 9 and 14 August.

• Selected calls with high signal-to-noise rations for analysis with Raven bioacoustics software. Calls were categorized as in Belikov and Bel'kovitch (2006), and matched with existing types from available literature.

• Viewed waveforms of recorded noise to select 10-second clips from noisy and quiet portions (N=165 clips from 125 recordings). Used custom MATLAB 7 programs to analyze 1/3-octave and broadband (20 – 20,000 Hz) RMS noise levels. Statistical analyses performed in Minitab.

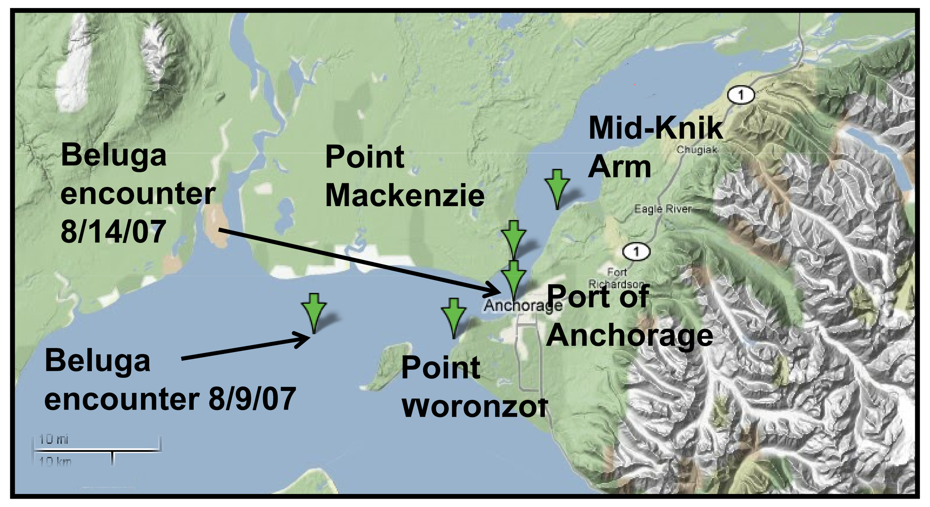


**Figure 1:** Approximate recording locations for the study (green arrows). Up to two locations were sampled per day. Map source: maps.google.com.

## Objectives

• Establish baseline data on noise levels near the Port of Anchorage prior to port construction and expanded operations.

• Determine relative contributions of anthropogenic sources and tidal currents to overall noise levels and frequencies during this period.

• Describe the vocalizations of Cook Inlet belugas, and investigate the amount of frequency overlap between vocalizations and noise levels in Cook Inlet.

## Noise Levels

• Broadband RMS levels were highest at the Port of Anchorage and Point Mackenzie, across Knik Arm from the port (Table 1).

• High tide noise levels at the port and Point Mackenzie were significantly higher than at the other 2 sites ($t = 13.25$, $p < 0.001$) (Figure 3).

• 1/3 – octave band levels peaked at frequencies below 500 Hz in the high traffic sites, but energy was present up to ~8 kHz (Figures 2 & 5).

**Figure 2:** 1/3 – octave band levels for two 10-second samples. Hearing curve adapted from Richardson et al. 1995.

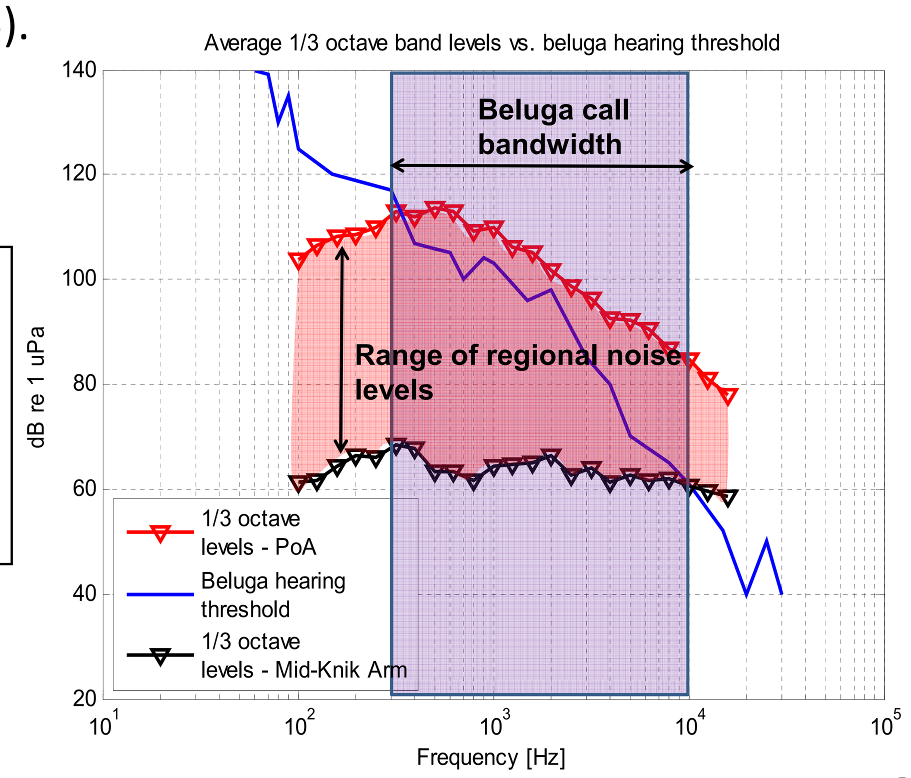


**Table 1:** Summary of high tide noise levels at measurement sites. Units are in dB re 1µ Pa unless otherwise noted.

| | Port of Anchorage | Point Mackenzie | Point Woronzof | Mid – Knik Arm |
|---|---|---|---|---|
| Mean RMS @ high tide ± stdev | 109.52 ± 4.74 (N=28) | 103.61 ± 6.25 (N=11) | 87.99 ± 2.60 (N=12) | 88.27 ± 7.96 (N=8) |
| RMS range | 102.80 – 123.26 | 95.42 – 116.66 | 84.13 – 92.2 | 81.27 – 102.03 |
| Peak 1/3 octave level (freq. band) | 113.61 (500 Hz) | 112.99 (100 Hz) | 69.51 (800 Hz) | 73.12 (400 Hz) |

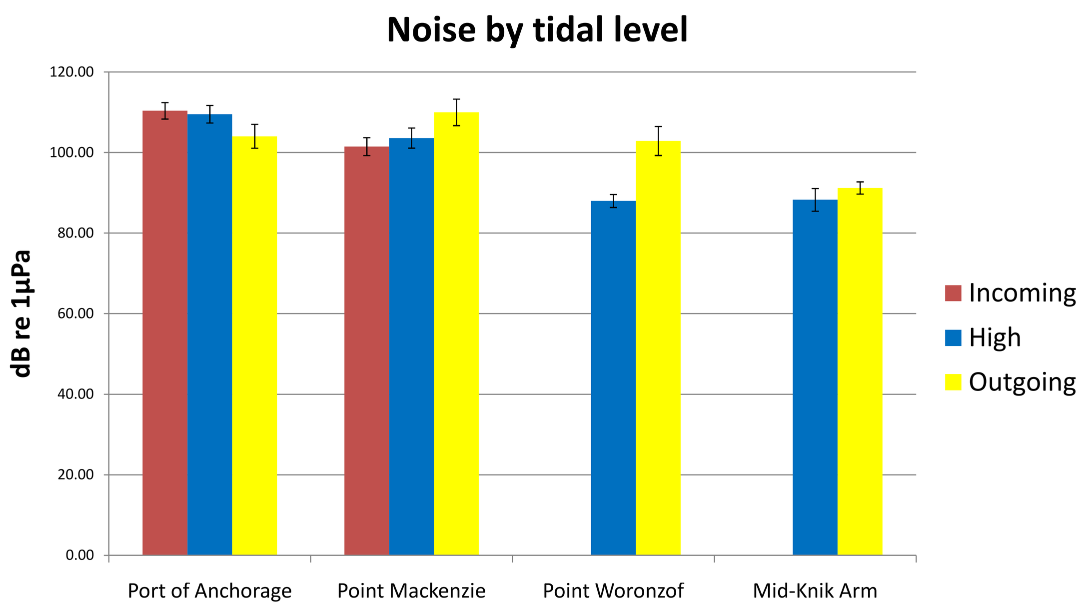


**Figure 3:** Broadband RMS levels varied by tidal level. The only site where noise at high tide was > noise at outgoing tide was the Port. Error bars represent standard error. High tide was ± 30 min. from predicted time.

## Vocalizations

• 1,384 total calls recorded; 1,023 useable calls analyzed (Figures 4 & 5)
• 405 whistles, 417 high-frequency whistles and 201 pulsed/noisy calls

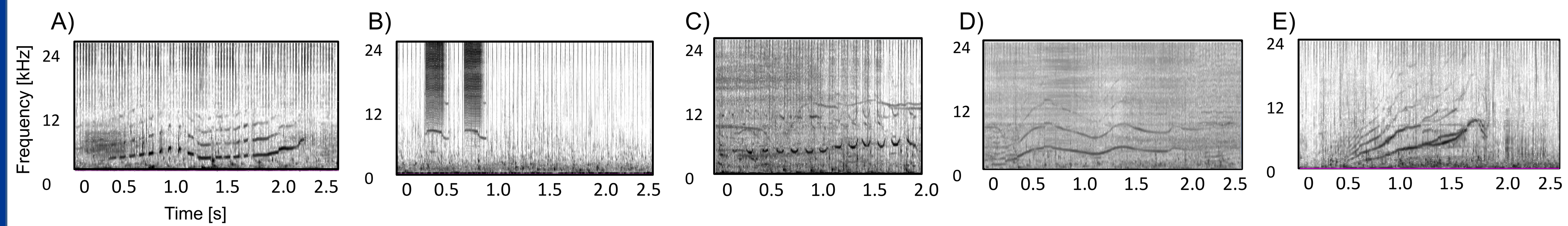


**Figure 4:** Example spectrograms of recorded call types. A) (N=6) Contoured pulsed series not found in any published repertoires. B) Contour described in Sjare & Smith (1986); noisy component is not. C) Chirp series described in all published repertoires; Belikov & Bel'kovitch (2006) HFWT4. D) Harmonic "whistle"; Belikov & Bel'kovitch (2007) WT8. E) Upswept call; Belikov & Bel'kovich (2007) WT11. Spectrogram parameters: 256 point Hanning window, 50 % overlap; 256 point DFT.

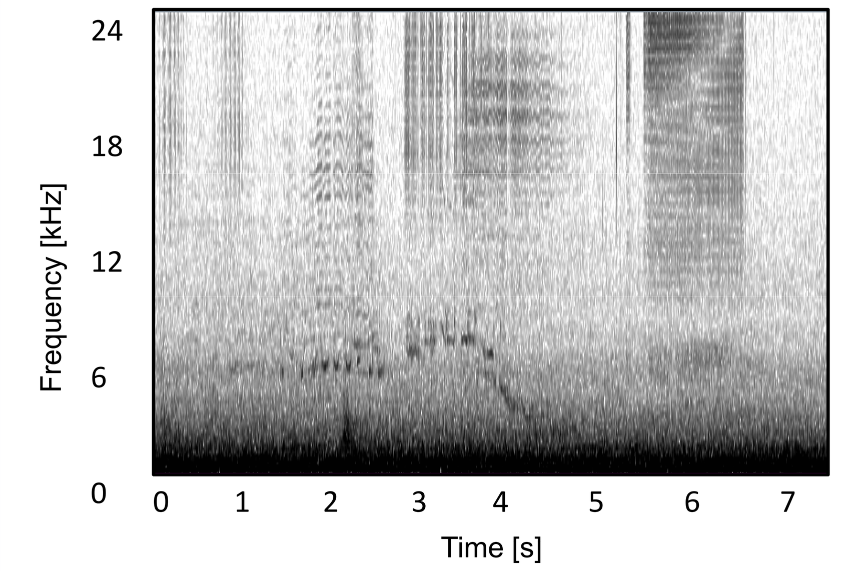


**Figure 5:** Beluga vocalizations and ship noise recorded at the Port of Anchorage on 14 August 2007. 6-8 animals were observed travelling from north to south during loading of the container ship "Midnight Sun".

## Conclusions

• The majority of beluga calls were at frequencies likely to be overlapped by ambient noise. Pulsed calls with no definitive contour often occurred at the limits of our recordings (24 kHz) (Figure 5), while whistles and other contoured calls ranged from 0.381- 10 kHz.

• Average broadband, high-tide sound levels in developed areas (Pt. Mackenzie and the Port of Anchorage) were 15 – 22 dB higher than those observed in low-traffic areas (Pt. Woronzof & mid- Knik Arm).

• Higher sound levels occur around transiting vessels and those performing dock operations, as observed in Blackwell and Greene (2002). Such levels may degrade the signal-to-noise ratio of frequency-overlapped vocalizations and interfere with beluga communication.

## References

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