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Effects of Low-Frequency Anthropogenic Noise on the St. Lawrence Beluga Hearing and Communication Processes: a Model

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CURRENT DATA FROM THE ST. LAWRENCE RIVER ESTUARY AREA

The average source level for whale watching vessels in the Tadoussac, Quebec, Canada area is 151 dB re 1 μPa at 1 m. Source levels increase with speed and are audible out to 10 km from two of the three sites monitored. The average time of continuous whale watching at close range (within 200 m) by at least three large vessels and up to five small craft and zodiacs was 2.7 hours at the three monitored sites (Tab. 1).

determined nor was there good knowledge of the animals' othology and the testing was done in either pool systems or embayments The behaviour of the Beluga varies but in many cases they remain with the larger whales. These behaviours range from habituation and acclimation (no obvious change of behaviour from the "norm") to flight. The groups traverse these sites routinely each day and mainly remain near the surface (down to 8 m). They have been seen following merchants but rarely whale watchers.

	Year 1995					Year 2001				
	dB re 1 μPa at 500 Hz									
	7:00	10:00	13:00	16:00	Marginal Mean	7:00	10:00	13:00	16:00	Marginal Mean
Saguenay	98.0205	106.5074	117.0003	100.5716	105.52495	96.9811	108.002	119.575	120.5996	108.1860333
Channel Head	101.2314	120.7552	122.9611	114.5951	114.8857	103.0001	123.9204	125.3961	115.9819	117.4388667
Allouette	91.1153	98.9857	98.1111	116.8251	101.5093	925631	120.8144	124	109.7229	112.4558333
	Year 1995					**Year 2001**				
	dB re 1 μPa at 1000 Hz									
	7:00	10:00	13:00	16:00	Marginal Mean	7:00	10:00	13:00	16:00	Marginal Mean
Saguenay	95.7666	102.3036	106.6135	100.5639	101.3119	98.1247	122.1824	139.0200	128.2837	121.9033
Channel Head	98.6279	99.7716	113.4151	108.2873	105.0255	116.4821	124.5229	125.001	128.5639	123.6425
Allouette	82.3825	91.0019	92.3428	95.7212	90.3621	89.4246	97.1932	94.2359	88.8025	91.4141

Tab. 1: Comparison of mean noise levels at three sites across four times of day in 1995 and 2001.

- Octave band noise (for = 504 and 1,007 Hz) *versus* audibility,
- 15 dB above at 500 Hz,
- 22 dB above at 1000 Hz,
- Broadband noise,
- Dominant tones from below 50 Hz to 1 kHz (excluding zodiacs).

The relationship of the noise to Beluga hearing can be observed and we do have hearing threshold curves for these animals (Fig. 1). The hearing threshold curves are based on behavioural, pure tone audiometry using captive animals. There are still issues with this type of hearing testing including the fact that age in some cases could not be accurately

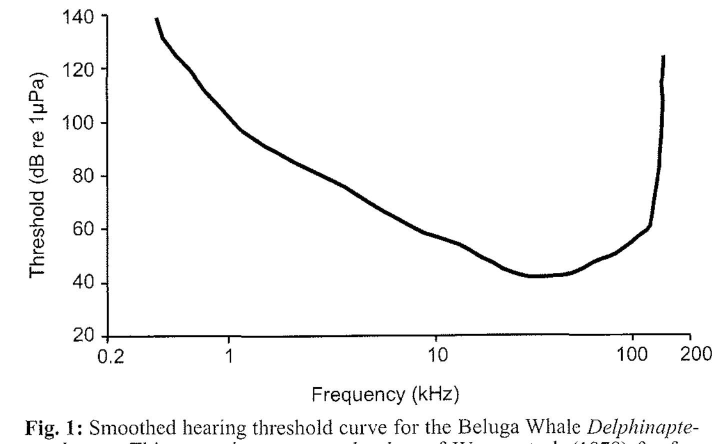

Fig. 1: Smoothed hearing threshold curve for the Beluga Whale *Delphinapterus leucas.* This curve incorporates the data of WHITE et al. (1978) for frequencies from 1 kHz to 120 kHz and SCHEIFELE (1996) from 100 Hz to 1 kHz.

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CURRENT METHODS OF NOISE MONITORING AND ANALYSIS

• Acoustic Tags; exposure duration, location, noise level- this year.
• Acoustic Buoys; used with vertical arrays planned.
• Articulation Index Methodology; used with vocalization classification for communications interference assessment being tested.

Three specific notes of caution regarding monitoring and judgments on noise impacts on cetacean hearing must be addressed:
(1) Frequencies of the noise relative to the dynamic range of hearing especially when specifying frequencies of interest such as with regard to animal communication and vocalization or echolocation frequencies.
(2) Intensity. The decibel is NOT a good unit of measurement with regard to hearing and noise. Simply making physical/mathematical conversions between air and water is in error and not satisfactory since it has no relevance to the ear and hearing and assumes that aerial and aquatic ears are equivalent. Intensity (Wm^{-2}) is a better choice.
(3) Duration of exposure is the item that actually forms the basis of damage risk criteria once the previous two items of interest are chosen. Constant exposure to lower intensity sounds can still cause hearing damage in the long run (reference OSHA Standards for occupational noise exposure and hearing loss).

In addition, "acoustic behaviour" is not a good indicator of hearing damage since:
(1) it cannot be shown with certainty that a behaviour on the part of an animal in the natural environment is actually the direct result of an acoustical event;
(2) it is likely that by the time the behaviour occurs, some hearing damage may have already been done.

SUMMARY

(1) St. Lawrence River Estuary appears to be an acoustic "hot-spot" in summer.
(2) Diving and foraging patterns need to be assessed in the noise to determine actual long-term hearing effects.
(3) Mitigation will require behavioural changes on the part of humans and can only be based presently on what we know of human and terrestrial animal information and audiology.
(4) More information is needed on central auditory processes in marine mammals to fully understand the impacts of noise.
(5) Some human audiological and speech science methods may prove useful in analyses.
(6) Artificial neural networks and information analysis techniques may be useful in the near-term

References

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