Aquatic Mammals 2002, **28.1,** 90–92

The source level of harbour seal flipper slaps

Magnus Wahlberg[1], Sven-Gunnar Lunneryd[2], and Håkan Westerberg[3]

National Board of Fisheries, Institute of Coastal Research, Nya Varvet 31, 426 71 Va Frölunda, Sweden

Abstract

A new method to estimate the source level of marine mammal percussive sounds is presented. The signal is simultaneously recorded with a microphone and a hydrophone. The range to the sound source is estimated from the difference in arrival time between the underwater and in-air sound path. The method is illustrated with a field recording of harbour seal (*Phoca vitulina*) flipper slaps. Source levels ranged between 186–199 dB re 1 μPa pp. This is significantly higher than what has been reported for flipper slaps from captive dolphins. This may be due to the difference in performance between captive and free-ranging animals.

Key words: acoustic ranging, bioacoustics, harbour seal vocalization, marine mammal acoustics, percussive sounds, source level, *Phoca vitulina*.

Introduction

Marine mammals produce several types of percussive sounds, such as breaches, tail and flipper slaps. It is important to quantify the acoustic characteristics of such sounds to predict the acoustic interaction range with other species and conspecifics (Finneran *et al.*, 2000; Nacthtigall *et al.*, 2000). An understanding of the acoustic signals is also of value in the development of mitigation measures in marine mammal–fishery interactions, which was the background for the present study.

One important acoustic feature is the source level, which is defined as the acoustic intensity 1 m away from the sound souce. To estimate the source level, the distance from the animal to the receiver must be assessed (Urick, 1983). This is a major problem in field studies. To our knowledge, there are only three previous source level studies of marine mammal slaps. Both Finneran's *et al.* (2000) and Nacthtigall's *et al.* (2000) measured on captive bottlenose dolphins (*Tursiops truncatus*), and Thompson's *et al.* (1986) field study on humpback whales (*Megaptera novaeangliae*), used visual cues to estimate the whale-to-hydrophone distance. Here, we describe an easy acoustic method for ranging marine mammal percussive sounds. The method is demonstrated with a field recording of harbour seal (*Phoca vitulina*) flipper slaps.

Materials and Methods

The sound recording was made in July, 1999, close to the island of Ursholmen on the Swedish west coast (58°50′N, 10°59′E). The area is a well-known breeding site of harbour seals, *Phoca vitulina* (Härkönen *et al.*, 1999). A simultaneous underwater and in-air recording was made (Fig. 1a). For the underwater recording, we used a *B&K 8101* hydrophone connected via a home-made amplifier to the recorder. The in-air recording was made with a *Primo EMU-4535* microphone supplemented with a directional element (*Primo EMU-4533*). The recorder was a *Sony TCD-D7* DAT recorder (sampling frequency 48 kHz, built-in antialias filter). The frequency response was 20 Hz–20 kHz and 20 Hz–15 kHz for the underwater and in-air

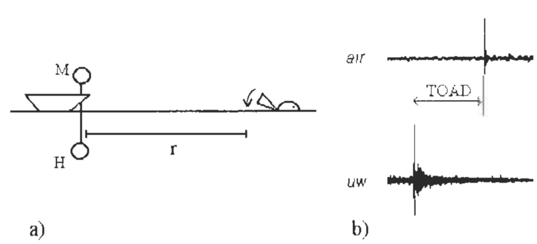

Figure 1. (a) Recordings were made from a small boat with a hydrophone (H) and a microphone (M) connected to a tape recorder. (b) Due to the difference in sound speed between air and water, sound arrives later at the microphone than at the hydrophone.

[1]Present address: Center for Sound Communication, Aarhus University, Department of Zoophysiology, CF Møllers Allé Building 131, DK-8000 Aarhus C, Denmark.

[2]Present address: Tjärnö Marine Biological Laboratory, SE-452 96 Strömstad, Sweden.

[3]Present address: National Board of Fisheries, Box 423, SE-401 26 Göteborg, Sweden.

Table 1. Estimates of the source level of flipper slaps from a wild harbour seal.

Slap	*RL* [dB re 1 µPa pp]	*TOAD* [ms]	Range [m]	*TL* cyl./sph. [dB]	*SL*cyl./sph. [dB re 1 µPa pp]
1	147	206	91	19/39	166/186
2	154	160	71	18/37	172/191
3	159	220	97	20/40	179/199

The Transmission Loss (*TL*) and Source Level (*SL*) are given for spherical and cylindrical spreading, *RL*: Received level, *TOAD*: Time of arrival difference between the in-air and underwater path.

recordings, respectively. Recordings were made from a small rowing boat with the hydrophone at a depth of 3–8 m. The water depth was 5–10 m. The recordings used in this analysis was made at a 100 m range from a harbour seal performing underwater acoustic displays (van Parijs *et al.*, 1997). Every few minutes the seal emerged and forcefully slapped the water surface with its flipper.

Three flipper slaps were chosen for underwater source level estimation. The received level (*RL*) was measured relative a *B&K 4223* calibrator signal recorded on tape. The range (*r*) to the animal could be assessed through the time-of-arrival difference (*TOAD*) between the in-air and underwater recording (Fig. 1b):

$$r = TOAD\frac{c_w c_a}{c_w - c_a}$$

The sound velocity in water was $c_w = 1499$ m/s, calculated from the Medwin equation (Urick, 1983) with salinity 21 ppm and a temperature at 18°C (measured a few kilometres away from the recording site). The sound velocity in air was $c_a = 341$ m/s, calculated from Spiesberger & Fristrup (1990) with an air temperature at 15°C (air saturated with humidity). The transmission loss (*TL*) was assessed for the extreme cases of spherical ($TL = 20 \log r$) and cylindrical ($TL = 10 \log r$) spreading. The source level (*SL*) was calculated from the sonar equation (Urick, 1983):

$$SL = RL + TL.$$

Results

In Table 1, the SL measurements for three flipper slaps are presented. The slaps had a mean duration of 2 ms and an almost flat energy content up to 5 kHz. Slap numbers 2 and 3 probably contained significant energy at frequencies above 20 kHz. The source levels from these signals are therefore a lower bound.

It is important to estimate the magnitude of the error in the source level estimates. A major source of error is the transmission loss. The transmission loss is a function of the range, which in turn is a function of the sound velocities and the *TOAD*. The variables used for sound speed calculation (temperature, water salinity, and air humidity) were measured with an estimated precision of 20%. A linear error propagation model (Taylor, 1997) incorporated the possible variation in these parameters, as well as the *TOAD* measurement accuracy (1 ms). The model showed that the transmission loss estimate was not affected more than 1 dB. Thus, both the cylindrical and spherical transmission loss estimates are very accurate, but it is not obvious which one should be used for the source level estimation. The transmission loss was not measured in this study, but probably it was close to spherical (Urick, 1983). Thus, the most likely source level estimates range from 186–199 dB re 1 µPa pp.

Discussion

Even for a very conservative measurement of a seal slap source level (slap no. 1 with cylindrical spreading), the source level is almost as high as the maximum dolphin tail slap source level reported by Finneran *et al.* (2000) and Naethtigall *et al.* (2000). Using the (more probable) spherical spreading law gives source level estimates of 186 199 dB re 1 µPa, which is very similar to the 183–192 dB reported by Thompson *et al.* (1986) for humpback whales flipper slaps in the field. These source levels are much higher than the ones from captive dolphins measured by Finneran *et al.* (2000) and Naethtigall *et al.* (2000). Finneran *et al.* (2000) noted that their animal was not motivated for the tail slap exercise, and therefore their recordings are not fully representative. It is likely that field measurements of dolphin slaps could yield source levels at least as high as the seal slaps. This would have major consequences for calculations of acoustic interactions ranges between e.g. dolphins and tuna fish (Finneran *et al.*, 2000).

More recordings are needed to assess the full range of the sound characteristics of marine mammal breaches, flipper, and tail slaps. The method presented here can be implemented using a single hydrophone, a microphone, and a tape recorder. The transmission loss calculation is very resilient against fluctuations in the sound velocity and *TOAD* measurements. However, it is desirable to perform explicit transmission loss measurements in the recording area. The frequency analysis suggested that a recorder with a higher frequency response than standard audio equipment is needed to cover the whole frequency range of the percussive signals.

Acknowledgments

This study was financed through the Swedish research programme on Sustainable Coastal Zone Management, SUCOZOMA, funded by the Foundation for Strategic Research, MISTRA.

Literature cited

Finneran, J. J., Oliver, C. W., Schaeffer, K. M. & Ridgway, S. H. (2000) Source levels and estimated yellowfin tuna (*Thunnus albacares*) detection ranges for dolphin jaw pops, breaches and tail slaps. *Journal of the Acoustical Society of America* **107** (1), 649–656.

Härkönen, T., Hårding, K. C. & Lunneryd, S. G. (1999) Age and specific behaviour in harbour seals (*Phoca vitulina*) leads to biased estimates of vital population parameters. *Journal of Applied Ecology* **36,** 825–841.

Nacthtigall, P. E., Au, W. W. L., Pawloski, J. L., Andrews, K. & Oliver, C. W. (2000) Measurements of the low frequency components of active and passive sounds produced by dolphins. *Aquatic Mammals* **26.3,** 167–174.

Spiesberger, J. L. & Fristrup, K. M. (1990) Acoustic localization of calling animals and sensing of their acoustic environment using acoustic tomography. *The American Naturalist* **135,** 107–153.

Taylor, J. R. (1997) *An Introduction to Error Analysis*, 2nd ed, University Science, Sausalito, CA.

Thompson, P. O., Cummings, W. C. & Ha, S. J. (1986) Sounds, source levels, and associated behavior of humpback whales, Southeast Alaska. *Journal of the Acoustical Society of America* **80,** 735–740.

Urick, R. J. (1983) *Principles of Underwater Sound.* Peninsula, CA.

Van Pariijs, S. M., Thompson, P. M., Tollit, D. J. & MacKay, A. (1997) Distribution and activity of male harbour seals during the mating season. *Animal Behaviour* **54,** 35–43.