Sperm whales (*Physeter catodon L.* 1758) do not react to sounds from detonators

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A number of observations show that sperm whales (*Physeter catodon L.* 1758) react to various man-made pulses with moderate source levels. The behavioral responses are described to vary from silence to fear. Click rates of five submerged male sperm whales were measured during the discharge of eight detonators off Andenes, northern Norway. In addition, the behavioral response of a surfaced specimen was observed. Click rates of the submerged whales and the behavior of the surfaced specimen did not change during the discharges with received sound levels of some 180 dB *re* 1 μPa peRMS. The apparent lack of response to the discharges could be due to similarity between sperm whale clicks and detonations. Accordingly, it can be speculated that the discharges may have been perceived as isolated clicks from conspecifics. *© 2000 Acoustical Society of America.* [S0001-4966(00)03401-9]

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INTRODUCTION

The interest on marine mammals and anthropogenic noise has been extensive in the last decade, with discussions on the possible effects on the physiology and behavior of the animals exposed (e.g., Richardson, *et al.*, 1995). Several investigators have reported on sperm whale reactions to man-made noise.

Watkins and Schevill (1975) showed that sperm whales in the Caribbean react to pinger pulses [6–13 kHz, source levels (SL, dB *re* 1 μPa referred to 1 m) between 110 and 130 dB *re* 1 μPa] by interrupting their click production for 2 min or more. André *et al.* (1997) have investigated sperm whale reactions to a number of artificial sounds with SL of 180 dB *re* 1 μPa: Artificial codas caused the same reactions, as reported by Watkins and Schevill (1975), and 10-kHz pulses induced startle reactions among surfaced specimens, whereas observations on the acoustical responses to other artificial sounds with similar SLs were lacking or inconclusive. Two coda-exchanging sperm whales apparently reacted to high-level submarine sonar pulses by click interruption and immediate submersion (Watkins *et al.*, 1993). Mate *et al.* (1992) report that the number of sperm whales decreased when airguns was used in seismic surveys in the Gulf of Mexico, and investigations by Bowles *et al.* (1994) indicated that low-frequency sounds (209–220 dB *re* 1 μPa at 57 Hz) from the Heard Island Feasibility Test may have caused sperm whales to fall silent or to leave the test area. Watkins and Tyack (1991) and Whitehead *et al.* (1990) have reported that splashes when missing darts, used for tagging and biopsy, hit the water caused a startle reaction and defecation from sperm whales. To summarize, it seems fair to conclude that sperm whales in general are sensitive to man-made sound pulses.

In this paper we describe and discuss click rates from five submerged male sperm whales and behavior of one surfaced specimen during discharges of eight detonators off the continental shelf at Andenes, northern Norway (N69.23, E15.45)

I. METHODS

The detonators in the present study were used for calibration of hydrophone positions in a large aperture array [see Møhl *et al.* (2000) for details]. The detonators, containing 1.0 g TNT (Thiele and Oedegaard, 1983), were set off at depths between 3 and 15 m within 5 min on the 23 July (detonations 1–3) and the 24 July (detonations 4–8) 1998. The detonation produces an omnidirectional pressure wave consisting of a steep front with exponential pressure decay (Urick, 1983). After approximately 600 ms, bottom reverberation follows with exponentially decaying amplitude (Fig. 1). As the recording chains were adapted to sperm whale clicks, the detonations caused minor saturation of the recorders for which reason the derived SL of the detonators would be underestimated. Thiele and Oedegaard (1983) have measured a SL of similar detonators to be 231 dB *re* 1 μPa peRMS (peak equivalent root mean square), which have been applied in the present study. Only one of the whales monitored (*t*71036, Møhl *et al.*, 2000) could be positioned by time of arrival differences (TOADs) of the clicks at all five hydrophones of the array. The distance between this whale and the detonation was 840 m, which, based on a SL of 231 dB *re* 1 μPa peRMS and spherical spreading, yields an estimated received sound level (RL) at the whale of about 173 dB *re* 1 μPa peRMS. Clicks from the four other whales monitored could not be detected at all hydrophones of the array. However, the TOADs at the hydrophones of the vertical part of the array indicated that the distances between these whales and the detonations were similar or greater than in the case of the positioned specimen. In addition, the distance to a surfaced whale was determined by a *F*-band radar to be 450 m from the detonation. Estimation of the RL of a

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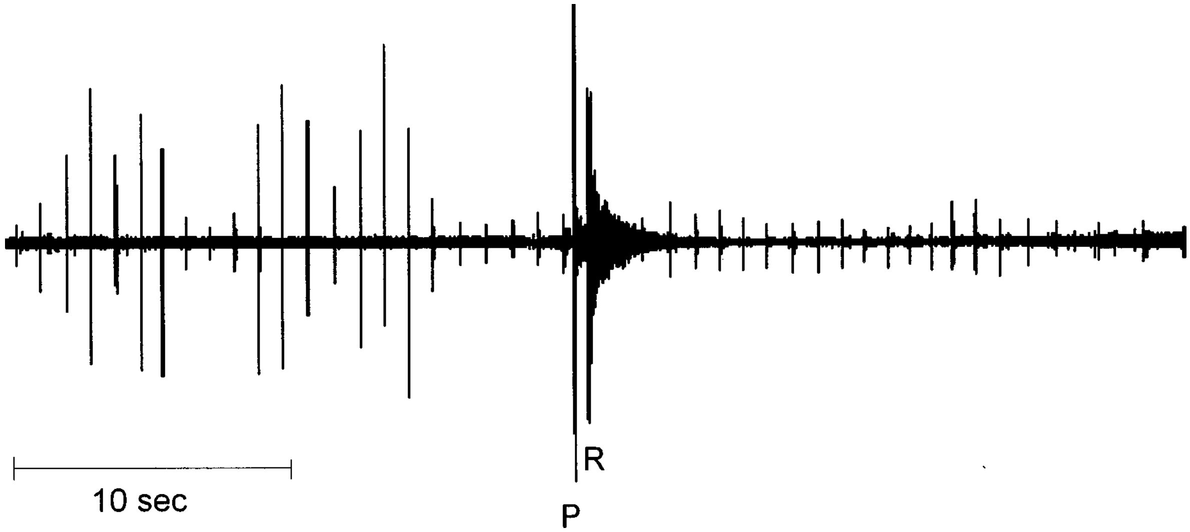

FIG. 1. Click train and discharge of the first detonator, *P*, pressure wave and *R*, reverberation. Note that the click train is masked by the reverberation within the first seconds after the discharge.

surfaced whale has some uncertainty, because of Lloyd mirror and other surface-related effects. An estimate neglecting such effects results in a RL at the whale of 179 dB *re* 1 μPa peRMS.

Click intervals in a period of 40 s, bracketing the discharge, were used as a measure of the behavioral response of the clicking whales to the detonations (Fig. 2). The pressure wave of the detonation and the following reverberation temporarily masked the click train (Fig. 1). Due to spectral similarity between clicks and detonations [Fig. 3(a) and (b)], it has not been possible to isolate the clicks from the reverberation by filtering within 2–3 s, after the onset. Consequently, the masking precludes any statements about putative clicks and their intervals in this period.

To insure that it was the same whale clicking before and after the onset, the TOAD of the clicks at three hydrophones (at 30, 100, and 460 m) in the vertical part of the array were measured throughout the sequences. No changes larger than half a millisecond before and after onset were found. Similarly, the interpulse intervals (Norris and Harvey, 1972) of the clicks before and after discharge were unchanged. These methods allowed us to distinguish between five different specimens exposed to eight detonations (Fig. 2).

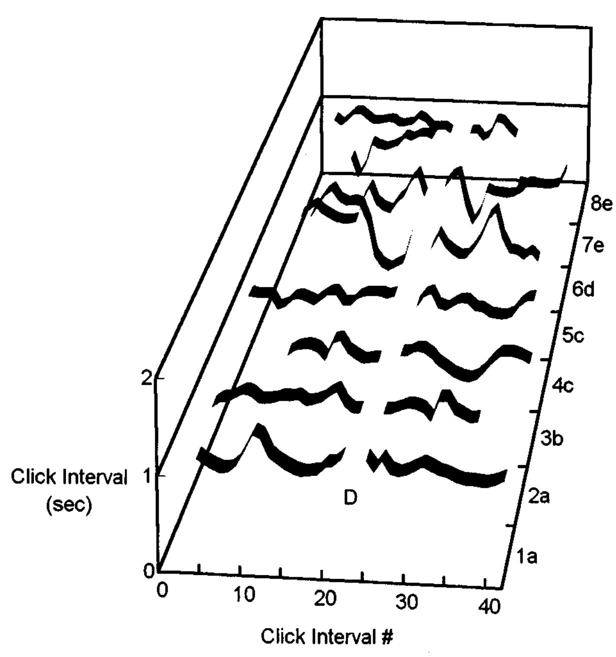

FIG. 2. Click intervals 20 sec before and after discharge of eight detonators (1-8). Letters a–e denote whales investigated. D marks the detonations.

II. RESULTS

In seven out of eight events, the whales did not interrupt their click production outside the aforementioned 2 s, of masking (Fig. 2). There is, however, no evidence to suggest that the whales interrupted their click production during the masking, as the click intervals following the discharges were largely unchanged compared to those prior to the discharges (Fig. 2). None of the changes in click intervals following the discharges were larger than what can be ascribed to the normal jitter (Fig. 2, Goold and Jones, 1995). In the case of the seventh discharge, the amplitudes of the clicks were decaying towards noise level prior to the discharge, and the clicks were not detectable within the next 13 s [Fig. 2; Fig. 7(e)]. Whether that was due to a poor signal-to-noise ratio or an actual interruption of the click production is not possible to say. The former interpretation is supported by the observation that the next discharge 35 s later does not cause any interruption or change in the click intervals from the same whale [Fig. 2; Fig. 8(e)]. One could imagine that the whales, if indeed aroused by the high-level detonations, would direct their putative sonar towards the source for examination. However, the click trains show no profound increase in click amplitudes after discharge (e.g., Fig. 1) at the hydrophone closest to the transient source.

We also made one visual observation of a surfaced sperm whale exposed to one discharge with a RL of 179 dB *re* 1 μPa peRMS. During the discharge, it remained at the surface without any visible movements and kept ventilating.

III. DISCUSSION

The observations reported here are coincidental in the sense that they do not come from an experiment designed to provide data on sperm whale reactions to the discharge of detonators.

The overall picture is, with the uncertainties and the risk of anomalous behavior inherent to limited sampling, that male sperm whales do not interrupt nor change their click production or alter their behavior in any detectable way in response to a broadband pressure wave from a detonating blasting cap with a received sound level of some 180 dB *re* 1 μPa peRMS.

Watkins (1986) has shown that cetaceans normally respond to sudden increases in sound level when these are in excess of 12 dB relative to the ambient sound level, for which the discharges in the present study qualify within a range of tens of kilometers. In the case of sperm whales, a number of observations show that they react to anthropogenic pulses from, e.g., splashes, pingers, airguns, and sonars (see the Introduction). Why do sperm whales not seem to react to high-intensity transients from detonating blasting caps?

One answer could be that most of the sounds, which have been reported to cause a reaction, are repetitive or quasi-continuous in contrast to the single event transients generated by the detonators. This explanation, however, is not supported by the sperm whale reactions to splashes from missing tagging darts.

Since the RLs of the detonations are likely to be higher than the SL of the above-mentioned sounds, it could be speculated that the nonreacting sperm whales in the present study are familiar with high-intensity, broadband pulses. A number of sources can potentially cause habituation, but the most likely source of such pulses is the whales themselves. The sperm whales off the continental slope at Andenes produce long-lasting trains of broadband [Fig. 3(a)], high-intensity clicks, with apparent SLs (ASLs) 40 dB higher than the RL of the detonations (Møhl *et al.*, 2000). Furthermore, the durations of sperm whale clicks (see Møhl *et al.*, 2000) and that of a detonation are both in the order of 1 ms. It is likely that sperm whales can tell the difference between detonations and clicks, but the transient nature and the spectral similarity [Fig. 3(a) and (b)] may be close enough to make the sperm whales perceive the detonations as isolated clicks from conspecifics.

Watkins and Schevill (1975) have suggested that interruption of click production as a reaction to the onset of pingers is due to resemblance between the pinger pulses and communicative codas of the sperm whales, who may fall silent because they listen. If indeed the detonations are perceived as single clicks from conspecifics, they are apparently not interpreted as communication attempts in the sense of codas, since the whales keep clicking. This can be due to the fact that the detonations are single events, while codas consist of a set of clicks (Watkins and Schevill, 1977). Moreover, communicative codas are very seldom heard among sperm whales in northern Norway, perhaps because high latitude stocks consist exclusively of solitary, feeding males (Berzin, 1971).

FIG. 3. (a) Amplitude spectrum of the P1 pulse in a sperm whale click. HP-filter at 300 Hz. Sample rate 88.2 kHz. Binwidth 345 Hz. (b) Amplitude spectrum of the pressure wave from a detonator. HP-filtering at 300 Hz. Sample rate 88.2 kHz. Binwidth 345 Hz.

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