

Behavior and Blood Catecholamines of Captive Belugas During Playbacks of Noise From an Oil Drilling Platform

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Belugas (*Delphinapterus leucas*) depend on sounds for communication and echolocation. To address the concerns that noise from oil platforms may have adverse effects, we examined behavioral responses of four captive belugas to playbacks of noise from SEDCO 708, a semi-submersible drilling platform. Swim patterns, social groups, and respiration/dive rates were not statistically different before and during playbacks. We assayed levels of blood catecholamines before and after playbacks as a measure of stress. Blood epinephrine and norepinephrine levels measured immediately after playbacks were not elevated. Using the parameters we selected, we could not detect any short-term behavioral or physiological effects of drilling noise playbacks on these captive belugas. However, care should be taken in extrapolating these results to the behavior of wild belugas around oil platforms.

Key words: *Delphinapterus leucas*, industrial noise, stress, epinephrine, norepinephrine

INTRODUCTION

The distribution of belugas (*Delphinapterus leucas*) overlaps areas of rich oil deposits in the arctic continental shelf [Griffiths and Øritsland, 1987]. Exploration, production, and transportation of offshore oil generate underwater noise that sometimes has high sound pressure levels [Greene, 1986]. Exposure to sustained high amplitude noise can cause discomfort, stress, or even physical damage in animals and humans. The effect of noise from a drilling platform on belugas is unknown. There is concern that this noise could mask sounds that belugas use for echolocation or communication or even cause hearing damage. Turl [1982] suggested that belugas

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may react to such noise by leaving or refusing to return to critical breeding or feeding areas.

Beluga hearing sensitivity declines at about 10 dB per octave at frequencies below 16 kHz [White et al., 1978; Awbrey et al., 1988]. Nearly all the energy in industrial noise, like that from SEDCO 708, lies below 4 kHz. Although belugas can hear these low-frequency sounds, they are not as likely to mask their high-frequency communication or echolocation signals. Johnson et al. [1989] showed that belugas have good critical ratios, especially at low frequencies. Furthermore, belugas probably can compensate for high-amplitude noise by making their own signals louder, raising the frequency to make them more directional, and reorienting themselves to take advantage of directional hearing. It is unknown whether a beluga would avoid a noise source that was so loud it interfered with their communication or echolocation.

Gales [1982] measured underwater sound pressure levels from several types of drilling platforms in Cook Inlet, Alaska and Santa Barbara, California. Using sound propagation theory and available data on hearing sensitivities of marine mammals, he modeled the potential influence in circular zones around a platform. His estimates of the distance at which whales probably hear drilling noise imply that only long-term exposure at extremely close distances would potentially damage the hearing of a whale. The goal of our study was to address whether drilling noise has psychoacoustic qualities that will stress belugas and cause them to change their normal activities. We projected noise recorded from SEDCO 708, a semi-submersible drilling platform, to a group of captive belugas and examined their swim patterns, social groups, and dive/respiration rates. We used blood catecholamine levels to indicate physiological stress [Palkovits, 1983].

MATERIALS AND METHODS

Subjects

Four belugas (an adult male and female and a subadult male and female) housed at Sea World's underwater theater in San Diego, were the subjects. Our study times were scheduled so they did not interfere with the animals' shows. The whales moved freely between the main pool (13 m × 13 m × 4.5 m) and an adjoining holding pool (8.5 m × 4.5 m × 1.5 m). Markers at the edge of the pool indicated the 10 areas we defined for this study (Fig. 1).

Baseline Behavioral Data

For 30 days, we collected baseline behavioral data on these belugas in 40-min sessions at 0000, 0600, 1200, and 1800 hr. Four observers, seated out of the whales' sight, randomly selected a focal-animal and narrated its activities on a cassette recorder. Behaviors were classified as blow, surface, or dive. The animal's movements were documented by reporting its numbered location in the pool. The narrators also noted any changes in the 14 possible social groups. During the transcription of the cassettes, we timed the duration of each event with a stopwatch. Behavior was summarized as blows/min, dives/min, blow interval, dive interval, time spent in each social group, and time spent in each area of the pool.

We tested for diel differences in the baseline samples. Student's t-test examined differences in respiration/dive parameters (i.e., mean number of blows per min, mean number of dives per min, mean dive interval, and mean blow interval). For swim

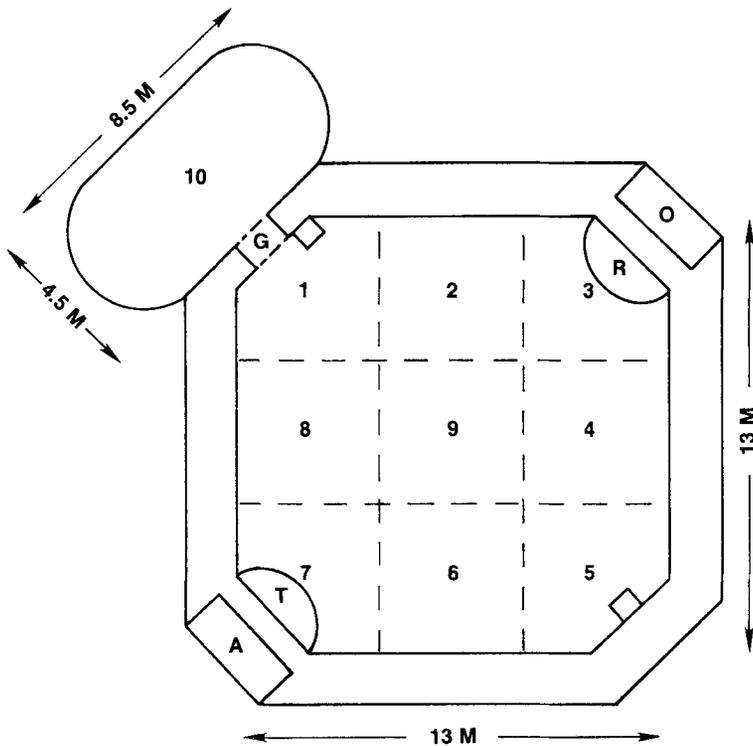


Fig. 1. Pool complex where playback experiments were conducted: A = playback equipment; G = gates; O = behavioral observers; R = monitoring hydrophone; T = projector. Numbers 1 to 9 are an imaginary grid in the main pool; the holding pool was area 10.

patterns (percent time in each area in the pool) and social combinations (percent time in each social group), we used a Spearman's rank correlation test. We chose a 5% level of significance for all statistical tests.

Baseline Blood Data

As part of Sea World's health maintenance program, all whales were trained to drape their flukes over the edge of the pool so that a laboratory technician could draw a blood sample. This behavior became part of the whales' daily routine, but actual blood samples were taken on randomly chosen days over a 3-month period. Animals fasted 15 to 18 hr before blood samples were drawn. To minimize possible aversion to sampling, we limited the number of blood samples during the study.

Playback Behavioral Data

We analyzed a recording made by Greene [1986] of noise from SEDCO 708, a semi-submersible oil platform (Fig. 2). This recording had frequent blocking and distortion generated by hydrophone motion in the rough Alaskan waters which saturated the hydrophone's amplifier. To provide a better playback tape, we synthesized noise with a similar spectrum (Fig. 2). We projected this synthesized noise with a Marantz PMD-360 stereo cassette player, an ASI TS107A amplifier, and a J9 trans-

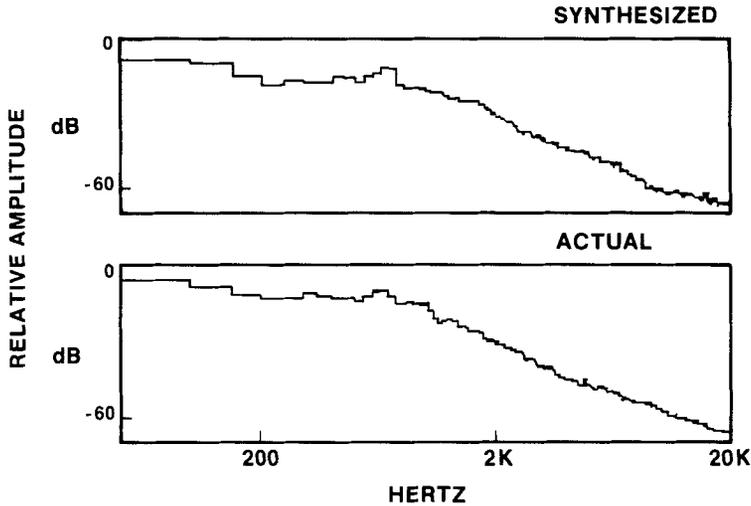


Fig. 2. Synthesized and actual spectra of noise from SEDCO 708 semi-submersible oil platform.

ducer (operating range 40 Hz to 20 kHz). Sounds were received and recorded on the opposite side of the pool with a Brüel & Kjaer 8103 hydrophone and a Nagra IV SJS tape recorder. All sound pressure levels are in decibels (dB) and referenced to 1 microPascal. The flat-weighted sound pressure level of the ambient noise in the pool before playbacks was 106 dB. The sound pressure level at the monitoring hydrophone across the pool ranged from 134 to 137 dB. The source sound pressure level of the projector was 153 dB, a level comparable to the source level of the oil platform, SEDCO 708.

Playbacks were conducted at 0730 hr before the Sea World park was open to visitors who might distract the whales. We used the same focal-animal techniques, as in the baseline samples, to describe the animals' responses to playbacks of noise. A 10-minute pre-playback behavior sample was taken followed by a 30-minute sample during exposure to the noise playback. Playbacks were projected nine times in a 13-day period.

Playback Blood Data

Collecting blood samples after playbacks was constrained by the time we needed to collect and process a blood sample and by the cooperation of the whales. The catecholamine assay must be conducted on samples immediately after exposure to potential stress. After playbacks, the whales swam into the holding pool and were released one at a time for sampling. The adult male, more experienced with fluke presents, usually was the first whale out of the holding area, and allowed us to take the most blood samples (6 baseline and 4 post-playback samples). The adult female and subadult male were reliable volunteers for fluke blood sampling and both allowed us to collect 3 baseline samples and 1 post-playback sample. The subadult female was relatively inexperienced and only volunteered for a fluke blood sample during one baseline and one post-playback session.

Blood samples were collected in four of the nine playback sessions within 8 to 40 min after the noise stopped. Unfortunately, we did not record the exact time each

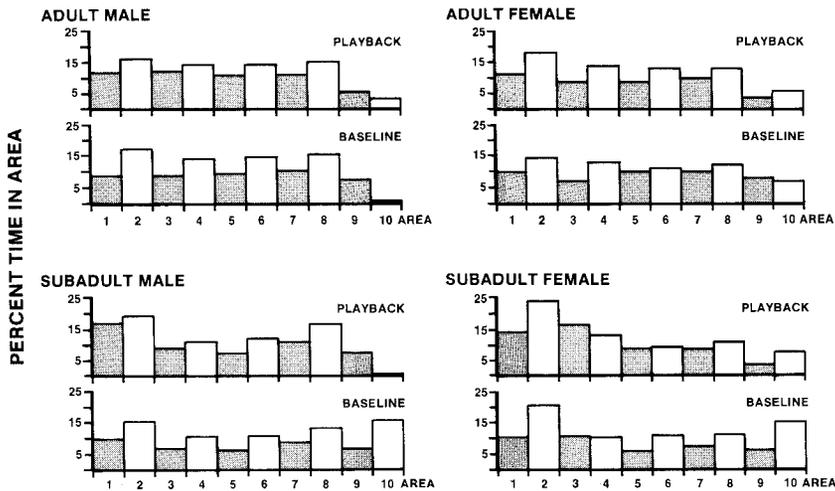


Fig. 3. Percent time spent by each beluga in the ten areas of the pool during the baseline and playback periods. Area 10 is the holding pool.

sample was taken relative to the end of playback, which would have allowed us to examine the time after exposure as an influence on catecholamine levels. We collected two blood samples in Vacutainer tubes with sodium heparin as an anti-coagulant and set them in ice water. One sample was used for hematology and blood chemistry panels. Within 1 hr of collection, the second sample was centrifuged for 10 min and the serum stored at -70°C . At the end of the study, epinephrine and norepinephrine levels of all blood samples were measured at the same time using radio-enzyme assays [Durrett and Ziegler, 1980] at the University Hospital in San Diego.

RESULTS
Swim Pattern

Whales usually swam clockwise around the perimeter of the pool. Because of this swim pattern, they used the center and the odd-numbered corners less often than the other perimeter areas (Fig. 3). We found no statistical differences in swim patterns among the four baseline periods (0000, 0600, 1200, and 1800 hr).

During five of the nine playback experiments, the whales reaction to the onset of SEDCO 708 noise was an initial flight response. They moved as a group toward and sometimes entered the holding area for about 30 sec and then returned to the main pool. On some occasions, whales showed curiosity about the sound source, swam toward and touched the fiberglass panel 1 m in front of the transducer, where the sound pressure level was 153 dB.

The swim pattern of the three whales during the baseline period was not significantly different from that during the playback periods (Fig. 3). The young male spent a large proportion of time in the holding pool during the 1200-hr baseline sample. He used this holding pool as a refuge from the dominant adult male, who often threatened him by chasing and jaw-clapping.

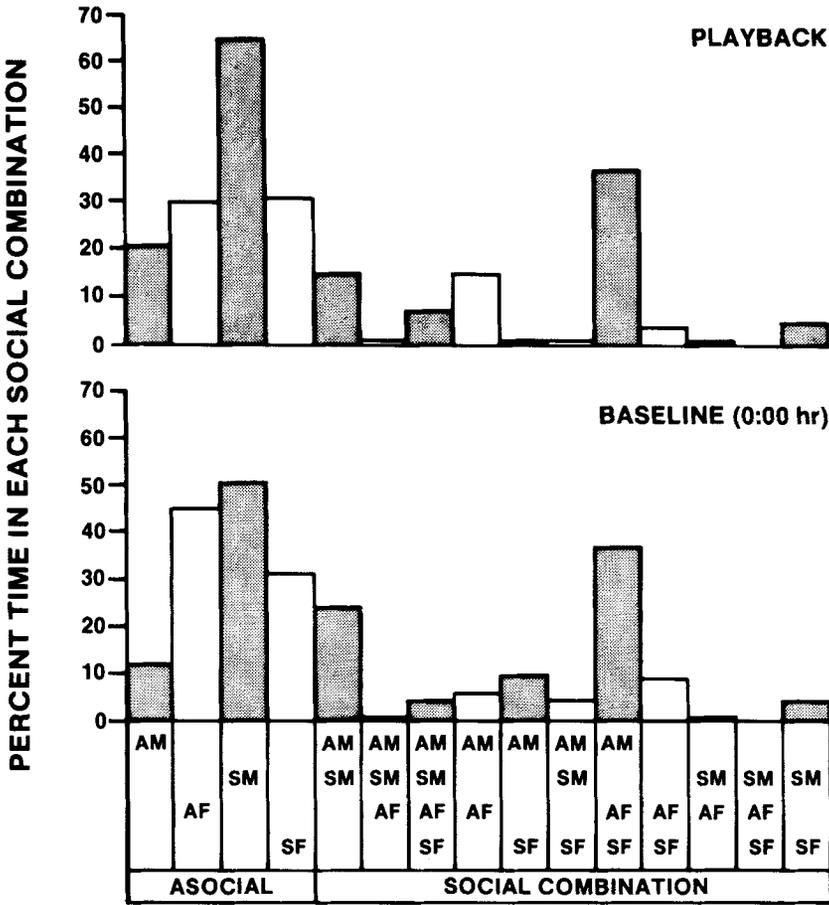


Fig. 4. Percent time spent by each beluga in different social groups during the 0000-hr baseline and playback periods; AM = adult male; AF = adult female; SM = subadult male; SF = subadult female.

Social Groups

During the baseline samples (Fig. 4), all whales spent some time alone (asocial). The young male spent nearly 51% of the time by himself; he rarely was exclusively with a female (< 5%), and he never was alone with both females. In contrast, the dominant, adult male spent only 12% of the time alone and was usually with one or both females. There was no statistical difference between the percentage of time spent in any social group during the baseline versus the playback period.

Respiration/Dive Rates

During the baseline samples, the whales' normal respiration/dive behavior was a series of rapid surfacings with respirations (blows) followed by a long dive. Often the whales breathed several times at the surface, which caused the mean blow rate to be larger than the mean dive rate and the mean blow interval to be smaller than the mean dive interval (Fig. 5). Respiration/dive behavior varied some between animals, but generally did not differ significantly during the baseline and playback samples.

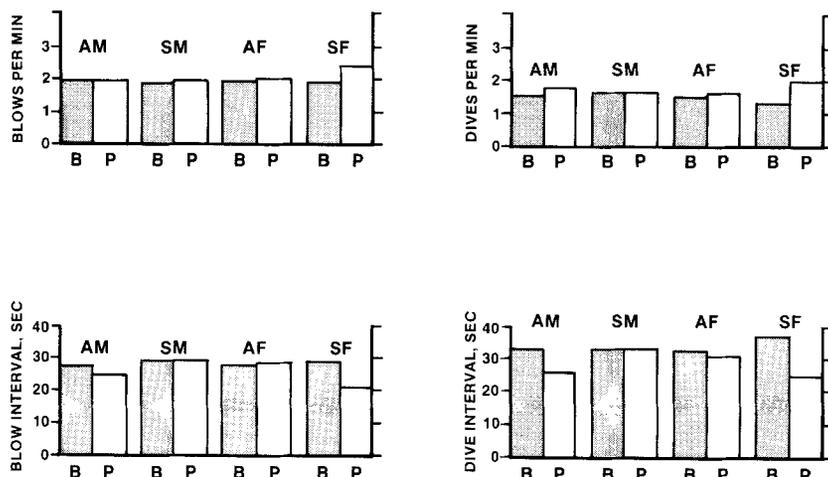


Fig. 5. Mean number of blows and dives per min and mean blow and dive intervals in seconds during baseline and playback periods; AM = adult male; SM = subadult male; AF = adult female; and SF = subadult female.

The adult male's mean dive interval for all playback samples was shorter than the 0600-hr and 1800-hr baseline value, but was within the daily variation of the 0000-hr and 1200-hr samples. The young male's mean dive interval was shorter during playbacks than during the 0000-hr baseline sample. The adult female's mean dive interval was shorter during the baseline period. The young female made more blows and dives during the playbacks.

Blood Catecholamines

All cell and platelet counts and 21 different blood chemicals were within normal limits for clinically healthy belugas [Cornell et al., 1988] throughout the baseline and playback periods.

Baseline plasma epinephrine levels ranged from 0 to 101 pg/ml and did not change in a consistent manner with repeated sampling or exposure to noise. Epinephrine levels were so low that the normal variance of the assay (± 20 pg/ml) may have obscured level changes.

Baseline values of norepinephrine for belugas ranged from 180 to 1,348 pg/ml. The highest norepinephrine value of 1,348 pg/ml was at the first sample from the subadult female. This high norepinephrine level probably reflects the stress associated with the first blood collection from this young and inexperienced animal. Norepinephrine levels declined steadily throughout the study as the whales habituated to the blood-sampling technique (Fig. 6). During playbacks norepinephrine levels ranged from 160 to 604 pg/ml, which was within the baseline values.

DISCUSSION

We could not detect behavioral or physiological effects on these captive belugas from playbacks of noise from SEDCO 708, a semi-submersible drilling platform. There was an initial flight response by some animals when the noise playback started.

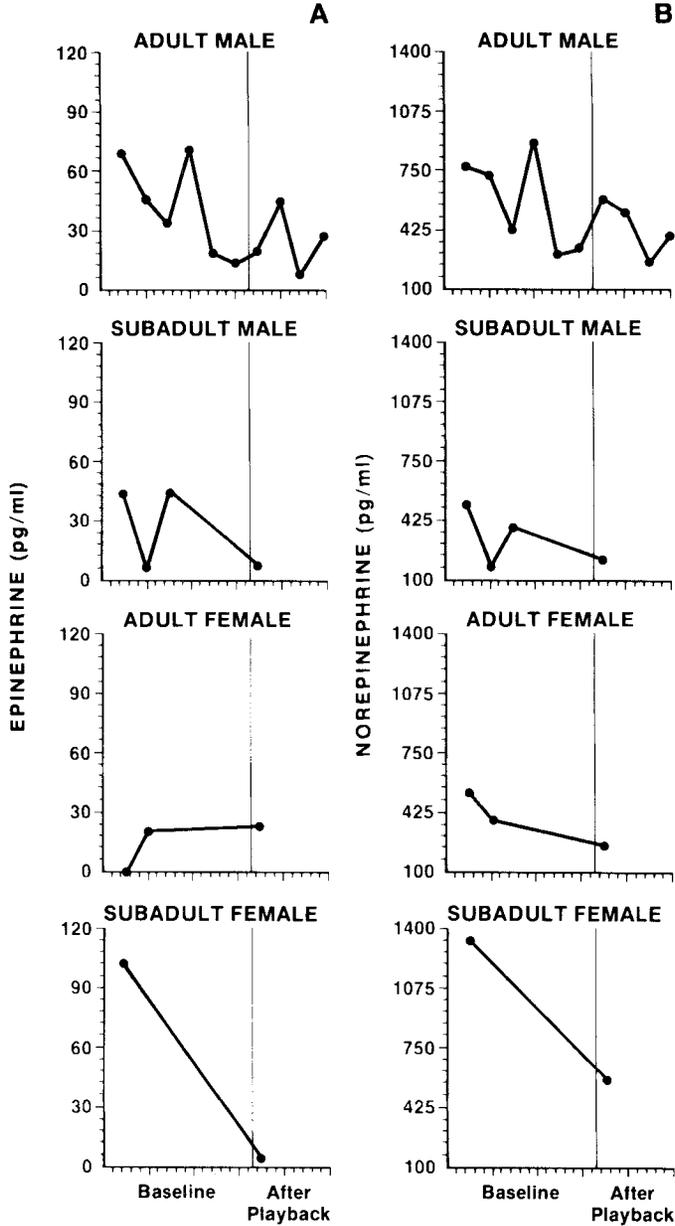


Fig. 6. **A:** Baseline plasma epinephrine levels (left side) and post-playback levels (right side) of four belugas. **B:** Baseline plasma norepinephrine levels (left side) and post-playback levels (right side).

Belugas soon accommodated and showed no change in swim pattern or social groups. Respiration/dive rates during noise playback were consistent with baseline rates for three of the four belugas. The young female's baseline behaviors were too irregular to be able to tell whether playbacks caused changes.

Levi [1972] reports that even short-duration environmental stress increases

blood catecholamine levels in humans and animals. Following exposure of animals or humans to stress, there is a rapid release of ACTH from the pituitary. Blood plasma epinephrine and norepinephrine levels increase in response to high ACTH production [Palkovits, 1983]. As a result, increased epinephrine and norepinephrine levels may indicate physiological stress.

As an extreme example in humans, stress induced by insulin hypoglycemia can increase epinephrine levels above 1,000 pg/ml. Change in epinephrine levels of belugas was small compared to the overall secretion capacity of the typical mammalian adrenal medulla.

Plasma norepinephrine levels in humans [Lake et al., 1976], rats and monkeys [Kopin et al., 1978], and dogs [Nechay et al., 1981] range from about 200 to 400 pg/ml during basal resting state. Beluga norepinephrine levels generally were similar, regardless of the baseline or post-playback situation.

Exposure to playbacks of noise from SEDCO 708 did not increase norepinephrine or epinephrine levels in belugas. Using catecholamines, we could not detect short-term stress caused by the noise playbacks.

Care should be used in extrapolating our results to the behavior of wild belugas around oil platforms. We could not replicate all aspects of belugas being exposed to noise from an oil platform. Captive whales are accustomed to low-frequency noise like water pumps. Our small sound projector could not imitate the large sound source and visible structure of an oil platform. Belugas were not exposed to long-term noise which might be the case near an oil platform. We did not address the effects of a noise playback on echolocation because these captive whales may not use typical echolocation in their familiar pool setting.

Although noise from a semi-submersible drilling platform seems unlikely to have short-term adverse effects on beluga whales, management policy must be conservative because long-term effects of such noise on belugas are unknown. To be safe, industrial equipment used on oil platforms should radiate as little sound into the water as possible.

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