

reasons, the air spaces in marine mammals are too large to be susceptible to resonant frequencies emitted by mid- or low-frequency sonar; lung tissue damage has not been observed in any mass, multi-species stranding of beaked whales; and the duration of sonar pings is likely too short to induce vibrations that could damage tissues (Gentry *et al.*, 2002). Opinions were less conclusive about the possible role of gas (nitrogen) bubble formation/growth in the Bahamas stranding of beaked whales. Workshop participants did not rule out the possibility that bubble formation/growth played a role in the stranding and participants acknowledged that more research is needed in this area. The only available information on acoustically mediated bubble growth in marine mammals is modeling that assumes prolonged exposure to sound.

In summary, little is known about the potential for seismic survey sounds to cause auditory impairment or other physical effects in marine mammals. Available data suggest that such effects, if they occur at all, would be limited to situations where the marine mammal is located at a short distance from the sound source. However, the available data do not allow for meaningful quantitative predictions of the numbers (if any) of marine mammals that might be affected in these ways. Marine mammals that show behavioral avoidance of seismic vessels, including most baleen whales, some odontocetes, and some pinnipeds, are unlikely to incur auditory impairment or other physical effects.

Possible Effects of Mid-Frequency Sonar Signals

A multi-beam bathymetric sonar (Atlas Hydrosweep DS-2, 15.5-kHz) will be operated from the source vessel at some time during the calibration study. Sounds from the multi-beam sonar are very short pulses, occurring for 1–10 msec once every 1 to 15 sec, depending on water depth. Most of the energy in the sound pulses emitted by this multi-beam sonar is at high frequencies, centered at 15.5 kHz. The beam is narrow (2.67°) in fore-aft extent, and wide (140°) in the cross-track extent. Each ping consists of five successive transmissions (segments) at different cross-track angles. Any given mammal at depth near the trackline would be in the main beam for only one or two of the five segments, i.e. for 1/5th or at most 2/5th of the 1–10 msec.

Navy sonars that have been linked to avoidance reactions and stranding of cetaceans (1) generally are more powerful than the Atlas Hydrosweep, (2) have a longer pulse duration, and (3)

are directed close to horizontally (vs. downward for the Hydrosweep). The area of possible influence of the Hydrosweep is much smaller (a narrow band below the source vessel). Marine mammals that encounter the Hydrosweep at close range are unlikely to be subjected to repeated pulses because of the narrow fore-aft width of the beam, and will receive only limited amounts of pulse energy because of the short pulses.

Masking by Mid-Frequency Sonar Signals

There is little chance that marine mammal communications will be masked appreciably by the multi-beam sonar signals given the low duty cycle of the sonar and the brief period when an individual mammal is likely to be within its beam. Furthermore, in the case of baleen whales, the sonar signals do not overlap with the predominant frequencies in the calls, which would avoid significant masking.

Behavioral Responses Resulting from Mid-Frequency Sonar Signals

Marine mammal behavioral reactions to military and other sonars appear to vary by species and circumstance. Sperm whales reacted to military sonar, apparently from a submarine, by dispersing from social aggregations, moving away from the sound source, remaining relatively silent and becoming difficult to approach (Watkins *et al.*, 1985). Other early and generally limited observations were summarized in Richardson *et al.* (1995). More recently, Rendell and Gordon (1999) recorded vocal behavior of pilot whales during periods of active naval sonar transmission. The sonar signal was made up of several components each lasting 0.17 sec and sweeping up from 4 to 5 kHz. The pilot whales were significantly more vocal while the pulse trains were being emitted than during the intervening quiet periods, but did not leave the area even after several hours of exposure to the sonar.

Reactions of beaked whales near the Bahamas to mid-frequency naval sonars were summarized earlier. Following extended exposure to pulses from a variety of ships, some individuals beached themselves, and others may have abandoned the area (Balcomb and Claridge, 2001; NOAA and USN, 2001). Pulse durations from these sonars were much longer than those of the LDEO multi-beam sonar, and a given mammal would probably receive many pulses. All of these observations are of limited relevance to the present situation because exposures to multi-beam pulses are expected to be brief as the vessel

passes by, and the individual pulses will be very short.

Captive bottlenose dolphins and a beluga whale exhibited changes in behavior when exposed to 1-sec pulsed sounds at frequencies similar to those that will be emitted by the multi-beam sonar used by LDEO (Ridgway *et al.*, 1997; Schlundt *et al.*, 2000), and to shorter broadband pulsed signals (Finneran *et al.*, 2000, 2002). Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure or to avoid the location of the exposure site during subsequent tests (Schlundt *et al.*, 2000; Finneran *et al.*, 2002). Dolphins exposed to 1-sec intense tones exhibited short-term changes in behavior above received sound levels of 178 to 193 dB re 1 μ Pa rms and belugas did so at received levels of 180 to 196 dB and above. Received levels necessary to elicit such reactions to shorter pulses were higher (Finneran *et al.*, 2000, 2002). Test animals sometimes vocalized after exposure to pulsed, mid-frequency sound from a watergun (Finneran *et al.*, 2002). In some instances, animals exhibited aggressive behavior toward the test apparatus (Ridgway *et al.*, 1997; Schlundt *et al.*, 2000). The relevance of these data to free-ranging odontocetes is uncertain. In the wild, cetaceans sometimes avoid sound sources well before they are exposed to the levels listed above, and reactions in the wild may be more subtle than those described by Ridgway *et al.* (1997) and Schlundt *et al.* (2000).

In summary, cetacean behavioral reactions to military and other sonars appear to vary by species and circumstance. While there may be a link between naval sonar use and changes in cetacean vocalization rates and movements, it is unclear what impact these behavioral changes (which are likely to be short-term) might have on the animals. Therefore, as mentioned previously, because simple momentary behavioral reactions that are within normal behavioral patterns for that species are not considered to be a taking, the very brief exposure of cetaceans to signals from the Hydrosweep is unlikely to result in a "take" by harassment.

Hearing Impairment and Other Physical Effects

Given recent stranding events that have been associated with the operation of naval sonar, there is much concern that sonar noise can cause serious impacts to marine mammals (for discussion see Effects of Seismic Surveys on Marine Mammals). It is worth noting that the multi-beam sonar