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UNDERWATER HEARING OF PHOCID SEALS

by

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Knowledge of the hearing abilities of a species will aid in estimating the importance of sound in its daily life. The basic attribute of an auditory system is its sensitivity. Sensitivity imposes the main limit on the intensity and frequency of detectable sounds. Two other major abilities are the localization of sound and the filtering out of unwanted sounds. This allows detection of specific signals in the presence of background noise. Recent studies indicate that the underwater hearing sensivities of Phoca vitulina, the harbour seal (Møhl 1968a), Pagophilus groenlandicus, the harp seal (Terhune and Ronald 1972) and Halichoerus grypus, the grey seal (Ridgway and Joyce 1974) are similar. These studies are somewhat limited in that only 4 individual seals have been examined. We believe that by determining the underwater sensitivity of 2 individuals of another species, we would better be able to estimate whether or not all phocids have a similar underwater hearing sensitivity. It seems likely that a closely related group, having basically the same anatomical structures and a similar sensitivity would also have similar hearing abilities. If this was the case, then within Phocidea, information determined on one species should generally be applicable to the others.

A minimum audible field, underwater audiogram was determined for each of 2 ringed seals. The method used was yes-no response to variable stimuli (Terhune and Ronald 1972). Each seal was trained to respond to sound by pushing a series of switches. Through its responses, the seal could indicate whether or not it detected a sound that may or may not have been produced when it pushed a "stimulus" switch. The seal was presented with an equal chance of being exposed to a sound or to a catch trial (no sound). As long as the seal correctly detected a sound, the loudness of the next sound to be presented was decreased by a set amount. This continued until the seal made a signal error. As long as the seal continued to make signal errors, the loudness of the next sound to be presented was increased. Thus, the sound levels decreased until they were below the seal's threshold and then increased until they were above threshold. The value of the threshold was estimated by averaging 10 turning points (i.e. the sound level of the first correct signal detection following an error or the sound level of the first signal error following a correct signal response) above and below the threshold. The signals presented were all sine waves between 1 and 90 kHz. The frequencies tested, and the resulting estimations, are shown in Fig. 1. A more detailed description of this work is currently being prepared for publication.

Threshold estimates obtained in the above manner are influenced by response biases (guessing) on the part of the seal, the size of the loudness increments and the presence of intensity fluctuations caused by echoes and standing waves. The close agreement between the audiograms of the 2 ringed seals indicates that the variability present in the threshold estimates is probably in the order of $\pm$ 10 dB or less.

Despite methodological differences, the 4 phocid species do not exhibit differences in sensitivity (at any particular frequency) of greater than 20 dB (from 1 to 90 kHz; technical difficulties above and below this range were present in this and some of the other studies). Fletcher (1940) reports that 50% of a group of humans have an in-air sensitivity that is within ± 10 dB of the average (for any given frequency). Assuming that seals exhibit a similar range, the variability among the 4 phocid species can be attributed to individual and experimental differences. It appears to be reasonable to talk in terms of "phocid underwater hearing sensitivity" at the sub-family level at least.

With a few exceptions (such as the outer ear) the anatomy of a phocid ear is similar to that of a typical mammal (Møhl 1968b; Ramprashad et al. 1972). Pitch discrimination abilities (Møhl 1967), the critical ratios, (the influence of background noise), (Terhune and Ronald 1971) and the ability to localize sounds (Møhl 1964; Terhune 1973) are generally of the same magnitude for seals as humans. A slightly reduced locational acuity in seals is attributed to the physical differences between the air and water media and not to significant neurological differences between phocids and humans. These "finer points" of hearing are determined by the inner ear and as such, are somewhat independent of the anatomical influences of the outer and middle ears. Although differences between various mammals do exist (such as the upper frequency limit), in the main, sounds reaching the inner ears are transformed into neural impulses in a similar manner in all mammals. Thus, the seal's sensitivity underwater is the same as a man in air (Møhl 1968a), except in the frequency range between 20 and 100 kHz where the seal is more sensitive. To put it another way, a seal underwater hears as well in the frequency range of 1 (at least) to 90 kHz as a human in air hears in the frequency range of 0.5 to 15 kHz. Within these limits, other hearing attributes are probably the same.

It is probable that hearing plays as important a role in the life of a seal as it does in other mammalian predators (including man but excluding known echolocators). Although it is probably possible, as it is for humans, for a seal to learn to echolocate, such abilities have not been demonstrated in the wild. Hearing is probably useful in prey location, predator avoidance, navigation (ice and shallow-water wave noises) and inter-animal communication. The relationship between the seal's underwater sensitivity and its reaction to background noise is such that a 0 sea state (Albers 1965) will not interfere but a number 6 sea state will raise the thresholds of the lower frequencies (Fig. 2), (Terhune and Ronald 1972). Noises introduced into the sea by man will, however, have a much greater effect because they are many times louder than natural ones. For example, a side ranging sonar (model LSS-30(PT) Omnidirectional Sonal, C-Tech Ltd., Cornwall, Canada) has an output pulse at 30 kHz that has an intensity of 116 dB re 1 ubar at 1 m. The operating range of this unit is 4 km. The initial pulse of this unit is about 140 dB above a seal's threshold. At close range, other things being equal, such a sound would be painful for a human.

In a free field, the sound pressure level drops by 6 dB every time the distance from the source is doubled (1/R law). Thus, if the output of a sonar system is 116 dB re 1 μbar at 1 m, it will be 110 dB at 2m, 104 dB at 4 m etc., to 44 dB at 4.096 km. At 4 km, the loss caused by sound absorption by sea water (for a 30 kHz sound) would cause an additional 30 dB loss. Thus the sound level 4 km from the sonar set would be at least 10 dB re 1 μbar. Such a level would easily be detected by a seal. Other noises such as seismic explosions, motor and propeller noises etc. will also be audible to phocids. The hearing of cetaceans is more sensitivie and has a wider frequency range than seals (Johnson 1967). As such, sounds audible to seals would certainly be audible to cetaceans.

In a short field study, we found that 4 of 7 free-swimming, feral harp seals altered their swimming patterns when they encountered the beam of a Heath ML-11A depth sounder. The exposure time was less than 10 sec in all cases. This indicates that, to some degree, the behaviour of seals can be altered by noises.

It is possible that "noise pollution" will adversely affect the acoustic regime of the seal. Although they may learn to live within, and cope with, a noisy environment, it is possible that they may try to seek out quieter areas. In any event, when planning refuge areas or considering the effects of human disturbance on phocid populations and distributions, the acoustic environment must receive some consideration.

Summary

Audiogram determinations and other psychophysical and anatomical studies indicate that all phocids will have similar underwater hearing abilities. With the additional ability to detect higher frequency sounds, the underwater hearing abilities of seals are similar to those of humans in air. Many man-made noises, such as sonar systems, produce loud, underwater sounds and these may influence the behaviour of seals.

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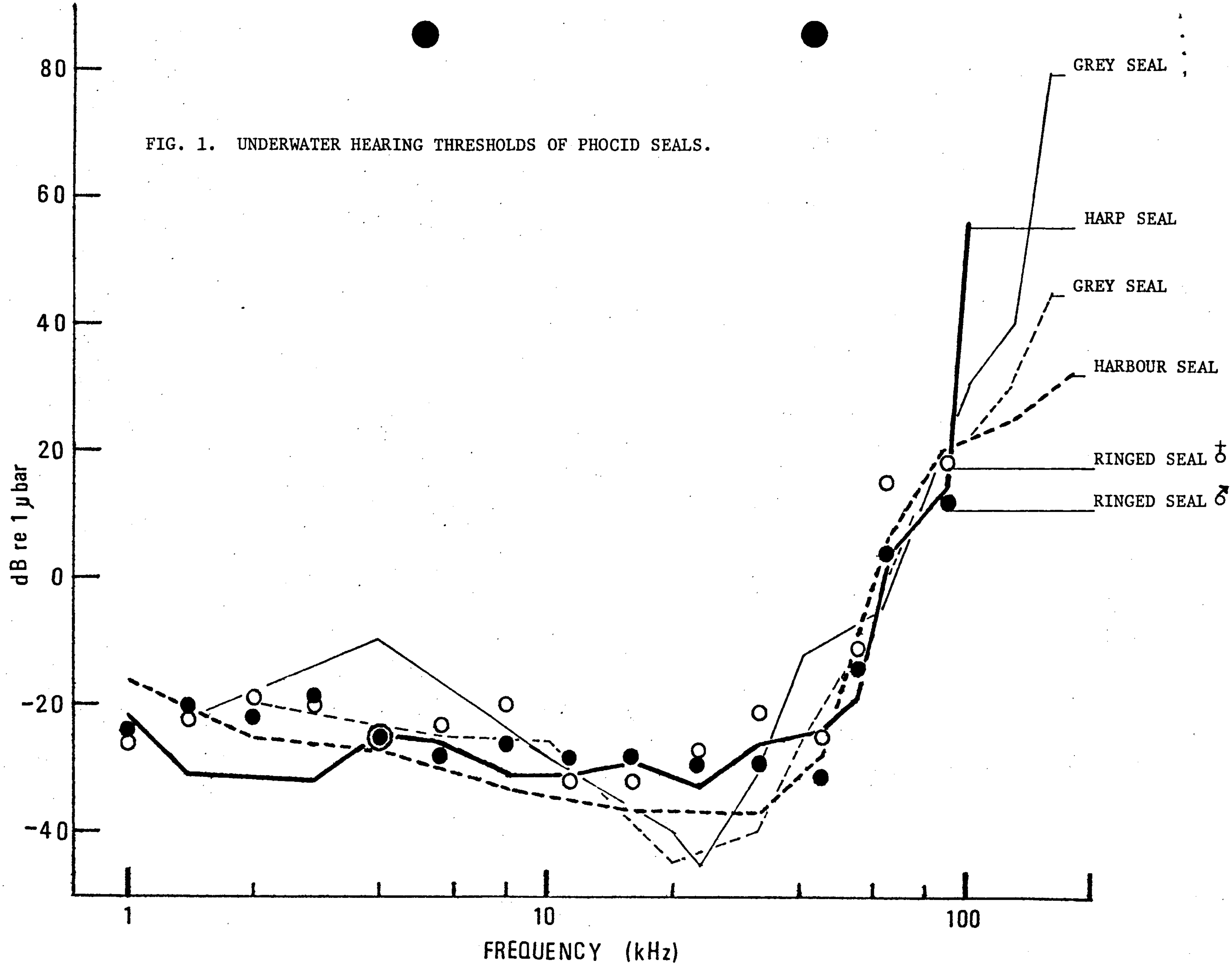
FIG. 1. UNDERWATER HEARING THRESHOLDS OF PHOCID SEALS.
GREY SEAL
HARP SEAL
GREY SEAL
HARBOUR SEAL
RINGED SEAL ♀
RINGED SEAL ♂
80
60
40
20
0
-20
-40
dB re 1 μbar
1
10
100
FREQUENCY (kHz)

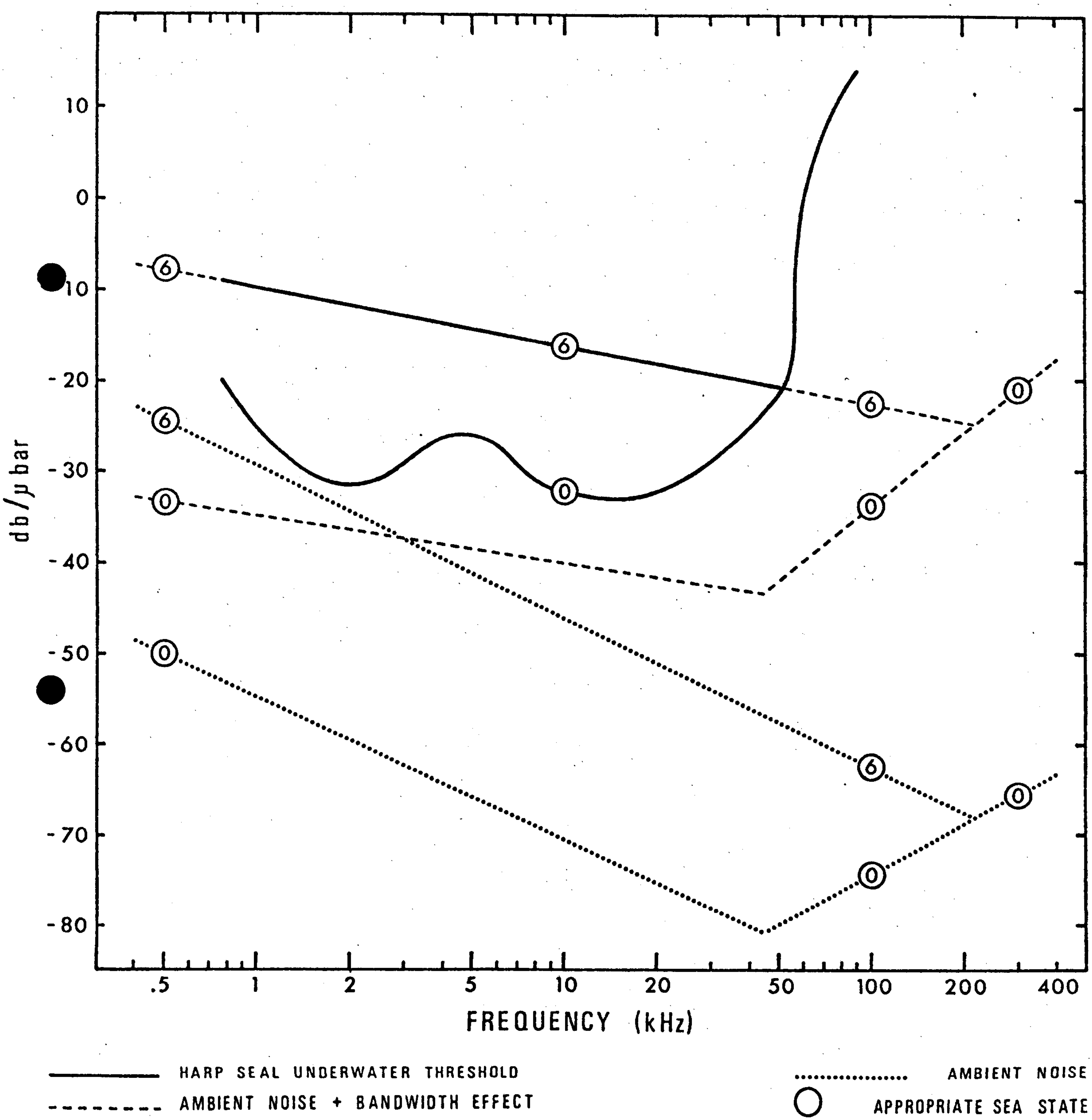

FIG. 2. EFFECTS OF AMBIENT NOISE ON THE UNDERWATER HEARING THRESHOLDS OF A HARP SEAL.