# Chapter 127
# Psychoacoustic Studies of Spotted (*Phoca largha*) and Ringed (*Pusa hispida*) Seals

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**Abstract** Human development of the marine environment raises questions regarding the potential adverse effects of anthropogenic noise on marine mammals. For species that live in remote Arctic regions, recent and expanding human intrusions may pose a particular threat. Northern seals are poorly studied relative to their temperate counterparts and little is known of their acoustic ecology or behavior. Given this scarcity of relevant data, studies of hearing in Arctic seals are essential to characterize their auditory capabilities and to inform management decisions. This paper describes ongoing psychoacoustic studies that are examining aspects of hearing in two ice seal species.

**Keywords** Seals • Amphibious • Hearing • Noise • Arctic

## 1 Introduction

In recent years, rising anthropogenic noise levels throughout many of the world's oceans have become a cause for concern. Low-frequency noise associated with shipping and industrial activities has dramatically increased in certain areas (Huntington 2009; Moore et al. 2012). In the Arctic in particular, what was once a relatively undisturbed ecosystem is increasingly influenced by industrialization, which is enabled by the rapid melting of sea ice due to climate change. Among the many effects associated

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with elevated background noise levels in marine environments is the potential for auditory masking of relevant sounds. Because sound waves travel much farther than light under water, sound is available as a biologically significant stimulus in the oceans. For many species of marine mammals, including Arctic seals, hearing is likely to be a key sensory channel. Whether a seal is passively listening to gain information about the environment or actively communicating with a conspecific using vocalizations, the ability to perceive auditory signals may be hindered by the addition of noise. An understanding of the implications of specific sound-generating activities must therefore be informed by quantitative measurements of hearing.

Despite the apparent importance of hearing for many of their life history events, little is currently known about the auditory capabilities of most Arctic seals. Some hearing data do exist for pagophilic seals: auditory thresholds have been measured for *Pusa hispida* (ringed seals) and *Pagophilus groenlandicus* (harp seals) above 1 kHz (Terhune and Ronald 1971, 1972, 1975a, b), but the extent to which these data may be extrapolated to other northern seals is unclear. Furthermore, audiometric data are not available for any ice seal at low frequencies (<1 kHz), where most of the energy from industrial sounds such as shipping and seismic operations is concentrated. More extensive data are available for the temperate-living *Phoca vitulina* (harbor seal; Møhl 1968; Terhune 1988, 1991; Kastak and Schusterman 1998; Wolski et al. 2003; Southall et al. 2005; Kastelein et al. 2009; Reichmuth et al. 2013), but these data may or may not be relevant to an examination of noise effects on Arctic seals. To learn more about the acoustic ecology of ice seals and to determine their vulnerability to anthropogenic noise, it is important that the hearing sensitivity of additional ice seal species be measured across the entire frequency range of hearing. The work described here is part of an effort to obtain a comprehensive set of auditory measurements that will enable comparisons within and across species. Ultimately, the goal of this ongoing project is to fully describe the auditory capabilities of ice-living seals.

## 2 Measurements of Absolute Hearing Sensitivity

Psychophysical measurements of absolute hearing sensitivity provide valuable information about the range of audible frequencies and the peak sensitivity of the auditory system. For the purposes of comparative study, whether related to function, anatomy, or evolution, absolute (unmasked) auditory threshold measurements are essential (see Nummela and Thewissen 2008). In terms of conservation efforts, these unmasked data are relevant for understanding the perceptual abilities and vulnerability of a species to noise exposures. Because the acoustic scene is altered by the addition of anthropogenic noise into the environment, scientists and regulators must consider how Arctic seals, which rely on auditory cues to orient in their marine environment, may be affected by a changing sound landscape.

## 2.1 Underwater Hearing

In this study, measurements of underwater hearing were made in quiet conditions in two well-trained *Phoca largha* (spotted seals) and two ringed seals across the frequency range of hearing. Standard psychophysical methods were used, with an emphasis on environmental controls and a thorough characterization of ambient-noise conditions during testing (see Sills et al. 2014). Peak sensitivity for the spotted seals was ~51 dB re 1 μPa at 25.6 kHz, with a broad range of good auditory sensitivity extending seven octaves (Sills et al. 2014). Similarly, the best sensitivity for the ringed seals was ~51 dB re 1 μPa near 25.6 kHz (Sills et al. 2014). Audiograms for both species exhibited a characteristic mammalian "U-shape," with a sharp decrease in sensitivity near the high-frequency hearing limit and a more gradual low-frequency roll-off. When comparing within species, thresholds were remarkably similar between subjects throughout most of their hearing range. These auditory data indicate substantially better sensitivity than previously reported for ringed and harp seals (Terhune and Ronald 1972, 1975a).

Taken together, the new underwater hearing measurements obtained for spotted and ringed seals along with existing audiograms for related species support the notion that northern seals may form a functional hearing group (although more data are required to confirm this hypothesis). Underwater hearing capabilities appear to be similar across the *Phocini* tribe, at the very least for harbor, spotted, and ringed seals. Because psychophysical data are often difficult and expensive to obtain, the ability to reliably extrapolate hearing data across northern seals would be significant, especially for those tasked with sorting out regulatory issues involving vulnerable ice-living seals and human-generated environmental noise.

## 2.2 Aerial Hearing

Due to the amphibious nature of seals, a study of absolute aerial hearing sensitivity was also conducted. In-air thresholds for the two spotted seals indicated extremely acute hearing sensitivity: <10 dB re 20 μPa across the range of best hearing (from ~0.60 to 10 kHz), with a peak measured sensitivity of −13 dB re 20 μPa at 3.2 kHz (Sills et al. 2014). These data show hearing capabilities rivaling those of the best terrestrial carnivores including cats, dogs, and ferrets (Heffner 1983; Heffner and Heffner 1985; Kelly et al. 1986). Audiometric testing for ringed seals is ongoing in our laboratory, but data collected thus far suggest that the hearing of the two species is similar. Such sensitive aerial hearing may support the acoustic vigilance of these seals when hauled out or resting on ice floes or rocky substrates, especially during vulnerable periods such as the breeding and molting seasons.

## 3 Measurements of Hearing in the Presence of Noise

In addition to absolute measures of sensitivity, it is important to quantify the influence of noise on hearing. Among the many possible effects is the potential for increasing noise levels to interfere with the detection of biologically relevant sounds. The very low aerial thresholds measured in this study demonstrate that the hearing of these seals may typically be limited by environmental noise rather than the sensitivity of the auditory system. An understanding of auditory masking may thus be even more relevant to applied conservation questions concerning noise pollution than an understanding of absolute auditory capabilities.

Psychophysical studies of auditory masking often begin with the detection of pure-tone or narrowband stimuli in the presence of spectrally flattened "white" noise, and the resulting critical ratio data describe the ability of the auditory system to extract signals from within this noise background. More specifically, a critical ratio is calculated as the difference between the sound pressure level of the masked hearing threshold and the spectral density level of the masking noise at the test frequency (Fletcher 1940; Scharf 1970). This helpful metric provides insight into auditory processing capabilities and can also be used to estimate zones of auditory masking around a particular noise source in the environment, whether natural or anthropogenic.

In this psychoacoustic study, masked hearing thresholds were measured in the presence of octave-band noise in air and under water to determine the critical ratios. For the spotted seals, the critical ratios increased similarly in both media from ~13 to 28 dB between 0.100 and 25.6 kHz (Sills et al. 2014). There was close agreement between subjects and media. For the one ringed seal tested thus far, the critical ratios under water were comparable to those of the spotted seal subjects, increasing from 16 to 31 dB across the same frequency range (Sills et al. 2014). Previous masking studies in seals and sea lions have also shown relatively low critical ratios in pinnipeds, especially the seals. Our data widen the frequency range for which critical ratios are available for representative species. A comparative view supports the conclusion that at least the true seals are hearing generalists with respect to frequency processing, with enhanced abilities to detect signals in noise, indicated by their low critical ratios, across a range of frequencies. It has been suggested that this ability in seals is related to efficient sound detection in a noisy marine environment (Southall et al. 2000).

## 4 Summary

This ongoing hearing study provides insight into the perceptual abilities of ice seals under different acoustic conditions, informing best management practices for these species in an increasingly human-influenced Arctic environment. Spotted and ringed seals possess similar and very sensitive hearing capabilities across a wide

range of frequencies. For at least the spotted seal, this acute sensitivity occurs both above and below the surface of the water and suggests a need for management of anthropogenic noise influences in both media.

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