HEARING IN ARCTIC SEALS

E&P **SOUND & MARINE LIFE** PROGRAMME

August 2018

HEARING IN ARCTIC SEALS

The Joint Industry Programme (JIP) co-sponsors research to understand the potential physical effect of sound from seismic surveys on a variety of marine mammals and fish. One area of continuing study is focused on Arctic seals, specifically spotted seals, ringed seals and bearded seals. Little research has been conducted with these marine mammals, relative to species that live in more temperate regions, and as oil and gas exploration expands into the Arctic, more information about these animals is needed to inform management decisions.

Beginning in 2010, the JIP has supported a series of studies with Arctic seals to learn more about their hearing sensitivity and the potential effects of sound. This work is conducted at the Long Marine Laboratory, part of the University of California Santa Cruz (UCSC). The team works with highly trained animals in a laboratory setting designed to support controlled studies of sensory biology. Principal researchers are Drs. Colleen Reichmuth and Jillian Sills at UCSC, with support from Dr. Brandon Southall at SEA, Inc.

This work began with fundamental studies on the auditory biology of spotted and ringed seals, including hearing abilities in quiet conditions (both in air and under water) and measurements of hearing within background sound (studies of masking to determine critical ratios). These measurements are essential to understanding how these animals hear and use sound.

How Research is Conducted

All research is conducted with the voluntary participation of the seals, who are trained to participate in research activities using operant conditioning and positive (fish) reinforcement. Research is conducted without harm in compliance with Association for Assessment and Accreditation of Laboratory Animal Care (AAALAC) standards and under National Marine Fisheries marine mammal research permits (14535, 18902). Oversight of animal research is provided by the Institutional Animal Care and Use Committee at UCSC.

To determine hearing thresholds, seals are tested in quiet conditions both under water and in-air.[1,2] To begin an experimental session, a trainer cues the seal to enter the test enclosure (either a saltwater pool or an acoustic chamber) and place its head on a chin rest positioned within a calibrated sound field. During the session, the seal listens for brief tonal signals. A small PVC paddle is located adjacent to the chin rest, which the seal can press upon detection of a sound.

Auditory trials have two possible types – signal present or signal absent – and four possible outcomes. Correct detections occur on signal-present trials when the seal touches the response paddle. Correct rejections occur on signal-absent trials when the seal ignores the paddle for the entire trial interval. Both types of correct responses are followed by a fish reward. Conversely, if the seal withholds a response when a signal is presented (miss) or touches the response paddle when no signal is generated (false alarm), it does not receive a reward and moves on to the next trial. Each session includes 40 to 60 trials, and frequencies are tested in a random order.

Audiograms, or curves depicting hearing sensitivity, are constructed from the hearing thresholds measured at each sound frequency. (See Figure 1). Although these

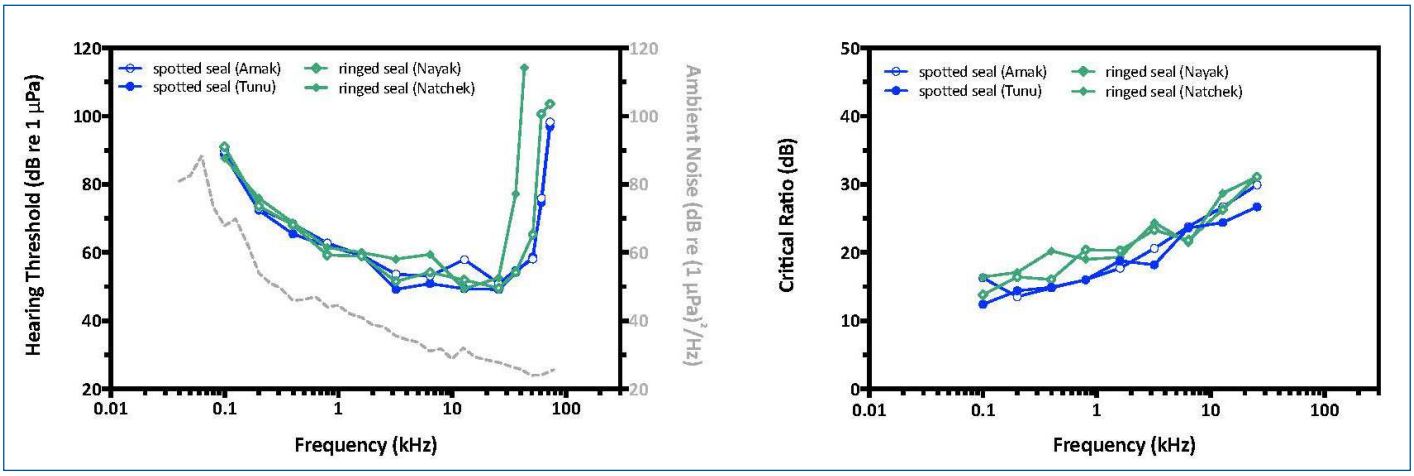

Figure 1: Underwater audiograms for the two spotted seals (blue) and two ringed seals (green). The left panel shows curves depicting hearing sensitivity at each measured frequency; the acoustic noise floor in the testing enclosure is shown by the grey dotted line. The right panel shows critical ratios measured for the same four Arctic seals. For each frequency tested, the points indicate the level by which an acoustic signal must exceed the surrounding background sound in order to be heard.[2]

curves vary somewhat by individual, they are used to describe species-specific hearing abilities, and in cases where species have similar hearing, group-specific hearing abilities. Complete aerial and underwater audiograms for spotted and ringed seals are now available, as are measurements of critical ratios that describe how well the seals hear in noisy (masking) conditions. (See Figure 1, above).

These experiments indicate that the hearing capabilities of spotted and ringed seals are quite similar. Both hear nearly as well under water as fully aquatic animals, but have greater sensitivity in the lower frequencies, which suggested to researchers that they might be more vulnerable to the effects of anthropogenic sound.[1,2] These seals also have surprisingly acute in-air hearing. Hearing tests conducted in the acoustic chamber revealed that their ability to hear sounds in air rivals that of terrestrial mammals such as cats.[3,4]

Applied Research

The basic research on auditory biology described above established the necessary foundation for specific questions to be asked about the effects of seismic airguns on hearing in seals. The applied research that followed has taken two forms.

Tunu was trained to perform cooperative auditory detection tasks under water. *(Photo Credit: Colleen Reichmuth/NMFS 18902.)*

Research on the masking potential of airguns has been conducted with these seals, essentially asking the question of how the impulsive sounds of airgun arrays limit the abilities of seals to hear biologically relevant sounds, both close to and distant from the sound sources. Understanding hearing in regard to masking sounds may actually be more relevant than an understanding of absolute auditory capabilities, because background sound usually limits hearing ability in nature. During these applied masking studies, a ringed seal and a spotted seal were tested on the ability to detect specific low frequency

1 Sills, J.M., Southall, B.L., and Reichmuth, C. (2014) Amphibious hearing in spotted seals (Phoca largha): Underwater audiograms, aerial audiograms, and critical ratio measurements. *Journal of Experimental Biology*, 217: 726-734.

2 Sills, J. M., Southall, B.L., and Reichmuth, C. (2015) Amphibious hearing in ringed seals (Pusa hispida): Underwater audiograms, aerial audiograms, and critical ratio measurements. *Journal of Experimental Biology*, 218: 2250-2259.

3 Heffner, H.E. (1983) Hearing in large and small dogs: Absolute thresholds and size of the tympanic membrane. *Behav Neurosci*, 97: 310–318.

4 Heffner, R.S., Heffner, H.E. (1985) Hearing range of the domestic cat. *Hear Res*: 19, 85–88.

signal in the presence of time-varying seismic airgun sound. This is the first study of its kind for any marine mammal.[5]

The second applied research project is ongoing and concerns whether and at what levels impulsive sounds from airguns cause temporary reductions in hearing sensitivity (temporary threshold shift (TTS)). The first stages of these studies, with spotted and ringed seals[6] found no evidence of TTS in four subjects exposed to impulse sound exposure levels previously predicted to cause TTS onset.[7] This indicates that the regulatory guidelines for impulse exposure established in 2007 may very well be conservative for spotted and ringed seals. Similar basic and applied studies for bearded seals have recently been completed by the UCSC team, and the work is being prepared for publication.

Researchers are currently working to determine the impulsive sound levels that do cause temporary, recoverable changes in hearing sensitivity. This research will address the question of how well the updated impulse exposure limits predict the onset of TTS in pinnipeds. For more information about this guidance, see www.nmfs.noaa.gov/pr/acoustics/guidelines.htm.

Spotted seals Amak and Tunu work with trainer Jenna Lofstrom and the research team at Long Marine Laboratory.
(Photo Credit: Colleen Reichmuth/NMFS 18902.)

The results of this JIP-funded research with seals have been used to inform regulatory guidelines put forward by the National Marine Fisheries Service of the United States (2015) and are used worldwide to mitigate the potentially harmful effects of industry sound on seals and other marine mammals.

[5] Sills, J.M., Southall, B.L., and Reichmuth, C. (2017) The influence of temporally varying noise from seismic air guns on the detection of underwater sounds by seals. *J. Acoust. Soc. Am.*, 141(2): 996-1008.

[6] Reichmuth, C., Ghoul, A., Sills, J.M., Rouse, A., and Southall, B.L. (2016) Low-frequency temporary threshold shift not observed in spotted or ringed seals exposed to single air gun impulses. *J. Acoust. Soc. Am.*, 140: 2646-2658.

[7] Southall, B.L., et al. (2007) Aquatic Mammals; Moline Vol. 33, Iss. 4: 411-414.

ABOUT THE JIP

One of the most extensive environmental industry research programmes bringing together the world's foremost experts across industry, academia and independent research centres.

This fact sheet has been produced by the IOGP E&P Sound and Marine Life Joint Industry Programme (JIP). The JIP was founded in 2005 and supports research to help increase understanding of the potential effect of sound generated by oil and gas exploration and production activity on marine life.

To learn more about the JIP and our research, please visit www.soundandmarinelife.org

Contact us

General Enquiries: info@soundandmarinelife.org

Media Enquiries: press@soundandmarinelife.org or +44 20 7413 3416