Amphibious hearing in the sea otter

Asila Ghoul and Colleen Reichmuth, University of California, Santa Cruz

BOEM Bureau of Ocean Energy Management

HDR

NAVFAC

Monterey Bay Aquarium

Aquarium of the Pacific

Sea otters are among several species of marine carnivores

Otariidae

Cape fur seal
Antarctic fur seal
Subantarctic fur seal
Guadalupe fur seal
New Zealand fur seal
South American fur seal
Galapagos fur seal
Juan Fernandez fur seal
Northern fur seal
California sea lion
Steller sea lion
Australian sea lion
New Zealand sea lion
South American sea lion

Phocidae

Bearded seal
Harbor seal
Spotted seal
Ringed seal
Caspian seal
Baikal seal
Grey seal
Ribbon seal
Harp seal
Hooded seal
Mediterranean monk seal
Hawaiian monk seal
Southern elephant seal
Northern elephant seal
Weddell seal
Ross seal
Crabeater seal
Leopard seal

Odobenidae

Walrus

Mustelidae

Sea otter

Ursidae

Polar bear

Sea otters are among several species of marine carnivores

Otariidae

Cape fur seal
Antarctic fur seal
Subantarctic fur seal
Guadalupe fur seal
New Zealand fur seal
South American fur seal
Galapagos fur seal
Juan Fernandez fur seal
Northern fur seal
California sea lion
Steller sea lion
Australian sea lion
New Zealand sea lion
South American sea lion

Phocidae

Bearded seal
Harbor seal
Spotted seal
Ringed seal
Caspian seal
Baikal seal
Grey seal
Ribbon seal
Harp seal
Hooded seal
Mediterranean monk seal
Hawaiian monk seal
Southern elephant seal
Northern elephant seal
Weddell seal
Ross seal
Crabeater seal
Leopard seal

Odobenidae

Walrus

Mustelidae

Sea otter

Ursidae

Polar bear

Hearing data available for 11 species from 3 families

Information about sea otter hearing necessary to fill critical data gap

To what degree is the auditory sense of sea otters adapted to a marine habitat?

Unlike other amphibious marine mammals,
sea otters have no ties to land

They can eat, sleep, breed, give birth, and
raise their young entirely at sea

Sea otters are essentially islands unto themselves—



while they live their lives almost entirely at sea, much of their time is spent with their primary sensory structures above the water's surface

Hearing data are critical to assessing the potential effects of human-generated noise

Measurement of hearing profiles

1. Describe the sea otter's hearing capabilities in air and underwater by obtaining hearing thresholds for narrow-band signals

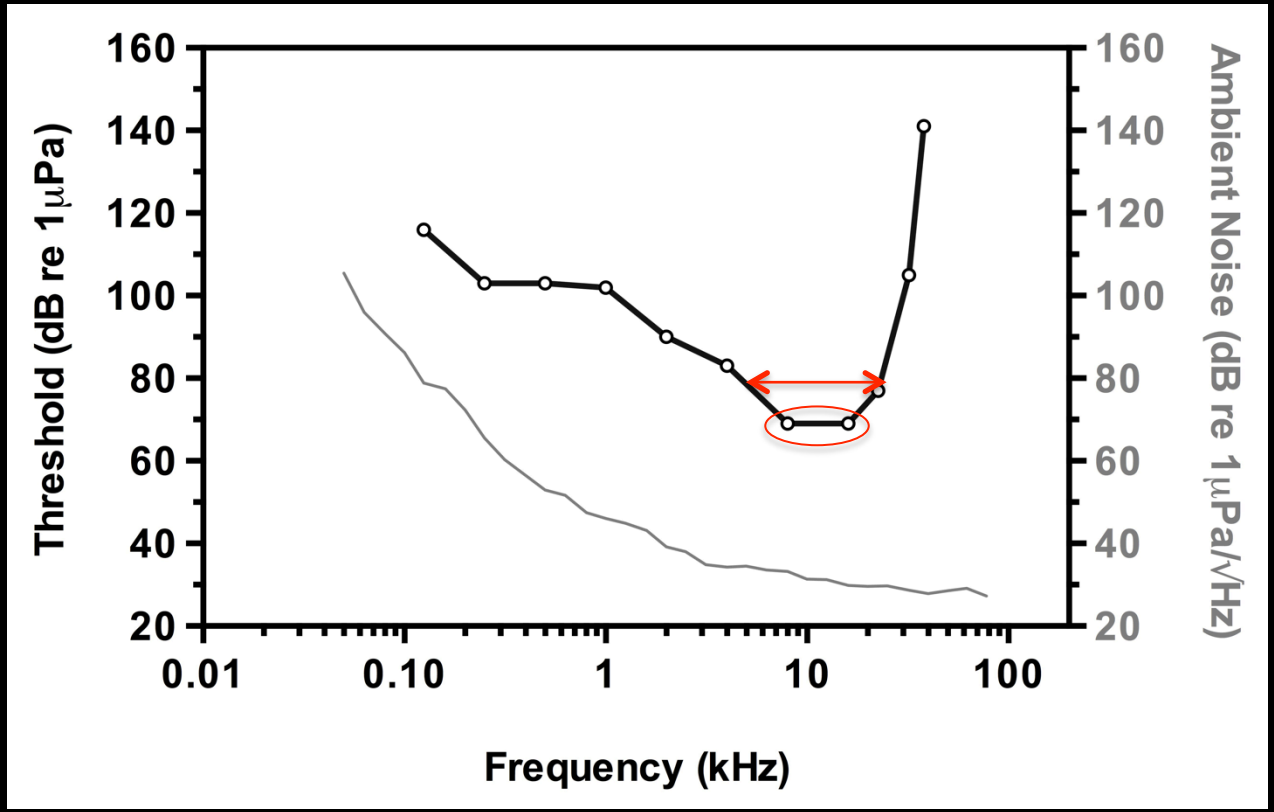
2. Evaluate hearing in a masking scenario by obtaining thresholds in air for the same signals, in the presence of noise

Underwater hearing test

Aerial hearing test

1. Description of basic hearing capabilities

Underwater hearing

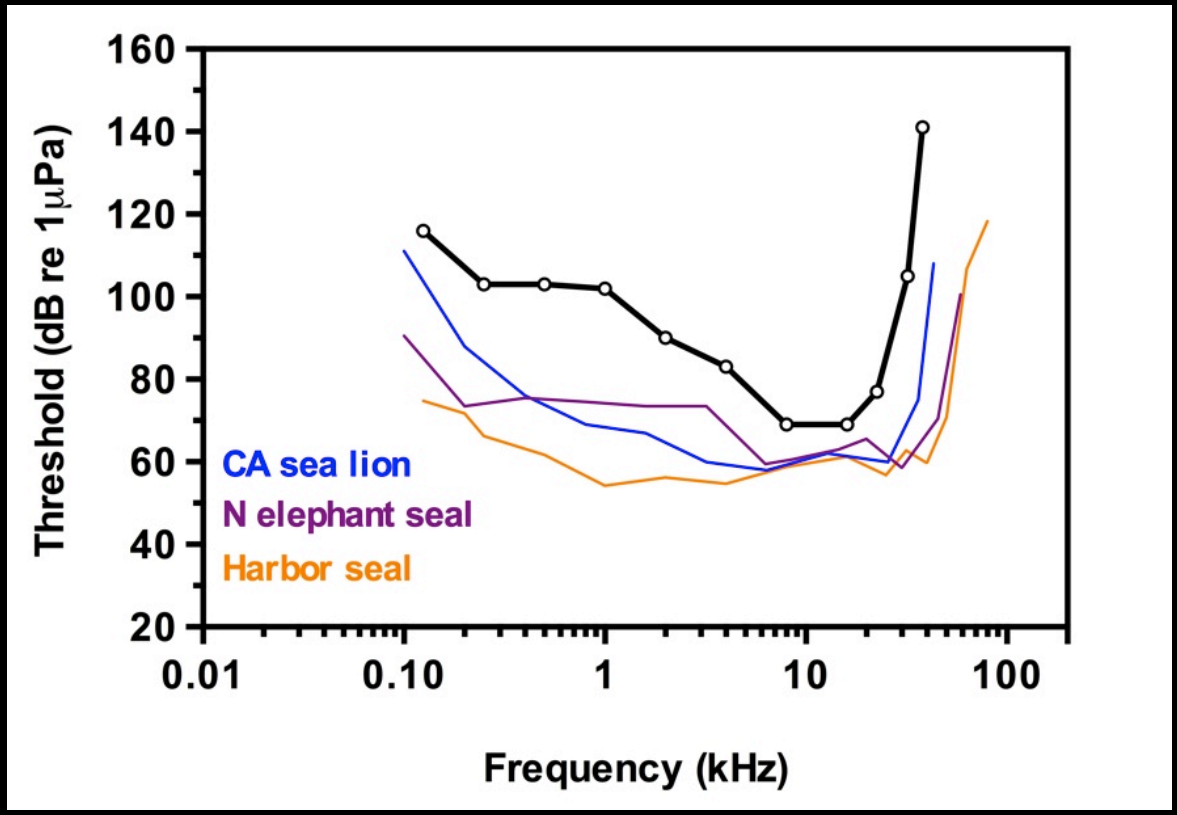


Most sensitive at 8 kHz and 16 kHz

Range of best hearing: 5 – 23 kHz

1. Description of basic hearing capabilities

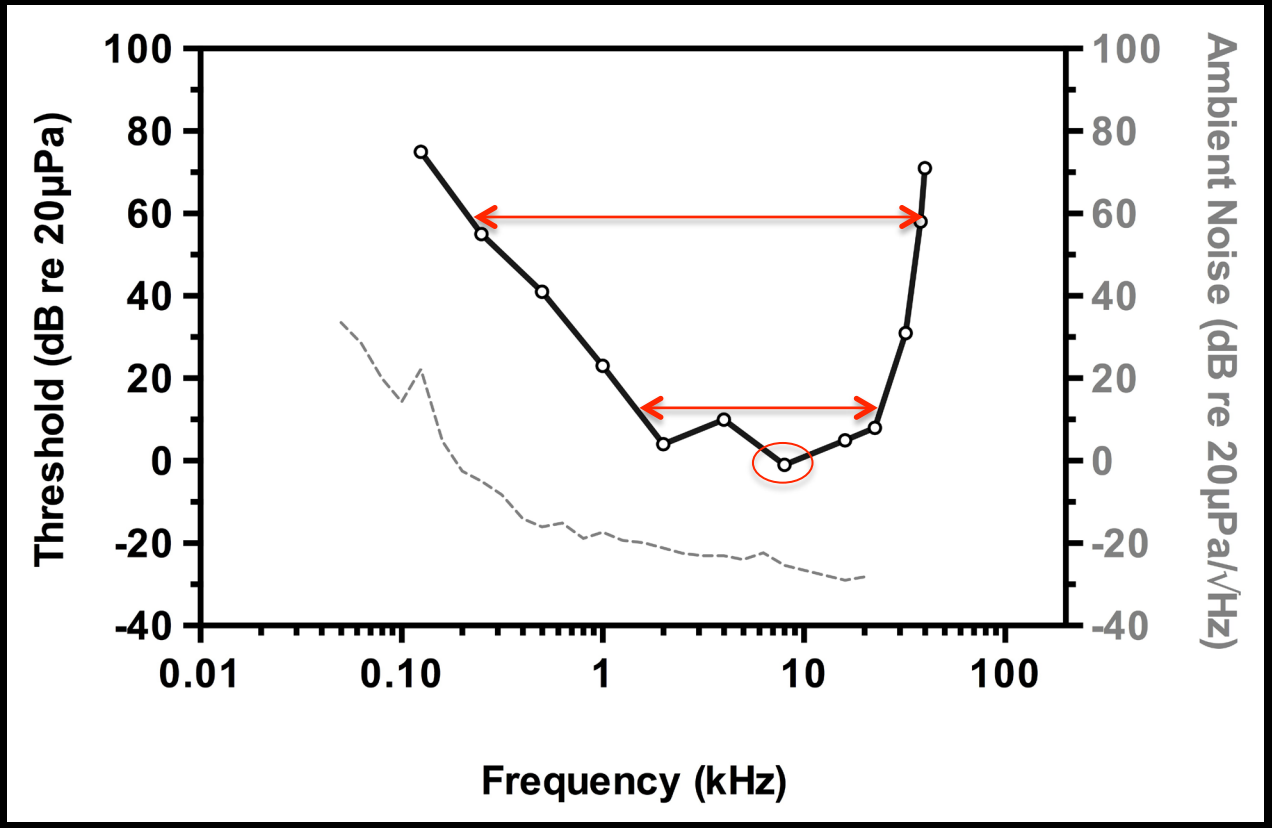
Underwater hearing



Adapted from Reichmuth et al. (2013), Kastak & Schusterman (1999), and Kastelein (2010)

1. Description of basic hearing capabilities

Aerial hearing



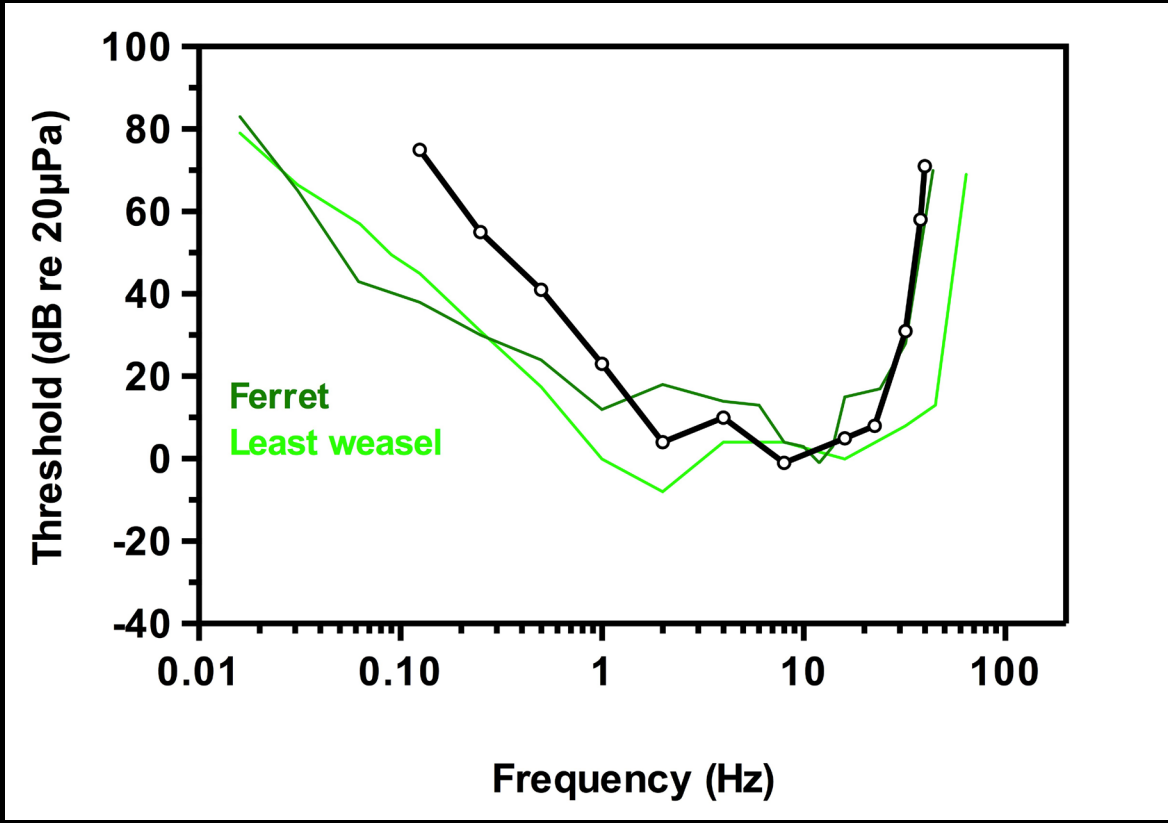
Most sensitive at 8 kHz

Range of best hearing: 2 – 22 kHz

Functional hearing bandwidth: 0.25 – 40 kHz

1. Description of basic hearing capabilities

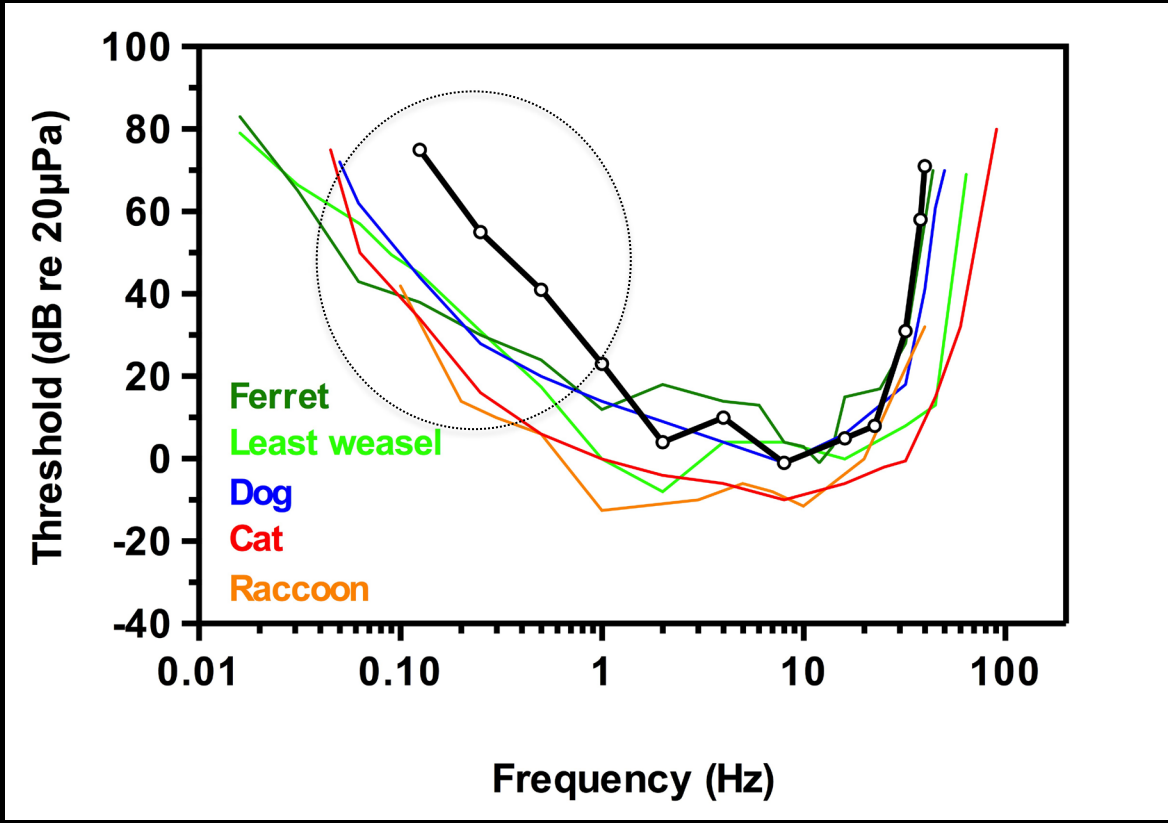
Aerial hearing



Adapted from Heffner & Heffner (1985) and Kelly et al. (1986)

1. Description of basic hearing capabilities

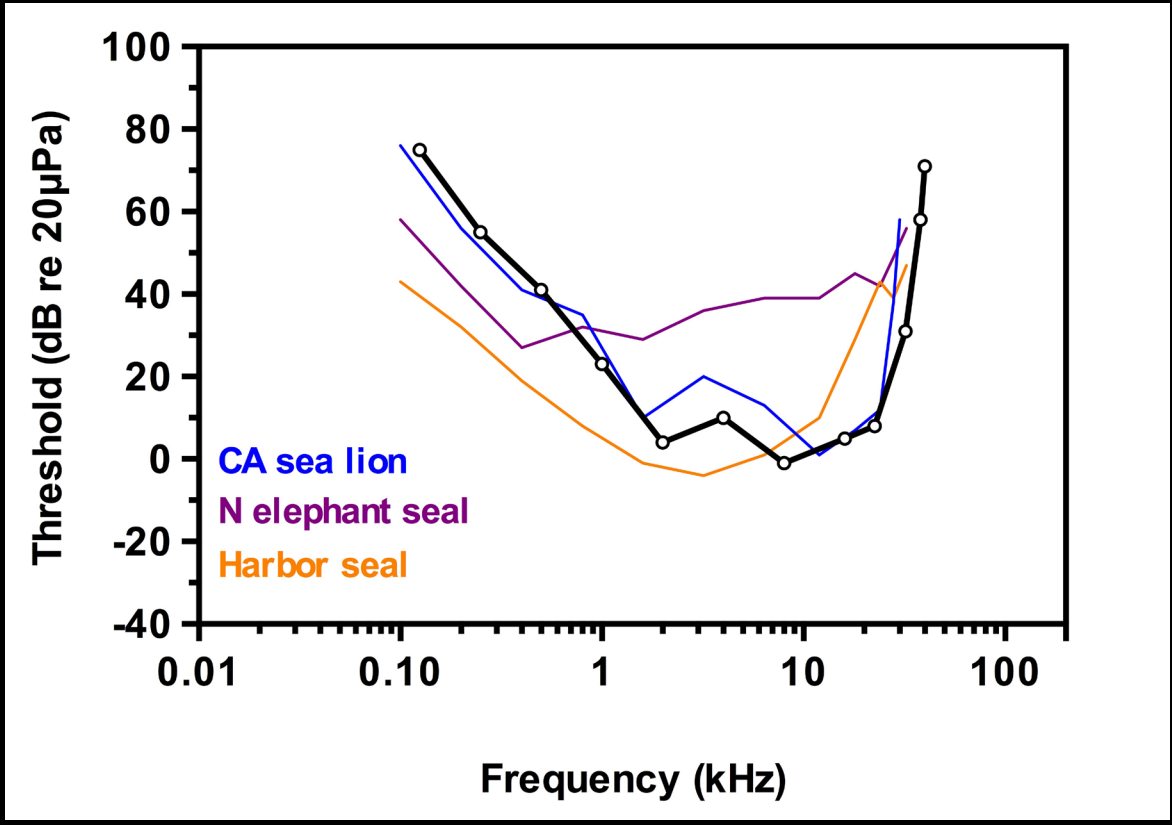
Aerial hearing



Adapted from Heffner & Heffner (1985), Kelly et al. (1986), Neff & Hind (1955), Heffner (1983), and Wollack (1965)

1. Description of basic hearing capabilities

Aerial hearing



Adapted from Reichmuth et al. (2013)

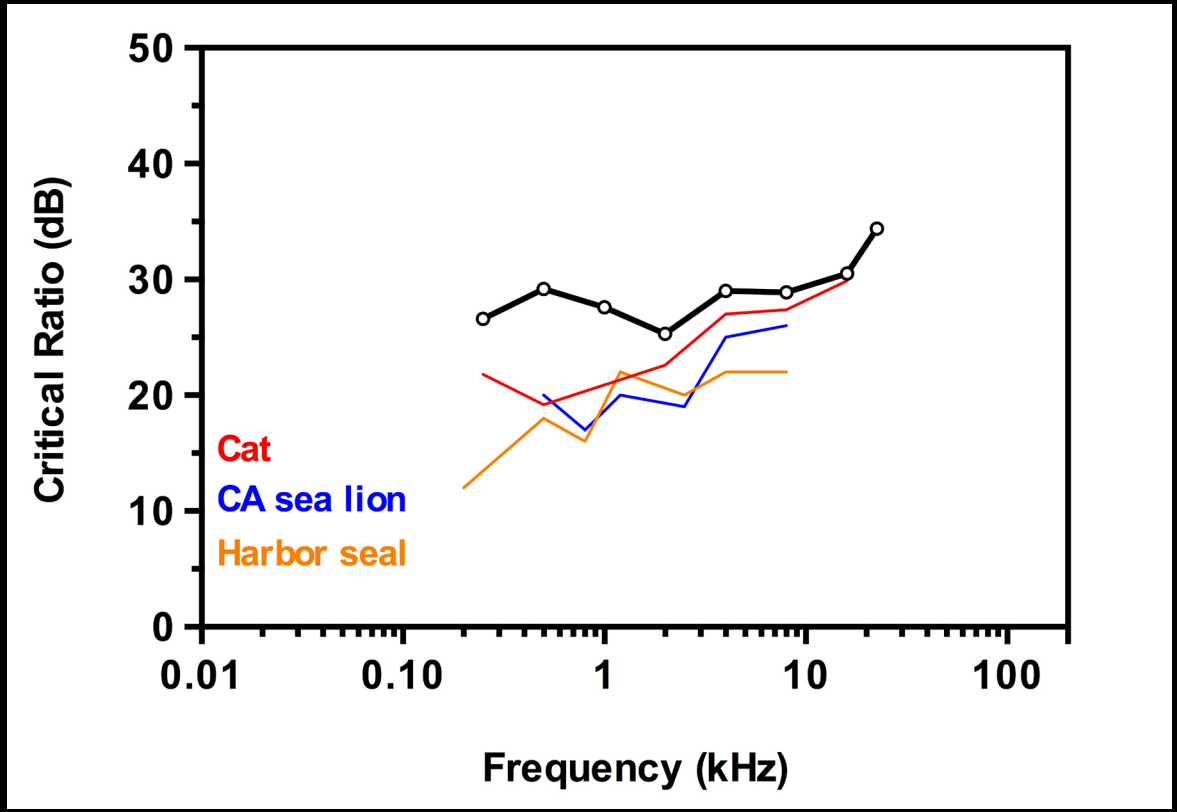
2. Evaluating hearing in a masking scenario

masked thresholds ➡ critical ratios

How loud does a signal has to be above background noise,
in order for detection to occur?

2. Evaluating hearing in a masking scenario

Critical ratios



Adapted from Costalupes (1983) and Southall et al. (2003)

Conclusions

Underwater sensitivity is reduced compared to other amphibious marine mammals, especially at low frequencies

Aerial hearing is comparable to that of terrestrial carnivores, but most closely resembles sea lion hearing

Ability to extract signals embedded in background noise is not specialized as seen in some pinnipeds

Conclusions

These hearing profiles will allow regulators to identify or exclude airborne and underwater sounds of potential concern

Support

CNO, N45 and NAVFAC Atlantic, HDR Inc.
Bureau of Ocean Energy Management
Monterey Bay Aquarium, Monterey, CA

Permissions

US Fish and Wildlife Service Federal Permit MA186914-0
UC Santa Cruz IACUC protocol approval

Special Thanks

Aquarium of the Pacific, Long Beach, CA
Jim Finneran (NMMP)
Staff and volunteers at the Pinniped Cognition and Sensory Systems Lab, especially Caroline Casey, Jenna Lofstrom, Jillian Sills, Kane Cunningham, Andrew Rouse, and Brendan Wakefield