Abstract

Humans produce significant noise levels in the ocean, especially through the operation of ships and sonar testing. Models of whale hearing are a critical step in assessing the impact of human-made sounds on whales. This thesis uses finite element methods and experimental testing to identify potential functional advantages of the whale tympanic bulla's geometry and material properties.

Finite element methods were used to determine the natural frequencies and mode shapes of free and fixed configurations of the right tympanic bulla of a mysticete (baleen whale). Fixing the tympanic bulla gave rise to pendulum-like mode shapes at low frequencies. At mid-frequencies, mode shapes showed vibrations concentrated at the bone's sigmoid process, showing that the sigmoid process can play a key role in both receiving vibrations and dampening them. At higher frequencies, mode shapes showed complex vibrations distributed over the bone's lateral wall. Modal analysis showed that the bone may specialize in hearing frequencies far above the whale's vocalization range.

Tests were performed on a gypsum-based 3-D print of the bone, in free and fixed configurations, to assess the validity of the finite element model and study the potential effects of soft tissues in contact with the bone. Excitation sources included an impact hammer, speaker, and bone-conduction transducer. Impact hammer tests identified natural frequencies and confirmed that natural freuqencies were closely-spaced in the fixed configuration. Damp polyurethane foam, Knox gelatin, and silicone polymer compound (Silly Putty) were used to approximate the viscoelastic properties of soft tissue. Interaction between a fat-mimicking material and a crevice on the tympanic bulla was observed to enhance vibrational response to a sound field.