Discovery of Sound in the Sea (DOSITS)
Hearing in Marine Fishes, Video Summary

Physiology of hearing in marine fishes

- All fish species detect **particle motion**, which is an oscillation back and forth along the line of transmission of a sound. Some fishes also have adaptations that let them detect **sound pressure**.
- Fishes detect sounds with the **inner ear**, a structure that is very similar to parts of the ears found in terrestrial vertebrates and marine mammals. However, fishes have no need for external and middle ears since their bodies have approximately the same density as water, and sound passes right through their bodies to the inner ear.
- Many fish species have calcium carbonate structures in the inner ear, called **otoliths.**
  - Each of these otolith organs differs in size and orientation.
  - The otoliths are also much denser than water and the fish's body tissues, and vary in overall size and shape among species.
- Each otolith organ consists of a solid mass, sitting on **sensory hair cells**. A sound propagates through the body tissues of a fish, and since the otoliths are denser, they move (or oscillate) at a different amplitude and phase in response to the sound waves than does the rest of the body tissues. The difference between the motion of the fish's body and the otoliths causes cilia on the hair cells of the inner ear to bend. This difference between the motion of the hair cells and the otolith is interpreted by the brain as sound.
  - Each otolith organ has a different orientation, which, in addition to the variable orientation of the hair cells, enables sound direction to be determined.

For more information on the DOSITS website:
www.dosits.org/animals/soundreception/fishhear/

Hearing sensitivities of marine fishes

- One factor affecting hearing sensitivity in fishes is the **proximity of the inner ear to the swim bladder**.
  - The density of the gas within the swim bladder is much lower than that of seawater and the fish's body. As a result, sound waves cause the walls of the swim bladder to oscillate. If the movements of the swim bladder wall are transmitted to the ear, this results in the stimulation of the hair cells of the inner ear.
  - Fishes where there are direct connections between the swim bladder and other gas-filled organs and the inner ear, and even in some fishes without direct connections, have been shown to be sensitive to sound pressure.
- Fishes lacking a swim bladder, or those that have a small or reduced swim bladder, or a swim bladder that is not in close proximity, or mechanically connected to the ears, are sensitive to particle motion.
  - These fishes can hear best when the levels of particle motion are especially high, for example, close to the surface or in shallow water.
  - They tend not to hear sounds at frequencies above 1 kHz.

- Fishes with swim bladders that are in close proximity to the inner ear and/or are connected to the inner ear can hear at a wider frequency range than those fishes without such connections.
    - Some of these fishes can hear up to 3kHz or more.
    - One group, the clupeiform fishes, have gas ducts that extend from the swim bladder and come in direct contact with the inner ear. These ducts end in "bullae" that contain a gas bubble. The bubble is in close proximity to the inner ear, and results in the transformation of sound pressure waves to particle motion.
        - Some clupeid species, such as the American shad, can detect high-level ultrasonic frequencies up to 180 kHz.

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- The structure of the inner ears and swim bladders vary greatly in different species of fish. Thus, it is difficult to predict hearing abilities of marine fishes based on their anatomy.

- Sound provides marine animals with a unique, three-dimensional "view" of their undersea world. Hearing provides information about things happening around an animal at considerable distances, and is useful for telling the direction to a sound source. Hearing is vitally important to all marine animals.

Discovery of Sound in the Sea (DOSITS; www.dosits.org) is a comprehensive, educational website on underwater sound, designed to provide accurate scientific information at levels appropriate for all audiences, including decision-makers. This video series is being sponsored by the Exploration and Production, Sound and Marine Life Joint Industry Programme (www.soundandmarinelife.org).