Underwater Acoustics: Webinar Series for the International Regulatory Community

Webinar Outline: Marine Animal Sound Production and Reception
Thursday, December 3, 2015 at 12:00pm (US East Coast Time)

Sound production and reception in teleost fish (M. Clara P. Amorim, Ispa – Instituto Universitário)

- Teleost fish are likely the largest vocal vertebrate group. Sounds made by fish can be an important part of marine soundscapes.

- Fish possess the most diversified sonic mechanisms among vertebrates, which include the vibration of the swim bladder through intrinsic or extrinsic sonic muscles, as well as the rubbing of bony elements.

- Fish sounds are usually pulsed (each sonic muscle contraction corresponds to a sound pulse), short (typically shorter than 1 s) and broadband (with most energy below 1 kHz), although some fish produce tonal sounds. Sounds generated by bony elements are often higher frequency (up to a few kHz).

- In contrast with terrestrial vertebrates, fish have no external or middle ear. Fish detect sounds with the inner ear, which comprises three semicircular canals and three otolithic end organs, the utricle, the saccule and the lagena. Fish mostly detect particle motion and hear up to 1 kHz. Some species have evolved accessory auditory structures that serve as pressures transducers and present enhanced hearing sensitivity and increased frequency detection up to several kHz. Fish hearing seems to have evolved independently of sound production and is important to detect the 'auditory scene'.

- Acoustic signals are produced during social interactions or during distress situations as in insects or other vertebrates. Sounds are important in mate attraction, courtship and spawning or to defend a territory and gain access to food.

Additional information on the DOSITS website:
Science of Sound > What sounds can we hear?
(http://www.dosits.org/science/soundmeasurement/soundshear/)

Science of Sound> What sounds can animals hear?
(http://www.dosits.org/science/soundmeasurement/soundsanimalshear/)

Science of Sound > What are common underwater sounds?
(http://www.dosits.org/science/soundsinthesea/commonsounds/)

Science of Sound > How do people and animals use sound in the sea?
(http://www.dosits.org/science/soundsinthesea/peopleanimalsuse/)

Science of Sound > Why do sounds have different properties?
(http://www.dosits.org/science/soundsinthesea/properties/)

Science of Sound > How does marine life affect ocean sound levels?
(http://www.dosits.org/science/soundsinthesea/marinelifeaffectoceansound/)

Science of Sound > Advanced Topic > What is intensity?
(http://www.dosits.org/science/advancedtopics/whatsintensity/)

Animals and sound > Why is sound important to marine animals?
(http://www.dosits.org/animals/importanceofsound/whyissoundimportant/)

Animals and Sound > How do marine animals use sound?
(http://www.dosits.org/animals/useofsound/animalsusesound/)

Animals and Sound > How do marine fish communicate using sound?
(http://www.dosits.org/animals/useofsound/fishcommunicate/)

Animals and Sound > How do marine fish and invertebrates use or make sound when feeding?
(http://www.dosits.org/animals/useofsound/fishinvertfeeding/)

Animals and Sound > How do marine fish produce sounds?
(http://www.dosits.org/animals/soundproduction/fishproduce/)

Animals and Sound > How do fish hear?
(http://www.dosits.org/animals/soundreception/fishhear/)

Animals and Sound > Advanced Topic > What components of sound are used for hearing?
(http://www.dosits.org/animals/advancedtopics/componentsofsound/)

Marine Mammals Underwater Hearing: Sound Production, Sound Reception, and Sound Impacts (Dr. Darlene Ketten, Jefferson Science Fellow, National Academy of Sciences and U.S. Dept. of State, Harvard University Medical School, Woods Hole Oceanographic Institution)

What is a Marine Mammal?

- Marine mammals belong to five vertebrate groups: cetaceans (dolphins and whales), pinnipeds (seals, sea lions, and walruses), sirenians (manatees and dugongs), mustelids (sea otters) and ursids (polar bears).
- Cetaceans are divided into the odontocetes (toothed whales and dolphins) and the mysticetes (baleen whales). Pinnipeds are divided into the phocids (true seals), the otariids (eared seals and sea lions), and the odobenids (walrus).
- Cetaceans and sirenians are completely aquatic adapted; the other groups are amphibious, adapted in varying degrees to air vs. water.

Marine Mammal Sound Production

- Like land mammals, all marine mammals have a larynx which is used to produce vocalizations ranging from infra to ultrasonic frequencies. Odontocetes also produce very high frequency clicks and buzzes for echolocation by manipulating air in specialized narial sacs and channelling the sounds through the fatty melon at the front of the odontocete head.
- Peak spectra of vocalizations and echolocation signals are correlated with the size of the animal, the distance over which it needs to communicate, and, for echolocators, the type of prey. Species that hunt small fish in complex environments use higher frequencies at lower intensities while off-shore species communicating across long distances use very low frequencies, sometimes at high intensities.

Marine Mammal Sound Reception

- Marine mammals, like land mammals, have a three-part auditory system: Outer Ear (sound collection and transmission); Middle Ear (amplification and mechanical transduction) and Inner Ear (neurotransduction).
- The most important adaptations in marine mammal ears for hearing underwater are in the outer and middle ears. Many have outer canal valves and specialized middle ear tissues to assist with pressure equalization during diving and extremely dense ear bones that are resistant to breakage from extreme ambient pressures. The outer ears of cetaceans have unique fats that receive and channel underwater sound to the middle and inner ear.
- The inner ear (cochlea) of all marine mammals is similar to land mammals but in many species it can receive and transduce a greater range of frequencies, in some species as much as 12 octaves. Cetacean inner ears also have double to triple the innervation density of those of other mammal and they are capable of better detection of signals in noise and better sound localization than most mammals.

Marine Mammals and Sound Impacts

- Again, like land mammals, marine mammals are subject to hearing loss from sound impacts but also from disease, aging, and trauma. Captive animals tested over several years have been shown to lose high frequency hearing as they age in a process similar to those known for humans. This suggests they are also subject to Noise Induced Hearing Loss (NIHL) if exposed to sounds in their hearing range for long periods of time and at high intensities.

Terminology

audiogram: A graph of hearing ability conventionally displayed as frequency vs. sensitivity measured as sound pressure or intensity

cochlea: the inner ear spiral which contains cells that transform sound energy into neural impulses.

decibel (dB): a scale based on the log ratio of two quantities. It is commonly used to represent sound pressure level. The value of the decibel depends upon the reference pressure, which differs in air vs. water. The decibel level of sound is properly stated in the form of n dB re n microPa . The microPascal is a unit of pressure. In terms of intensity, 100 dB re 20 microPa in air equals approximately 160 dB re 1 microPa in water.

infrasonic: below 20 Hz, the lower limit of human hearing

kHz: kilo Hertz. A Hertz (Hz) is a measure of sound frequency equal to 1 cycle/sec. A kHz is one thousand cycles per second

nares/narial: air passages that connect the throat area with the external opening of the nose.

octave: An octave is broadly defined as a doubling of frequency. Thus, a one octave shift from 500 Hz is 1,000 Hz; from 3,000 Hz, it is 6,000 Hz. Adult humans have on average an 8 octave functional hearing range of 32 Hz to 16 kHz

ossicles: the middle ear bones that act as levers to mechanically transform sound waves into pressure, frequency, and velocity components transduced by the inner ear.

ultrasonic: above 20 kHz, the upper limit of human hearing.

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Animals and Sound > How do marine mammals hear?
(http://www.dosits.org/animals/soundreception/mammalshear/)

- Hearing in Land Mammals
  (http://www.dosits.org/animals/soundreception/mammalshear/landmammals/)
- Hearing in Pinnipeds, the Amphibious Ear
  (http://www.dosits.org/animals/soundreception/mammalshear/hearinginpinnipeds/)
- Hearing in Cetaceans and Sirenians, the Fully Aquatic Ear
  (http://www.dosits.org/animals/soundreception/mammalshear/hearingincetaceans)

Animals and Sound > Marine Mammal Communication

- Individual-specific vocalizations
  (http://www.dosits.org/animals/useofsound/mammalscommunicate/individualspecific/)
- Group-specific vocalizations
  (http://www.dosits.org/animals/useofsound/mammalscommunicate/groupspecific/)
- Vocalizations associated with reproduction
  (http://www.dosits.org/animals/useofsound/mammalscommunicate/reproduction/)
- Sounds associated with aggression
  (http://www.dosits.org/animals/useofsound/mammalscommunicate/aggression/)

Animals and Sound > How do marine mammals use or make sound when feeding?
(http://www.dosits.org/animals/useofsound/howdomarineanimalsuseormakesoundwhenfeeding/)

Animals and Sound > How do marine mammals use sound to navigate?
(http://www.dosits.org/animals/useofsound/soundtonavigate/)

Animals and Sound > What are the potential effects of sound on marine mammals?
(http://www.dosits.org/animals/effectsofsound/marinemammals/)

Animals and Sound > Advanced Topic > What components of sound are used for hearing?
(http://www.dosits.org/animals/advancedtopics/componentsofsound/)

Animals and Sound > Advanced Topic > Hearing Loss
(http://www.dosits.org/animals/advancedtopics/hearingloss/)