TECHNICAL COMMITTEE REPORT

Animal Bioacoustics

Members of the Animal Bioacoustics Technical Committee have diverse backgrounds and skills, which they apply to the study of sound in animals.

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Animal bioacoustics is a field of research that encompasses sound production and reception by animals, animal communication, biosonar, active and passive acoustic technologies for population monitoring, acoustic ecology, and the effects of noise on animals. Animal bioacousticians come from very diverse backgrounds: engineering, physics, geophysics, oceanography, biology, mathematics, psychology, ecology, and computer science. Some of us work in industry (e.g., petroleum, mining, energy, shipping, construction, environmental consulting, tourism), some work in government (e.g., Departments of Environment, Fisheries and Oceans, Parks and Wildlife, Defense), and some are traditional academics. We all come together to join in the study of sound in animals, a truly interdisciplinary field of research.

Why study animal bioacoustics? The motivation for many is conservation. Many animals are vocal, and, consequently, passive listening provides a noninvasive and efficient tool to monitor population abundance, distribution, and behavior. Listening not only to animals but also to the sounds of the physical environment and man-made sounds, all of which make up a soundscape, allows us to monitor entire ecosystems, their health, and changes over time. Industrial development often follows the principles of sustainability, which includes environmental safety, and bioacoustics is a tool for environmental monitoring and management. Animal systems can be superior to man-made systems in various ways. As a consequence, understanding bioacoustic systems can advance the development of biomimetic technology such as sonar hardware and software. Last but not least, studying animal hearing and hearing impairment holds great potential for understanding human hearing and mitigating human auditory injury and disease.

One research topic of interest to animal bioacousticians is animal communication (Bradbury and Vehrencamp, 2011; also see articles in this issue of *Acoustics Today* by Tyack on communication by marine mammals and Pollack on the bioacoustics of insects). Animals send signals to "persuade" others to mate with them, to inform them about some object in the environment, and to coordinate group hunts and other social behaviors. There are often costs to producing animal signals, namely, that it makes one vulnerable to predators in the vicinity. Yet not communicating could be costlier. Effective acoustic communication by animals is essential for survival in many species, and many animal bioacousticians have parsed the process to better understand what animals are doing (e.g., Narins et al., 2006).

Some of us study the first stage of the animal communication process, the sender. Animals produce different signals based on their anatomy, such as the size of their signal-production apparatus. Larger animals typically produce lower frequency sounds than do smaller animals, and in many species such as frogs, this makes males more attractive to females who are deciding with whom to mate. Animals can produce sounds by banging body parts against the surface, such as head-banging termites, tail-slapping beavers, and breaching whales. Others rub body parts together in a process known as stridulation. Although insects such as grasshoppers are probably the most famous animals to do this, stridulation is documented in a wide variety of animals including catfish, seahorses, birds such as manakins and hummingbirds, and spiny lobsters. Other animals such as rattlesnakes vibrate appendages to make sounds, and still others force air through a small orifice to call. This last mechanism of sound production occurs through the larynx in humans and nonhuman primates and through an organ known as the syrinx in birds. The syrinx is a specialized version of the larynx that allows songbirds to breathe while they sing and results in the beautifully complex songs we hear outside our windows each spring (e.g., Marler and Slabbekoorn, 2004). The complexity of song produced by songbirds is the subject of interest for many animal bioacousticians.

Speaking of songs, the next stage of the animal communication process studied by animal bioacousticians involves the signals themselves. Whether produced via stridulation or forcing air through a syrinx, many signals that animals produce can be quite complex and meaningful to receivers. Animals can convey information about species, family, and sometimes even individual identity in their signals. They can let others around them know about some new positive (food) or negative (predatory) object in their environment. Animal bioacousticians have learned that females of some species of birds prefer highly stereotyped acoustic signals, whereas other females prefer males who are good improvisers. Some animals such as whales have the ability to change many spectrotemporal properties of their sounds, whereas others such as ants are limited. Finally, many species of animals are born knowing their vocalizations, whereas others must be exposed to a tutor to produce species-appropriate calls and songs. Knowing what sounds animals make and understanding their associated behavior is crucial information for population monitoring by noninvasive passive listening and, ultimately, for conservation management. Animal bioacousticians have borrowed signal-processing tools from unrelated fields (e.g., computer science or geophysics) and developed algorithms for the detection, classification, localization, tracking, and density estimation of (vocal) animals (e.g., Au and Hastings, 2008).

Another popular area of research by animal bioacousticians is the effect of the environment on animal communication (Wiley, 2015). A male frog may produce a beautifully complex set of calls intended to attract all female conspecifics in the vicinity to mate with him, but if the environment is too noisy, the females will not receive those signals and he will be out of luck. Noise in the environment can be weather related or produced by humans or other animals. Noise can mask animal communication, change behavior, induce stress, injure tissues, and thus disrupt critical life functions (e.g., Popper and Hawkins, 2012, 2016). Animals have adapted various ways to lessen the effects of noise on the communication process. Some whales near whale-watching boats produce longer calls than those in quieter environments. Many species of animals produce louder calls in noise than in quiet. Other animals produce higher frequency signals to avoid the low-frequency noise of cities. These changes in sound emission are collectively known as the Lombard Effect that has been well documented in humans. Still, the broader impact of noise on animals and the limits of many species to adapt in noisy environments need much more attention.

Finally, the last stage of the communication process is the receiver, with many animal bioacousticians studying animal sound reception mechanisms, anatomy, and neurophysiology. Discovering what animals hear can be accomplished in the field or in the laboratory by performing playback or psychoacoustic experiments. Bioacousticians know a lot about what animals detect, discriminate, localize, and categorize (e.g., Fay, 1988). Animals such as bats, cats, dolphins, and barn owls have excellent auditory acuity and are used as behavioral, anatomical, and physiological models for auditory processing. Insects are often able to localize sounds accurately despite having ears right next to each other. Some animals have coevolved with their predators to avoid being eaten, such as crickets hearing high-frequency bat calls and fish hearing high-frequency dolphin signals. Comparative hearing studies have advanced the field of animal bioacoustics in both quiet and noisy environments for the purposes of understanding the evolution of auditory systems as well as for creating models of human hearing and disorders.

Some animals not only produce sound for communication but also for echolocation. Bats and dolphins have a biosonar system that lets them navigate and forage in dark places, at night or in murky deep waters (Griffin, 1958; Au, 1993). Sonar stands for SOund Navigation And Ranging and involves the emission of brief broadband clicks and the processing of echoes. The time delay between the outgoing and incoming click carries information about the range of the reflecting object, whereas the intensity and phase differences between the incoming clicks at the two ears yield information about the direction to the reflecting object. The biosonar system contains only one source and two receivers (the ears) as opposed to military or fisheries sonars that come in multibeam and receiver-array configurations, yet animals can perform the most complex tasks such as recognizing objects buried in the seafloor. Understanding biosonar has great potential for biomimetic sonar technology and biologically inspired signal processing and is a great example of the application of bioacoustic principles to human-made systems.

One of the newer and rapidly growing research topics within animal bioacoustics is soundscapes, terrestrial and aquatic. A soundscape is made up of biotic (animal-made), abiotic (e.g., wind, waves, precipitation, earthquakes, ice breakup), and anthropogenic (human-made) sounds (Farina, 2014; Au and Lammers, 2016). Understanding soundscapes allows us to monitor environmental and ecosystem changes (e.g., due to climate change, urbanization, or industrialization). In particular, underwater acoustic technology was historically restricted to military use, but in recent years, the broader research community gained access. As a consequence, there are now live, real-time, passive acoustic listening stations across the oceans as well as miniature, off-the-shelf autonomous recorders. It is fair to say that the field of animal bioacoustics has progressed the development of terrestrial as well as aquatic instrumentation, hardware, and software as well as data management and warehousing techniques and processes.

Because of the interdisciplinary nature of animal bioacoustics, many of us are part of other Acoustical Society of America (ASA) Technical Committees such as Acoustical Oceanography, Underwater Acoustics, Psychological and Physiological Acoustics, and Signal Processing. In fact, Animal Bioacoustics has not been a Technical Committee for all that long. We started out as a Technical Specialty Group within the Technical Committee on Bioacoustics in 1988 under the leadership of Bill Cummings. We had 11 members back then. In 1996, Bioacoustics split into Animal Bioacoustics and Biomedical Acoustics. Animal Bioacoustics at the ASA has grown ever since. Two of our members are past presidents of the ASA (Whitlow W. L. Au, 2009-2010, and Mardi Hastings, 2011-2012), and our members' research achievements have been awarded ASA Silver (Whitlow W. L. Au, dolphin biosonar, 1998; James A. Simmons, bat biosonar, 2005; and Richard R. Fay, fish hearing, 2012) and Gold (Whitlow W. L. Au, 2016) Medals.

Biosketches

Christine Erbe is the director of the Centre for Marine Science and Technology and an associate professor in physics at Curtin University, Perth, WA, Australia. After obtaining her PhD in geophysics from the University of British Columbia, Vancouver, BC, Canada, she worked for Fisheries and Oceans Canada. She then was director of JASCO Applied Sciences Australia for several years before returning to academia. Christine studies underwater noise, its generation, propagation, and effects on marine life. Marine bioacoustics is clearly more invigorating than terrestrial bioacoustics.

Micheal Dent is an associate professor in the Department of Psychology at the University at Buffalo, The State University of New York. After obtaining at PhD in integrative neuroscience from the University of Maryland at College Park, she worked as a postdoctoral research scientist at the University of Wisconsin Medical School, Madison, before going to Buffalo in 2004. Dr. Dent studies acoustic communication in mice and birds using psychoacoustic methods and recording vocalizations. She has recently assumed the role of associate editor for *Acoustics Today*. Terrestrial bioacoustics is clearly more invigorating than marine bioacoustics.

References

Au, W. W. L. (1993). *The Sonar of Dolphins*. Springer-Verlag, New York.

Au, W. W. L., and Hastings, M. (2008). *Principles of Marine Bioacoustics*. Springer-Verlag, New York.

Au, W. W. L., and Lammers, M. O. (Eds.). (2016). *Listening in the Ocean*. Springer-Verlag, New York.

Bradbury, J. W., and Vehrencamp, S. L. (2011). *Principles of Animal Communication,* 2nd ed. Sinauer Associates, Sunderland, MA.

Farina, A. (2014). *Soundscape Ecology: Principles, Patterns, Methods and Applications*. Springer Nertherlands, Dordrecht, The Netherlands.

Fay, R. R. (1988). *Hearing in Vertebrates: A Psychophysics Databook.* Hill-Fay Associates, Winnetka, IL.

Griffin, D. R. (1958). *Listening in the Dark: The Acoustic Orientation of Bats and Men*. Yale University Press, New Haven, CT.

Marler, P., and Slabbekoorn, H. (2004). *Nature's Music: The Science of Birdsong*. Academic Press, San Diego, CA.

Narins, P. M., Feng, A. S., Fay, R. R., and Popper, A. N. (Eds.). (2006). *Hearing and Sound Communication in Amphibians*. Springer-Verlag, New York.

Popper, A. N., and Hawkins, A. (Eds.). (2012). *The Effects of Noise on Aquatic Life.* Springer-Verlag, New York.

Popper, A. N., and Hawkins, A. (Eds.). (2016). *The Effects of Noise on Aquatic Life II.* Springer-Verlag, New York.

Wiley, R. H. (2015). *Noise Matters.* Harvard University Press, Cambridge, MA.