

## Book Review

AU, WHITLOW W. L., ARTHUR N. POPPER, AND RICHARD R. FAY (EDS.). 2000. *HEARING BY WHALES AND DOLPHINS*. SPRINGER-VERLAG, NEW YORK, XVI+485 PP. ISBN 0-387-94906-2. PRICE (CLOTH) \$129.00. This well-organized book is volume 12 in the *Springer Handbook of Auditory Research* series. In keeping with the intent and design of the series, this volume serves as a comprehensive review and introduction to one of (p. ix) 'the fundamental topics in modern auditory research'. For this volume, co-editor Whitlow W. L. Au of the Hawaii Institute of Marine Biology has joined the series editors, Richard R. Fay and Arthur N. Popper. His expertise in the field of whale and dolphin hearing is apparent, not only in the two chapters he wrote, but in the overall organization and editing of the volume.

The first chapter, written by Dr. Au, serves as both an overview and a preview of what is known and not known about hearing and sound production in whales and dolphins. It begins with a succinct introduction to the importance of acoustics to cetaceans and to basic acoustic concepts, such as sound absorption loss. Supported by figures that illustrate the major points, the chapter continues with brief, but information-packed, sections first on hearing in dolphins and the limited knowledge of hearing in mysticetes, followed by sound production by both groups. Table 1.1 (pp. 2, 3) 'Characteristics of vocalizations of mysticete whales' would be more helpfully placed with the discussion of sound emissions by mysticetes later in the chapter (p. 27), but clearly expressed are the gaps in knowledge of mysticetes primarily because of the difficulties of working with these large and protected aquatic mammals. The chapter concluded with a well-written introduction to the use and different categories of auditory evoked potential.

Chapter two, written by Darlene R. Ketten of Woods Hole and Harvard Medical School, will be of special interest to those interested in comparisons of hearing anatomy between cetaceans and terrestrial mammals. The author is eloquent in communicating her view that (p. 45) 'by analyzing the structure of a broad spectrum of cetacean ears, we can gain insights not only into whale hearing and aquatic adaptations but also into some basic hearing issues'. Early in the chapter, the reader is

provided with a primer on the nature of sound in air versus water and cetacean acoustic categories. Then, mammalian ear morphometrics are discussed generally before launching into specific details about cetacean ears. The underlying premise is that while (p. 57) 'there are substantial adaptations in all cetacean ears related to coping with increased sound speed, large pressures, and a host of other aquatic demands, whales retained the essentials of air-adapted ears, such as a spiral cochlea and discrete middle ear cavity with a three-part ossicular chain'. Table 2.1 (pp. 49–52) provided an invaluable summary of comparative cochlear morphometry in cetaceans, amphibious mammals, and nonaquatic mammals.

The purpose of chapter 3, written by Ted W. Cranford of San Diego State University, is to provide (p. 109) 'a chronologic look at the quest to understand biosonar signal generation'. What structures are responsible for the (p. 110) 'internally generated sounds that function, or might function, in echolocation, prey capture, or social facilitation'? The author initially clarified the definition of three sound categories: pulses or clicks, whistles, and bangs. Pulses are the focus of the majority of the chapter because they have been most often studied. Beginning with the 1956 experiments of Schevill and Lawrence, the experimental work and debates of cetacean sound production are traced through the most recent work leading to the (p. 124) 'indisputable and unequivocal conclusion that sounds (in dolphins) were being generated in the tissues above the superior bony nares (i.e., they originated in the nose)'. Similar discussions of sound generation mechanisms and signal propagation lead eventually to suggestions for future research in odontocete sound production. The chapter ends with a kindly and generous acknowledgment of the contributions of Dr. Kenneth Norris, one of the researchers to whom the volume is dedicated. The volume is also dedicated to Dr. Margaret Tavolga who worked extensively on dolphin behavior.

Lengthy, but very readable, chapter 4 uses information on vocal behavior and tenets of behavioral ecology (p. 157) 'to provide background on possible selection pressures for auditory specializations in cetaceans'. With references to the more completely studied bats, P. L. Tyack of the Woods Hole Oceanographic Institution and C. W. Clark of Cornell University explored why cetaceans might

have evolved specific sound repertoires. They discussed the literature on a wide range of related topics encompassing the use of produced and perceived sounds by cetaceans to detect predators, detect and incapacitate prey, orient themselves, explore their physical environment, and detect and communicate with conspecifics. The chapter concluded with two brief discussions on: (1) comparing cetacean sounds to body size and hearing ability and (2) reviewing the limited literature on vocal learning. The entire chapter laid a firm foundation for appreciating the more specific work on *Stenella frontalis* and *Tursiops truncatus* described by Denise Herzing of the Wild Dolphin Project in chapter 5. These two species have been studied for several years in the Bahamas. Chapter 5 provided a detailed summary of these species' vocalizations associated with contact, reunions, broadcasting, excitement, distress, alarm, pursuit, herding, discipline, agonistic and aggressive behavior, group synchrony, cohesion, interspecific interactions, foraging, and feeding. Not surprisingly, these investigations led the author to suggest a long list of (p. 257) 'areas of future inquiry'.

The focus of the next two chapters shifts from considerations of vocal behavior to the anatomy and physiology of auditory processing and its measurement. In chapter 6, Sam Ridgway reviewed what is known about the auditory organization of the cetacean brain while underscoring the fact that (p. 281) 'a great deal remains to be done to understand' it. Beginning with the observation that (p. 273) 'most likely, the ear is functional and the dolphin auditory system is receiving acoustic input for a long period in the womb', the author explored what is known about early brain development, auditory pathways, the role of the cerebellum and the auditory cortex, and the processing of auditory input in the brain. Numerous comparisons are made to other mammals including humans. The brief review of studies using evoked brain potentials provided a comfortable segue into W. F. Dolphin's detailed discussion of the topic in chapter 7.

After delineating the advantages of using auditory evoked potential (AEP) techniques and the suitability of cetaceans for the recording of AEPs, Dr. Dolphin noted that (p. 295) 'we may learn a great deal about the mechanisms and computational algorithms employed in auditory processing in mammals; much of this knowledge may have direct human clinical applications as well as application in human engineered sonar systems'. What auditory evoked potentials are is clearly explained, as is their use as potential measures of auditory processing. Readers for whom this area of research is a new one will be delighted with this overview.

Prior to the application of electrophysiological techniques, researchers relied almost exclusively on

the psychoacoustic, behaviorally based methodologies discussed in chapter 8 (p. 330) 'to accurately measure the acoustic sensations that are experienced by whales and dolphins'. Researchers, P. E. Nachtigall, D. W. Lemonds, and H. L. Roitblat, of the Marine Mammal Research Program at the Hawaii Institute of Marine Biology surveyed the work on the auditory capabilities of primarily one species, the Atlantic bottlenose dolphin (*T. truncatus*). The authors summarized the large amount of worthwhile information that has been gained on auditory sensitivity, auditory localization, and masked hearing and frequency selectivity using these techniques but also acknowledge their limitations. They call for good comparative studies between evoked auditory potential and behavioral techniques to determine how well evoked potential measures coincide with what has been established using behavioral responses.

Chapter nine, written by Dr. Au, pulls together ideas from several of the other chapters to specifically address the topic of echolocation in dolphins. After a brief review of how dolphins generate and transmit echolocation signals, the author differentiated the echolocation signals of dolphins capable of whistling from those of dolphins that do not whistle. A discussion of the properties of echolocation signals follows accompanied by very helpful visual aids. The last half of the chapter reviewed the work on target detection and target discrimination as measures of echolocation capabilities. Dr. Au concluded the chapter by acknowledging that (p. 403) 'our knowledge of how dolphins utilize echolocation in the wild is extremely poor', and by posing a large number of unanswered questions regarding dolphin echolocation abilities and uses. He suggested that researchers will begin to answer these questions only if they are creative and willing to take advantage of more sophisticated technologies, such as miniature computer-controlled systems. The final chapter of the volume suggested that (p. 409) 'acoustic models based on physics and mathematics may yield significant advances' in the field. Written by J. L. Aroyan *et al.*, the chapter considers two acoustic models. The first model simulated echolocation signal propagation through the head of a dolphin by combining tissue modeling with numerical wave propagation techniques. The second model predicted low-frequency sound production by the blue whale, *Balaenoptera musculus*, by considering the whale's anatomical structures along with the physics of acoustics. To fully understand the models, the reader will have to be comfortable with certain mathematical and physical concepts, but the simulation results and predictions are fascinating. Hopefully, further research will determine if all of the assumptions underpinning the models are correct.

In summary, this book clearly meets its first stated goal which is to present a (p. ix) 'comprehensive and synthetic review' appropriate for all adult audiences interested in hearing research. It also meets its second stated goal which is (p. xi) 'to introduce marine mammal bioacoustics to investigators interested in hearing in terrestrial animals, with the intent that there be more interaction

between investigators interested in hearing by marine and terrestrial mammals.' This clearly-written volume should help increase the cross-pollination of both ideas and techniques across research areas.

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