

Dr. Robert E. Knowlton: Considering the Coastal Acoustic Carpet

By Heather Ruth Spence

A curious natural sound was described in 1943 in *The Journal of the Acoustical Society of America* –

When putting out to sea at night in a small boat one is concerned about little things. We imagined a leak or that we were dragging a blackberry bush under the keel, but there was no leak and no blackberry bush. ... As we proceeded on our course the sound grew louder until it was easily heard on deck and the separate ‘crackles’ were clearly noticeable. We imagined that it might come from pebbles on a beach rolled back and forth by surf, but the nearest beach was six miles away and there certainly were no pebbles rolling about beneath us. (Hulburt 1943)



Readers of *Soundscape* will likely guess the source of this sound. Snapping shrimp, described at least as early as 1818, by Thomas Say, are ubiquitous and some would say conspicuous, yet their reputation far exceeds their recognition. These same finger-sized decapod crustaceans (genus *Alpheus* and *Synalpheus*) that can individually create loud “snap” sounds are responsible for the dominant crackling sound of shallow tropical and subtropical waters (Johnson 1943, Everest et al. 1948). Yet much of snapping shrimp behavior, ecology and acoustics remains elusive.

These shrimp are a key part of the coastal soundscape. The sound is an impediment to antisubmarine detection, so military strategists investigate its physical acoustic properties (e.g., Chitre et al. 2003). Animal behavior researchers focusing on the animals themselves find snapping shrimp remarkable subjects, and the significance of their sounds includes defense, feeding and communication (e.g., Hughes 2000, Versluis 2000). Certain species of *Synalpheus* have taken the spotlight because they were the first discovered eusocial crustaceans, and even display defensive ‘coordinated snapping’ (Tóth and Duffy 2005). Reef sounds, predominantly snapping shrimp, have also been found important in attracting larval fish to settle (e.g.

Simpson et al. 2004). The sound is obvious when you focus on it, yet people are often not aware of the source. From Rachel Carson’s *Silent Spring*, people could foresee how they would miss the sounds of the birds, but while snapping shrimp are very much part of the familiar seashore soundscape and would be missed if they were silenced, it’s hard to imagine how different that would be.

Dr. Robert E. Knowlton says his first research with the snapping shrimp got him “hooked.” On an NSF-supported undergraduate program during his senior year at Bowdoin College (1959–60), he worked with Dr. James M. Moulton, known for a series of studies determining the morphological basis of sounds produced by marine fishes. Knowlton assisted in analyzing recordings of sound-producing fishes, yet his particular satellite study was an investigation of snapping shrimp sounds around Bermuda. Knowlton felt it was an honor to be chosen by Moulton to do these studies. It all started so innocently, yet how could he know that shrimp would continue to snap up his life.

Knowlton’s early work with Moulton on the snapping shrimp of Bermuda focused on a prominent sound producer at multiple scales and perspectives. Investigation of the morphology of the shrimp that could impact sound production ruled out some previous theories by linking morphology with behavior via examinations of live shrimp. For instance, the sound is not caused by movement of the wrist joint of the larger claw (Miner, 1950), because “[i]n the living animal, one can easily see that movement of the dactylus of the large claw immediately precedes the snap” (Knowlton and Moulton, 1963). Through various angles of research into the mechanism of sound production, Knowlton and Moulton determined the importance of the hardened tips of the claws coming together. Their work also describes a simultaneous water jet that might stun prey organisms but which was not associated with the sound. This study was on the frontier of bioacoustics.

Knowlton and Moulton paved the way for further research into the mechanism and physical implications of the loud individual snapping sound. Knowlton says, “We analyzed the sounds on the tapes by means of a ‘Vibralyzer,’ which gives a visual picture of frequency as a function of time, as well as a ‘section’ of a particular snap (measures intensity over a freq. range)...I wish we could have done this study 40 years later, now that the technology for recording sounds has improved so much.” More recently, studies have further elucidated the phenomena explored by Knowlton and Moulton, including the discovery that the formation of cavitating bubbles is the source of the surprisingly loud sound (Versluis et al. 2000).

In addition to investigating individual snaps, Knowlton and Moulton linked shrimp behavior and the physical environment, making connections between sheltering activity and sound reception. Along with lab investigations of size, spectrum, and species, field recordings were analyzed for the presence and characteristics of shrimp

and water 'noise.' Variables of station, depth, bottom substrate, temperature, spectrum and time (diurnal and seasonal variations) were examined. The contribution of individual 'snappers' was calculated by counting spikes in each vibrogram. Sounds generated by the same species, but in areas with and without the preferred sponge habitat, resulted in different spectra. Even the behavior of other animals was considered, and its potential effect of reinforcing the diurnal variation by stimulating more snapping due to these other animals' increased activity. Knowlton and Moulton's expansive approach in these investigations continues to provide a basis for further research.

Knowlton's subsequent research includes further investigation of snapping shrimp, focusing on life history and other ecological studies. He worked with Dr. Austin B. Williams at the University of North Carolina for his PhD, studying larval development of "big claw snapping shrimp," *Alpheus heterochaelis* Say. His extensive career at George Washington University continues to emphasize the importance of morphology and individual characteristics linked with broader ecosystem ecology and trends in time and space (e.g., Spence and Knowlton, 2008). The full story of Knowlton's work is not necessarily contained in published research papers, as is often the case. His lab studies are painstaking (ask anyone who tries new approaches to rearing larvae!) and he keeps his balanced perspective examining the dynamics of the living shrimp in their natural habitat. His ear is experienced for finding the shrimp. Knowlton approaches his investigations by looking at morphology and behavior in context of the living organisms and ecosystems.

For Knowlton, teaching and research go hand in hand. His students go out into the field, to hear for themselves the soundscape that is better experienced than explained in a lab. All who have gone on a trip with him have a richer perspective on that ecosystem. He points out details, sounds, indentations in the mud: small things as well as connection to large processes. Students of Dr. Knowlton get a special appreciation and awareness of the natural wealth around them that is often overlooked. They are impressed by how everything is interconnected. His field expeditions are exciting opportunities to learn to really see and hear. As Knowlton says, "sound is one of many stimuli that humans use in generating an awareness of what is going on around them. In teaching activities, we tend to focus on using only visual effects (videos, etc.) to complement the spoken word (lecture), which is fine and dandy. But I believe that it is important to use any available stimuli to provide a fuller appreciation and understanding of scientific concepts, with possible side effects such as increased motivation and entertainment." Even in the classroom, before each lecture he plays a song chosen to relate to the day's theme. Training ears to listen is central to his curriculum and research.

The innovative approaches taken by Knowlton in his research and teaching can be used in varied soundscape studies. He links direct acoustic study with indirect insight through other means, especially morphology and behavior. He shows that individual morphology can influence behavior, which can dramatically impact the collective input to the soundscape. Even 'silent' creatures impact sound producing creatures, thus impacting the soundscape. Knowlton also highlights the importance of getting as close to the dynamic system as possible, because there you can recover the intricacies of the connections between creatures and acoustic phenomena. Collaborative and multi-scale, his work reiterates the necessarily interdisciplinary nature of soundscape investigation.

Knowlton's expansive approaches are particularly important in



the context of increased noise pollution and endangered ecosystems. As Knowlton reflects on sound, nature and society, he remarks: "We (humans), even though we can hear, are not always content to listen." He would like people to be made aware of snapping shrimps

and their crackling sounds, and the other sounds around us. While he has developed what he calls a rather mechanistic view of sound, "as just one other manifestation of nature, a form of energy that is 'available' to humans since they have the receptors that are sensitive to this kind of stimulus," he is intrigued by the importance of sound and the uses of sound in communication. However, as the general cacophony of society increases, we are subjecting ourselves to blocks to communication and other harmful and unknown effects. In

addition to listening, Knowlton adds that we should be paying more attention to the sounds we produce and their impacts, including "excesses in testing of sound production," particularly testing of new technology where there is considerable evidence that it is harmful to marine mammals. Knowlton's work highlights how changes in habitat and community structure can alter the soundscape, and we know that changes in the soundscape also affect the overall functioning and dynamics of the ecosystem. As noise pollution increases, and if we remain detached from our auditory surroundings, will we miss warning signs emitted from tiny claws hidden among the shallowly submerged coastal rubble?

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