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Editorial: Innovation and Discoveries in Marine Soundscape Research

Robert P. Dziak[1]*, *Adrienne Copeland*[2], *Ana Širović*[3], *DelWayne R. Bohnenstiehl*[4] *and Ilse van Opzeeland*[5]

[1] National Oceanic and Atmospheric Administration (NOAA), Pacific Marine Environmental Laboratory, Newport, OR, United States, [2] National Oceanic and Atmospheric Administration (NOAA), Ocean Exploration, Silver Spring, MD, United States, [3] Department of Biology, Norwegian University of Science and Technology, Trondheim, Norway, [4] North Carolina State University, Raleigh, NC, United States, [5] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany

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Editorial on the Research Topic

Innovation and Discoveries in Marine Soundscape Research

OVERVIEW OF SPECIAL TOPIC RESEARCH STUDIES AND RESULTS

It is our pleasure to introduce the Frontiers of Marine Science Research Topic issue on *Innovation and Discoveries in Marine Soundscape Research*. In total, 19 research studies were published in this special issue, covering four main themes in ocean acoustics: (1) quantification of biological sound sources and the insights these provide into the species distribution in space and time, (2) assessment of ambient ocean sound levels and the contribution of anthropogenic, geophysical, cryogenic, and biological sources to the ocean noise budget, (3) development of new, efficient, passive acoustic data-analysis software, and data management methodologies for the ocean soundscape community to consider as standardized approaches, (4) state-of-the-art in acoustic modeling to better understand propagation effects on soundscapes.

Here we briefly summarize each paper under their relevant theme.

QUANTIFICATION OF BIOLOGICAL SOUND SOURCES, AND USE IN SPATIO-TEMPORAL SPECIES DISTRIBUTION

Marine Mammals

Kügler et al. presented findings that confirm male humpback whale chorusing intensity is predictive of overall whale numbers, including non-singing animals off west Maui, Hawai'i. Although only adult and juvenile male humpback whales sing, their contribution to the marine soundscape during the breeding season mirrors the bell-shaped abundance curve. Visual observations of whale numbers had the same second-order polynomial correlation with acoustic recordings. These findings demonstrate how passive acoustic monitoring can be used for quantitative remote sensing studies on marine mammals.

McElligott et al. showed that spinner dolphin habitat-use patterns in Maui Nui do not follow consistent use of specific bays as has been documented off the Hawai'i Island and O'ahu coasts. Based on the combination of passive acoustic monitoring and vessel surveys, evidence suggests that Maui Nui spinner dolphins utilize a combination of the west Maui coastline, the southeast Lāna'i coastline, and the 'Au'au channel. This study exemplifies how PAM studies can contribute crucial information on habitat usage of marine species.

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****Correspondence:***
Robert P. Dziak
robert.p.dziak@noaa.gov

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Pegg et al. applied acoustic metrics and random forest classification models to long-term passive acoustic data to explore the occurrence of baleen whales on the west North Atlantic shelf and slope edge. This technique was successful at discriminating the presence/absence of the call repertoire of different baleen whale species. Overall this work shows that with the expansion of long term PAM data sets, acoustic metrics provide a promising complementary approach to current methods to efficiently extract high resolution information on marine soundscapes.

Truong and Rogers used ∼16 years of acoustic data to compare the broad seasonal presence of Antarctic and Chilean blue whales, and Southeast Indian Ocean (SEIO) pygmy blue whales, across the Pacific and Indian Oceans. Chilean and SEIO pygmy blue whales showed similar seasonal patterns despite occurring in different ocean basins. Although Antarctic blue whales were sympatric with Chilean and pygmy blue whales during annual migration, Chilean and pygmy call detections peaked earlier during the austral autumn while Antarctic detections peaked in the austral winter. Despite the potential of Antarctic blue whales to encounter other subspecies, distinct groups have remained acoustically stable over time.

Warren et al. used passive acoustic monitoring to show that critically endangered Antarctic blue whales co-occur with pygmy blue whales in New Zealand waters by analyzing their sub-species specific calls. The calls of both blue whale subspecies were highly stereotyped and comparable to previous studies. Acoustic model estimates of detection areas provided context for the blue whale calls, and highlighted the relative importance of the varying marine environments in central New Zealand.

Fish and Invertebrates

Anderson et al. examined larval response to backreef sound *via* playback experiments to determine the maximum range marine larvae use sound to locate settlement habitat. Their results suggest that at calm surface conditions, healthy hardbottom soundscapes can be detected up to ∼500 m from the source, but in most cases larval response to sounds was weak. This could indicate acoustic cues are used in combination with other environmental prompts to orient to distant nursery habitats. Lastly, the effective detection of healthy hardbottom by larvae may also depend on the spatial scale of the patches. Small scale patches may limit the range of the acoustic settlement cue, thereby restricting the restoration of larval assemblages and overall ecological recovery.

Hyeok Lee et al. report on the sounds of snapping shrimp observed at ∼100 m depth, deeper than previous observations. The temporal variation of the snap rate was investigated using two hydrophones separated by 5.5 km over a 5-day recording period. Interestingly, the snap rate at the two sites was strikingly similar despite the distance, and the snap rate exhibited a strong one-quarter-diurnal cycle, which is different from snap rates reported for shallower habitats. Moreover, they found that snap rate correlated with current speed at a time lag of ∼1.25 h.

Luczkovich and Sprague used a wave glider fitted with a passive acoustic recorder to survey the Atlantic Ocean soundscape off North Carolina (USA). They calculated power spectral band sums in frequencies associated with soniferous fish species in the families Sciaenidae (drums and croakers), Ophidiidae (cusk-eels), Batrachoididae (toadfish), Triglidae (sea robins), and Serranidae (groupers). The soundscape in water < 20 m was dominated by nocturnal fish Sciaenidae and Ophidiidae choruses. At 27–30 m water depth, they recorded Triglidae, toadfish, Sciaenidae, and grouper growls. Noise from large cargo vessels, rainfall and thunder were also part of the soundscape.

Zhang and Katsnelson report on a biological chorus from the New Jersey (USA) continental shelf and attribute it to an unidentified fish species. The chorus occurred nightly from July to August 2006, covered a frequency band of 150 Hz to 4.8 kHz, with maximum intensity between 1.45 and 2.0 kHz. The intensity of the chorus was weaker near the coast. The signal was made up of 8.7 ms long double-pulse bursts, with 1.5–1.9 s intervals between bursts. Despite comparing the chorus with the sounds of numerous relevant fish species, no match was found. The chorus characteristics nevertheless strongly point to the general features typical for fish sounds.

QUANTIFICATION OF SOUNDSCAPE BIOLOGICAL AND ANTHROPOGENIC SOURCES AND LEVELS

Butler et al. presented the first multi-season study of two kelp forest soundscapes, showing their complex and dynamic nature. During the late spring and summer, choruses of two putative fish calls dominated the dusk soundscapes. Snapping shrimp sounds were also recorded and displayed the stereotypic crepuscular periodicity, peaking at dawn and dusk, although not much seasonal variation was observed. Extensive anthropogenic noise from small vessels also pervaded the soundscapes. This study demonstrates how soundscape studies can provide information on the dominant acoustic features of protected areas.

Haver et al. applied the one-third octave bands at 63 and 125 Hz to measure underwater ambient noise levels from shipping activity to data from five dispersed sites across the U.S. coasts collected in 2016–2017. Where cargo vessels were less common, e.g., Hawai'i and the Alaskan Arctic, sound levels were ∼10–20 dB lower year-round as compared to other sites. They propose that the one-third octave bands can be useful for identifying shipping as a driver of ambient noise under the U.S. management framework.

McCordic et al. established baseline sound levels within two marine National Park Zones (NPZs) along the east coast of Australia. They determined hourly presence of anthropogenic and biological sounds between 20 Hz and 24 kHz. Acoustic spectral patterns were similar at both NPZs, and were driven by seasonal differences in biological contributions rather than anthropogenic sound sources, indicating NPZs are not yet heavily impacted by anthropogenic noise.

McKenna et al. showed the benefit of integrating source identification and site features to interpret sound levels across a diversity of shallow water marine soundscapes (<150 m) using data from a U.S. national-scale sound monitoring effort. High sound levels can reflect anthropogenic influences, biological features, or even large tidal changes. Importantly, relatively nearby sites can have divergent sound levels because of the contribution of various proximate sources, and propagation features can vary between sites. They point to a need for more integrated methods to increase the utility of soundscape analysis for marine resource management.

Merkens et al. presented the results of a decade of soundscape monitoring effort off the Kona coast, Hawai'i. The soundscape was dominated by anthropogenic sounds and odontocete cetaceans, alternating on a diel cycle. During daylight hours the dominant sources were vessels and echosounders, while at night odontocetes clicks dominated in mid-to-high frequencies. Winter-resident humpback whales dominated seasonally at lower frequencies. These results represent the first long-term analysis of a marine soundscape in the North Pacific.

Yun et al. reviewed soundscapes at the Balleny Islands (BI) and Terra Nova Bay (TNB) regions of Antarctica. They found cryogenic events and marine mammals were the major sound sources in both regions, with earthquake and vessel sounds also found at various times. Antarctic blue whales (late summer-fall) and leopard seals (early summer) were the dominant vocal species. Dense sea-ice cover near BI reduced ambient sound levels, whereas ambient noise in TNB increased due to strong, local winds, regardless of sea-ice coverage.

ACOUSTIC DATA ANALYSIS AND MANAGEMENT TOOLS

Miksis-Olds et al. introduced the Making Ambient Noise Trends Accessible (MANTA) software package. MANTA's purpose is to assist users in creating calibration metadata and products that are comparable over time and space. The software package has a Metadata App, which allows users to specify recording information, and a Data Mining App, which produces calibrated sound pressure levels in the hybrid millidecade bands. The hybrid millidecade band processing was adopted because it provides data products of a tractable size for exchanging and archiving sound pressure level products.

Wilford et al. applied a collection of metrics to unique soundscapes to identify the optimal suite of standards that will enable quick, quantitative soundscape comparisons. Measures of amplitude (SPL_{rms} and SPL_{pk}), impulsiveness (kurtosis), uniformity (D-index), and periodicity (acorr3) were identified as the best metrics. Analysis codes consisting of these optimal metrics were proposed as a tool for soundscape analysis.

Wall et al. presented the recently established passive acoustic archive at the NOAA National Centers for Environmental Information. The archive currently contains over 100 TB of audio files collected from stationary recorders across U.S. territorial waters. These datasets have standards-based metadata, and are freely available to the public. First order sound level comparisons from three long-term acoustic projects in the archive showed the strong influence of vessel traffic noise at sites near dense coastal populations. Conversely, biological sources dominated soundscapes at sites away from population centers. Seasonal sound level variability was apparent for most sites, representing changes in presence or behavior of sound-producing species.

STUDIES OF ACOUSTIC PROPAGATION (2- AND 3-D) AND EFFECTS ON AMBIENT SOUND AND SOUND LEVELS

Oliveira et al. applied a parabolic equation (PE), underwater sound propagation model to the complex shallow water environment in Long Island Sound (USA). The 2D and 3D PE models were compared to normal mode and beam tracing models for two idealized cases: a 2D 50-m flat bottom, and a 3D shallow water wedge. Transmission loss results from the three models were consistent; however, differences emerged with increased bathymetric complexity, expanded propagation range, and at the limits of model applicability.

SUMMARY

Passive acoustic methods have been used since the mid-twentieth century to characterize underwater biological sources, geophysical phenomena, and human-made sounds. However, the last few decades have seen significant advances in the use of passive acoustic techniques to quantify ocean soundscapes. This has been enabled by dramatic technological advances, including data logging and storage in underwater passive acoustic recording instrumentation, and engineering advances in seafloor cabled hydrophones, moorings, and mobile platform technologies. Moreover, in the light of ongoing climate-induced and human-made changes to oceans worldwide, passive acoustic data can provide a wealth of information on how these changes impact marine ecosystems. The holistic approach of soundscape research has the potential to observe these changes and also archive the current soundscape characteristics of oceans to understand change over time. The studies presented in this special collection represent the state-of-the-art of ocean soundscape research and its wide span of applications. Given the insightful results and new approaches presented here, we envision an exciting future of widespread, continuous monitoring of the deep-ocean, coastal, and urban seas to better understand the marine environment and aid in mitigating human impacts on marine ecosystems.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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