Chapter 151
Mapping the Acoustic Soundscape off Vancouver Island Using the NEPTUNE Canada Ocean Observatory

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Abstract NEPTUNE Canada is a cabled ocean observatory system containing five nodes located in the northeast Pacific Ocean. Using passive acoustic data recorded at two nodes (Folger Passage Deep and Barkley Canyon Axis) between June 2010 and May 2011, we sought to quantify the levels of vessel traffic and the occurrence of biological sounds to determine the potential impact of anthropogenic sound in masking acoustic communication. The results from a comparison of the relative amplitude and occurrence of low-frequency biotic sounds to broadband sounds resulting from vessel traffic are presented. Additional contributions to the marine soundscape from self-generated instrument noise are discussed.

Keywords Passive acoustics • NEPTUNE Canada • Marine soundscape • Northeast Pacific • Anthropogenic noise

1 Background

Elevated anthropogenic noise in marine soundscapes and their potential to decrease the communication efficacy of marine organisms is of increasing global concern. In the northeast Pacific, recent modeling studies have outlined areas of excessively

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high cumulative sound exposure levels from vessels (Erbe et al. 2012). Yet baseline levels of large-scale ambient noise are limited (Urick 1986; Andrew et al. 2002; Hildebrand 2009). Therefore, there is a strong need for continued research of sounds impacting deep-sea marine ecosystems that are particularly vulnerable to increasing anthropogenic noise (e.g., McDonald et al. 2006), especially with respect to the importance of biological sound production (Slabbekoorn et al. 2010). The implementation of cabled ocean observatory systems such as the North East Pacific Time-series Undersea Networked Experiment (NEPTUNE) Canada (Favali and Beranzoli 2009; Barnes et al. 2011) provide potentially ideal platforms to conduct long-term passive acoustic research on the marine soundscape (Wall et al. 2014).

The goal of this paper is to quantify the levels of biological sounds and vessel traffic above the ambient noise to determine the potential impact of anthropogenic sound in masking the communication of marine organisms using passive acoustic data collected at the NEPTUNE Canada Ocean Observatory over a 1-year period.

2 NEPTUNE Canada Ocean Observatory

NEPTUNE Canada, part of the Ocean Networks Canada Observatory, is a cabled ocean observatory system containing five nodes located in the northeast Pacific Ocean (www.neptunecanada.ca). A suite of data is collected at each node to characterize the chemical, geological, physical, and biological properties of the surrounding ocean environment. In particular, passive acoustic data are recorded at two nodes, Folger Passage Deep (100 m depth) and Barkley Canyon Axis (985 m depth), located in Barkley Sound. Acoustic files were recorded continuously at both nodes at a 96-kHz sample rate. These systems incorporated Naxys ethernet hydrophones (Folger Passage Deep: −171 re 1 V/μPa with a 20-dB gain; Barkley Canyon Axis: −179 dB re 1 V/μPa with a 20-dB gain; NAXYS Technology). Both hydrophones were only calibrated to 10 kHz. Therefore, despite accounting for the calibration coefficient, the amplitude measurements remain relative and incomparable between the nodes. Files were stored in 5-min segments, producing 12 files/h.

The long-term soundscape is displayed as a composite spectrogram in which 100-Hz resolution fast Fourier transforms (FFTs) are applied to each file and then placed together chronologically to create an image comprising the duration of data collected at both nodes from 26 June 2010 to 1 May 2011. To reduce processing time, a subset of 1 file recorded every 30 min was incorporated in this analysis, resulting in a total of 14,144 files from Folger Passage Deep and 11,933 files from Barkley Canyon Axis.

From the values calculated for the FFT in each file, three frequency bands were extracted and averaged to identify potential noise from vessel traffic and biological sound production, namely, soniferous fish and marine mammals (100–2,000 Hz; band 1); potential noise from vessel traffic and marine mammal sounds (2,500–10,000 Hz; band 2), and ambient noise (24,000–27,000 Hz; band 3). Band 3, which served as a baseline, was subtracted from bands 1 and 2 in each file to determine the relative increase in amplitude of biotic and abiotic sounds and thus their contribution to the marine soundscape. Results were binned hourly and monthly to determine diel and seasonal variability.

3 Acoustic Soundscape

Composite spectrograms calculated for the Folger Passage Deep and Barkley Canyon Axis nodes are illustrated in Fig. 151.1. Noise associated with instrumentation on both nodes was consistently recorded. The echo sounder located on the Folger Passage Deep node emitted high-amplitude broadband pulses visible in the composite spectrogram from 28 to 48 kHz. However, pulses were present down to 1 kHz in individual files. A narrowband tone at 33 kHz was present in all the Barkley Canyon Axis files. This noise is from general instrument operation. Broadband (1–48 kHz) click trains from sonar and 900-Hz tones from the pan/tilt video camera located on this node were also consistently recorded. Due to their short duration, these sounds were averaged out and are not visible in the composite spectrogram; however, they provide additional noise to the environment and potential interference for biological communication.

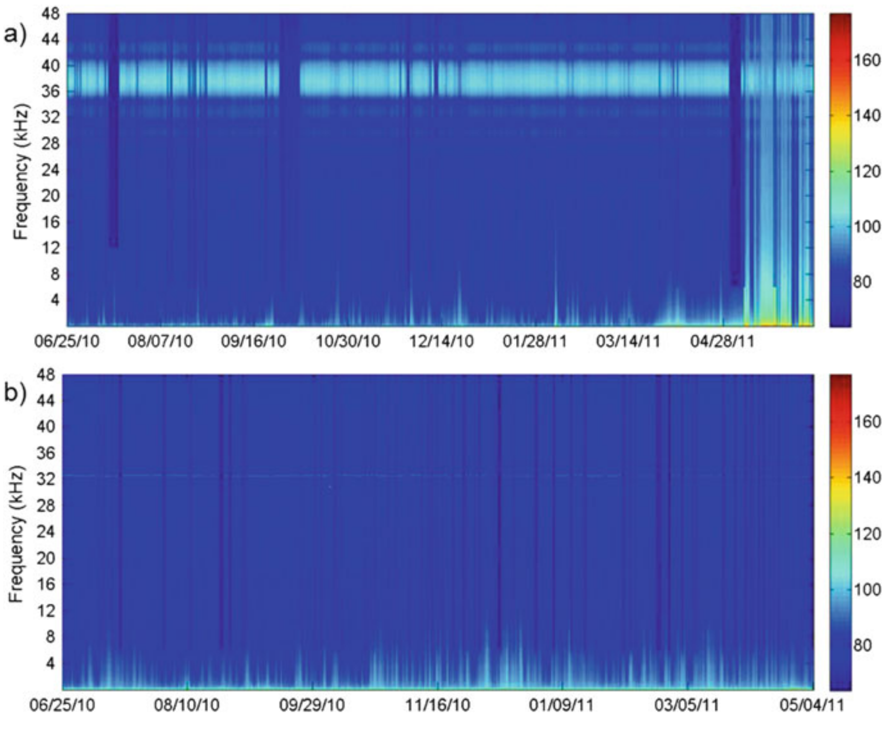

Fig. 151.1 Composite spectrograms of 100-Hz resolution fast Fourier transforms (FFTs) calculated for the NEPTUNE Canada nodes at Folger Passage Deep (**a**) and Barkley Canyon Axis (**b**). Values shown are relative and not directly comparable between the 2 nodes

3.1 Folger Passage Deep

There was no significant hourly difference in amplitude for sounds produced within band 1 or band 2 (Fig. 151.2a). However, amplitude variation within each hour was consistently high for band 1 (±3.5–3.8 dB) and band 2 (±2.1–2.2 dB). Amplitudes in band 1 and band 2 were more variable within (±0.2–3.0 dB) and between months (Fig. 151.2b). Amplitude increased significantly from September to December 2010, with April 2011 containing a significantly higher amplitude than all other months. The increase in April is attributed to electrical noise associated with the hydrophone housing leaking toward the end of the study period. Band 1 had consistently higher hourly and monthly amplitudes compared with band 2. Both bands were highly correlated ($R^2 = 0.93$), whereas each band showed a very low correlation to band 3 (band 1 and band 3, $R^2 = 0.24$; band 2 and band 3, $R^2 = 0.32$).

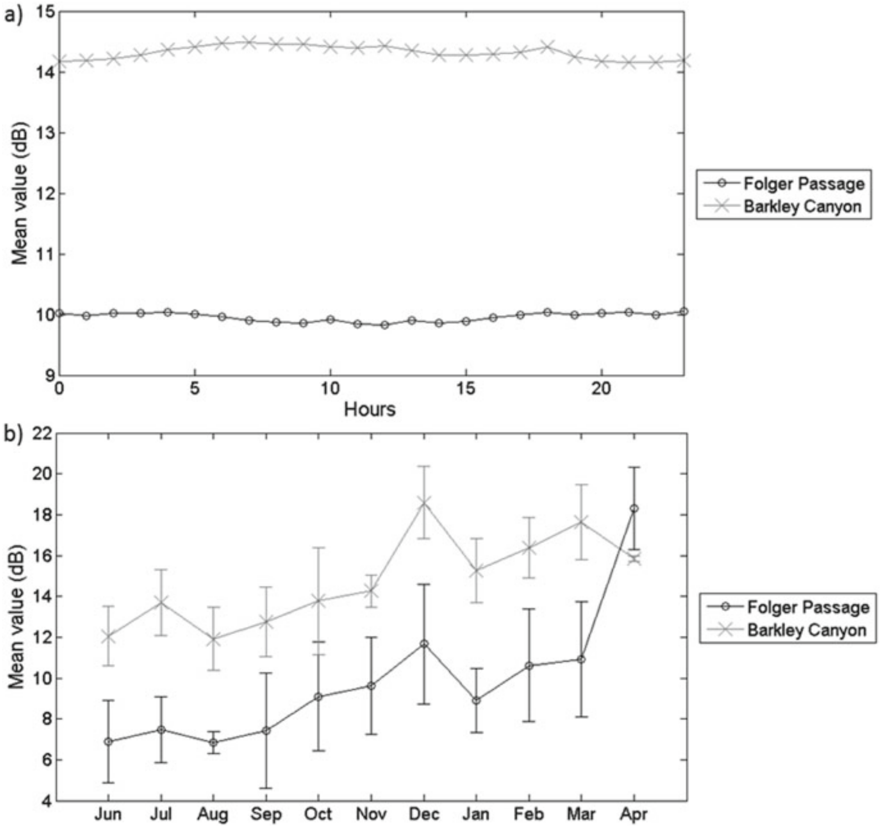

Fig. 151.2 Amplitudes extracted from band 1 for Folger Passage Deep and Barkley Canyon Axis binned by hour (means; **a**) and by month (means ± SD; **b**). Values shown are relative and not directly comparable between the 2 nodes. For clarity, error bars are not shown for the hourly bin

3.2 Barkley Canyon Axis

Similar to Folger Passage Deep, the amplitude did not vary significantly by hour for either band, whereas monthly values were more variable (see Fig. 151.2). Amplitude variation within each hour was consistently high (±2.1–2.7 dB). Increasing amplitude was again observed from September to December 2010. Amplitude variation within each month ranged widely (±0.1–2.6 dB). Band 1 had a consistently higher amplitude (hourly and monthly) compared with band 2. Both bands were highly correlated ($R^2=0.96$), whereas each band was less correlated to band 3 (band 1 and band 3, $R^2=0.46$; band 2 and band 3, $R^2=0.45$).

4 Conclusions

This paper examined the marine soundscape off west Vancouver Island in the northeast Pacific using passive acoustic data collected at two nodes within the NEPTUNE Canada cabled ocean observatory system. We sought to quantify the contribution of biotic and abiotic sounds to ambient noise over time using three frequency bands encompassing potential fish and marine mammal sounds and vessel traffic (band 1), marine mammal sounds and vessel traffic (band 2), and ambient noise (band 3).

The high-correlation average values within band 1 and band 2, corrected for ambient noise, suggests that low-frequency (<2-kHz) sounds, such as those made by fish, do not contribute greatly to the acoustic soundscape due to the infrequent occurrence and/or short duration of such sounds. Therefore, broader band and longer duration sounds resulting from marine mammals and passing vessels dominate frequencies below 10 kHz. Sounds from humpback whales (*Megaptera novaeangliae*) in June, October, November, and December; from pinnipeds (Otariidae) in August, September, and October; and from killer whales (*Orcinus orca*) in February have been documented at Folger Passage Deep (C. Pomerleau, personal communication). At Barkley Canyon Axis, sounds from baleen whales, humpback whales, and fin whales (*Balaenoptera physalus*) from September through December; from Pacific white-sided dolphins (*Lagenorhynchus obliquidens*) in August and September; and from killer whales in March were observed (C. Pomerleau, personal communication). Marine mammal calls can range from 50 Hz to 10 kHz (Mellinger et al. 2007). Similarly, harmonics associated with vessel traffic can reach beyond 10 kHz. Considering these overlapping frequency ranges, there is a high potential for anthropogenic noise to mask marine mammal communication (Richardson et al. 1998; Lesage et al. 1999; Sousa-Lima and Clark 2008; Van Parijs et al. 2009). The cause of elevated sound levels from September to December and a subsequent decrease from January to March at both sites is suspected to be due a combination of marine mammal migration in the winter (Gregr et al. 2000) that, in turn, largely reduced sound production from January to April; seasonal shipping patterns that resulted in a decrease in vessel noise after December (C. Pomerleau, personal communication);

and seasonal wind patterns and storms (e.g., Wenz 1962) that can contribute to the marine soundscape specifically in the winter.

Although ocean observatories such as NEPTUNE Canada provide excellent opportunities to conduct long-term acoustic research, there are limitations. Most important is self-generated noise. Active sonar and moving equipment as well as regular maintenance efforts can contribute largely to ambient-noise levels and thereby complicate the results of the above analysis (Wall et al. 2014). In 2012, efforts were made to improve the Folger Passage Deep passive acoustic data quality by moving the hydrophone further from the node, thereby reducing noise from the echo sounder. Further analyses comparing the improved (noise-reduced and new calibrated hydrophone) acoustic data currently being collected at this node as well as additional efforts to reduce instrument noise at the Barkley Canyon Axis node are recommended to be able to provide more accurate and longer term noise estimates.

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