Coral reef and tropical shallow water soundscapes

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Much is known about deep ocean ambient noise, rather less about the more highly structured and variable noise in temperate coastal waters, and rather little about the tropical shallow waters that include coral reefs and the biological diversity these ecosystems support. Interest in shallow water acoustics has been growing over the last decade, and more recently specific interest has bloomed in tropical shallow water and the features particular to these areas. As sonar systems and operations become more complex, moving towards the use of ambient noise and the need for communicating via networked acoustic modems in noisy environments, the soundscape of shallow waters has become more important. This paper presents some of the challenges and advantages of tropical shallow water acoustic environments, and makes some geographic comparisons. While some aspects of tropical ambient noise make life more difficult, such as the non-Gaussian energy distribution of snapping shrimp noise, other aspects are seen to be quite robust, such as the very similar pulse signatures of snapping shrimp over widely-separated regions. The development of signal processing tools based on wavelet and other compact transforms to deal with the detection, separation, and classification of overlapping tropical shallow water noise sources is discussed.

INTRODUCTION

We present a simplified characterisation of ambient noise conditions in shallow tropical waters, excluding wind-driven noise from the sea surface. Wind and resulting wave noise has been more extensively studied and much more is known about these sources than biological sources in warm shallow water. Surf noise can also be very important, but obviously only when near a surf line. This paper concerns itself with ambient sources in somewhat deeper water, in the region of 5-50 m.

WARM SHALLOW WATER NOISE SOURCES

In the absence of wind and surface wave sources (or, if present, in addition to them), this paper argues that the plethora of ambient noise sources in shallow water can be usefully divided into four main classes, so separated because of their very different structures in the time-frequency plane. These classes may be described as:

- Near transients (such as snapping shrimp)
- Near tonals (such as shipping machinery noises)
- Coloured background (smoothly varying in the frequency domain)
- Time-Frequency transients (biologic or man-made).

The Near-transients are of particular interest to us, since they often consist of snapping shrimp (at least in warm waters, above 11 degrees C) and dominate 99% of the commonly usable bandwidth (from a few kHz to over 350 kHz)

SOME CHARACTERISTICS OF SNAPPING SHRIMP SOUNDS

The characteristics of snapping shrimp noise are remarkably consistent across the globe. This may perhaps be explained by the recent discovery that it is not the mechanical impact of the animals jaw parts that creates the sound, but the cavitation bubble formed by the rapidly ejected water jet [1]. Thus, while the exact physiological characteristics of the jaws may differ between slightly different species, cavitation bubble physics remains much the same. Differences in amplitude and some changes in bandwidth may be expected from larger or smaller shrimp. A typical time series acoustic record (normalised to ±1) in warm shallow water is shown in the upper panel of Fig. 1. The lower panel shows the time-frequency plane result for the same data. A measure of the degree of non-Gaussian behaviour can be made by calculating the scintillation index, SI (normalised variance of intensity) given by

$$SI = \left\langle I^2 \right\rangle - \left\langle I \right\rangle^2 \Big/ \left\langle I \right\rangle^2 \qquad \text{Equation 1}$$

where I is the acoustic intensity and <> indicates the ensemble average [2]. The value of SI increases as extreme values of acoustic pressure become more common. For a zero-mean Normally distributed random variable, SI = 2 irrespective of the mean power. We have analysed shallow-water acoustic records from several widely spread countries and calculated