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Impact of tropical cyclone Vardah on the fish chorus in shallow waters of Southwest Bay of Bengal

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ABSTRACT

Time series data of ocean ambient noise measurements during the passage of tropical cyclone Vardah in December 2016 are used to analyse the impact on fish chorusing behavior in the shallow waters of Southwest Bay of Bengal. A curve-fitting technique is applied to the time series data to study the fish chorus prior to, during and after the passage of the cyclonic storm. The multifitted components indicate the presence of fish chorus prior to and after the passage of the cyclonic storm. However, the fish chorus is absent during the day of the passage of cyclone and recurs after the cyclone. The study provides a unique dataset that reveals on the acoustic energy associated with the passage of the tropical cyclone and its impact on fish chorus, and illustrates that the passive acoustic technique is the most suitable method for biological measurements with respect to natural episodic events.

1. Introduction

Tropical cyclones are natural episodic events which have the capacity to alter coastal ecosystems (Mallin et al., 1999). The energy of destructive tropical cyclones comes from the high winds in the eyewall, which is proportional to the cube of the maximum wind speed (Holland, 1997). The cyclones during landfall bring an intense pulse of wind that generates large wave height and sea swell, which cause inundation of the near-shore environment (Locascio and Mann, 2005), and it significantly affects the biotic communities as well as their marine ecology (Cahoon, 2006). Studies on ecological impact following cyclonic events have traditionally included an assessment of habitat alteration, subsequent changes in biological community, and recovery rates in areas, where pre-tropical cyclonic data are available for comparison. However, to understand the posterior scenarios, there is no clear evidence on response of biota in temporal scales immediately after the passage of a cyclone. On 12th December 2016, the tropical cyclone Vardah crossed the study location, providing a unique opportunity to record the acoustic energy of the fish chorus associated with the passage of the cyclonic storm and analyse the impact on chorusing behaviour of soniferous fishes.

The soniferous fishes produce a variety of sounds, and most of them are associated with spawning (Parsons et al., 2013). Lobel (2002) studied the list of fishes, including Ostraciidae, Pomacentridae, Serranidae, and Scaridae that make spawning sounds. McCauley (2001) recorded the trumpet sound produced by Terapontidae fish chorus, which is associated with spawning aggregations as part of the reproductive process. Studies have revealed that spawning was more productive when the amount of fish calling increased; longer call duration and more number of pluses indicate more spawning activity (Connaughton and Taylor, 1996; Montie et al., 2017). In marine ecosystems, it is challenging to determine the commencement and ending of spawning period because of logistic issues pertaining to the underwater visual observation. In this regard, the passive acoustic technique has been very useful to detect the fish chorus signals during their spawning period. Fish sounds provide valuable information to the bioacoustician and fisheries management to identify the species distribution, timing of spawning seasons, and their essential fish habitat (Luczkovich et al., 1999; Gilmore, 2002; Aalbers and Drawbridge, 2008; Madan et al., 2017). Moreover, there is growing evidence that a variety of biological fish choruses and their influence on the local soundscape may be an indicator of ecological health or a part in the successive recruitment of juveniles to a specific location (Tolimieri et al., 2000; Simpson et al., 2005).

2. Materials and methods

To investigate the time series measurements of ambient noise, a vertical linear array of 21 omnidirectional hydrophones (CHP210214) was deployed in the shallow waters of Southwest Bay of Bengal at 17 m

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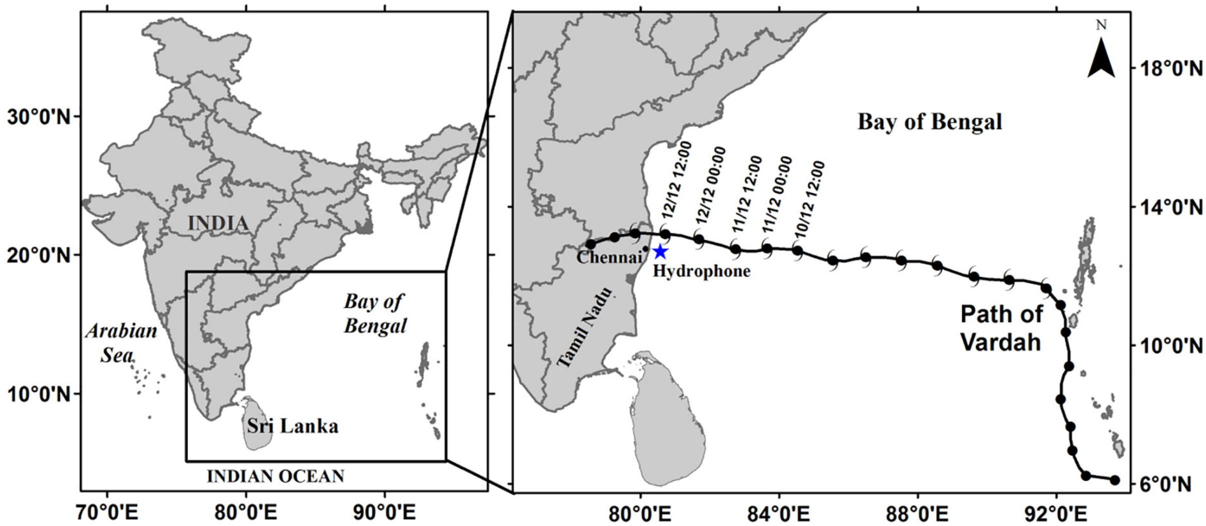

Fig. 1. Location map of study site and path of Vardah cyclone as it crossed on the southwest Bay of Bengal. The track of the cyclone indicates as per the IMD report. Hydrophone is depicted as ★.

ocean depth from 1st to 15th December 2016 (Fig. 1). The subsurface system comprised data acquisition modules associated with battery pack in an enclosure, together with a surface marker buoy and subsea drift in the mooring line. The hydrophones were calibrated at the Acoustic Test Facility of NIOT, Chennai, which is the main NABL accredited laboratory in India. The frequency response of the hydrophones is 2–20 kHz. However, data have been analysed below 2 kHz, based on the receiving sensitivity of the calibrated hydrophones.

The system was deployed at an ocean depth of 17 m with the array of hydrophones positioned at mid-water column, and the data from first element of the array were used for the analysis. The acoustic data were sampled at 100 kHz per channel for 60 s every 3 h. The recorded acoustic pressure fluctuations produced by various sources of noise translate into electrical signals and are converted into units of micropascal (μPa) by applying pre-amplifier gain and receiving sensitivity of −160 dB re 1 V/μPa. These data were processed through spectrogram, oscillogram and Welch's averaged periodogram (dB re 1 $\mu Pa^2 Hz^{-1}$) using MATLAB (v. 7.11). Each 60 s of the recorded data was segmented into smaller portions and processed with fast Fourier transform (FFT) with 2048 points, a Hamming window with 50% overlap, and averaged to obtain the final power spectrum.

In order to investigate the impact of cyclone Vardah on the daily sound-producing behaviour of fish chorus, the statistical parameters, such as Sum of the Squared Error (SSE) and correlation coefficient, are estimated as fitted Probability Density Functions (PDFs) of the recorded time series signals. Pearson et al. (1992) described the PDF components by using the Gaussian multimodal technique. In this study, a curve-fitting technique has been applied to the time series data of the fish choruses recorded from 11th to 13th December 2016 at 20:00 h.

The wind data were measured using weather data loggers and analysed further to obtain the noise levels during the study period associated with the passage of cyclone.

3. Results and discussion

Vardah, the very severe cyclonic storm, produced a maximum sustained surface wind speed of 130 (kmh^{-1}) as it crossed over south Bay of Bengal nearly westwards with a speed of 20 (kmh^{-1}) (Charan, 2016). The system weakened into a severe cyclonic storm and moved towards the Tamil Nadu coast, about 50 km east-northeast of Chennai between 1400 and 1700 h IST of 12th December 2016 with a wind speed of 100–110 kmh^{-1}, gusting to 120 kmh^{-1} (Naresh, 2016). After landfall, it moved west-southwestwards and consolidated into a cyclonic storm, rapidly weakening into a depression due to land interaction on 13th December over North interior Tamil Nadu. Vardah was the strongest cyclone to hit the east coast of India, preceded by the cyclones Phailin and Hudhud in 2013 and 2014, respectively. The eye of the severe cyclonic storm, ∼10 km in diameter, crossed at 1400 h on 12th December, in the shallow waters off Chennai over the study site.

The fish chorus is characterized by using the main acoustic features, such as sound type, spectral peak frequency, frequency bandwidth, pulse repetition frequency, call duration and sound levels. As no visual observation data are available, the acoustic characteristics of the chorus reported here have been analysed and identified as that of Terapontidae family, since they show similarities to the fish chorus of that family described in Australian region and all around the world (McCauley, 2001, 2012; McCauley and Cato, 2006; Parsons et al., 2016; Mahanty et al., 2015; William et al., 2015; Madan et al., 2017). McCauley and Cato (2000) described the Terapontidae fish calls with spectral peak frequency range of 0.5–1.5 kHz and pulse repetition frequency values of 0.11 and 0.14 kHz with the single call duration range of 79–105 ms. However, Parsons et al. (2016) detailed the Terapontidae individual calls comprising an average of 51 pulses and 0.32 s duration in the frequency band of 0.05–3 kHz. The single call duration is about 0.35 s and comprises a series of pulses ranging from 35 to 40 (Mahanty et al. 2015). The spectrogram of Terapontidae fish chorus recorded in this study is shown in Fig. 2(a). The noise spectrum level of single fish chorus is shown in Fig. 2(d). The pulse repetition rate varies in the frequency range between 0.1 and 0.12 kHz with the spectral peak ranging from 1 to 2 kHz, as shown in Fig. 3(a and d).

The spectrogram shown in Fig. 2(b) is composed of power spectrum levels of the ambient noise averaged over the recording duration of 60 s of each sample in the study period. It shows a major source of biological signature, which is the evening fish chorus regularly observed at 1–2 kHz (blue ellipse). By 1400 h IST on 12th December, low frequency acoustic signals associated with the storm recorded the maximum noise levels of ∼105 dB re 1 $\mu Pa^2 Hz^{-1}$ with the frequency range of 0–0.3 kHz (magenta ellipse). The wind speed of 26 ms^{-1} was recorded at the study site during the passage of cyclone (Fig. 2b).

The acoustic energy signals generated by the cyclone are mainly below 0.4 kHz, but the maximum energy are in the band of 0–0.3 kHz, whereas the spectral peaks occur between 1 and 2 kHz produced by Terapontidae fish chorus. An analysis of the 1–2 kHz band shows that there is a distinct diurnal periodicity in fish chorus soon after sunset (red circle) at each night (Fig. 2c) prior to the cyclone. However, the fish chorus signature has not been observed during the day of the