Vocalization patterns of Indo-Pacific Humpback Dolphins (*Sousa plumbea)* in Puttalam Lagoon, Sri Lanka

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Abstract

Indo-Pacific Humpback Dolphins (IPHD) occur in the coastal waters of the Indo-Pacific region from the Eastern coast of Africa through Southeast Asia to the Northern coast of Australia. Throughout their range, the habitat and vocalization patterns of IPHD remains poorly known, with the exception of populations off South Africa and Hong Kong, where the animals have been relatively well studied. In January 2012, passive acoustic recording of IPHD at Puttalam Lagoon, located Western shores of Sri Lanka were taken and their vocalizations were classified as broadband click trains, burst pulses, whistles and grunts generally similar to those of some other delphinid cetaceans. The frequency of highest intensity (energy), frequency range, the maximum frequency and the interval were compared. A comparison of our results to previous vocalization of humpback dolphins of Eastern Australia and Western Hong Kong waters showed similar patterns except the absence of quacks in the present study. The spectra of broad band click pulses ranged from 8 to >48 kHz showing the highest intensity around 38 kHz. Narrow banded, frequency modulated whistles ranging between 5.5 and 17 kHz. Low frequency narrow band grunt vocalizations were identified in the range of 0.4-2.5 kHz having highest intensity around 1 kHz. IPHD in Puttalam Lagoon often are found at fishing vessel routes, where their feeding grounds are crossed.

Keywords*:* Vocalization, Passive acoustic, Delphinid, Harmonic

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Introduction

The Indo-Pacific Humpback Dolphin (IPHD) are categorized as near threatened species by the International Union for Conservation of Nature (IUCN). It is a species of humpback dolphin that is discontinuously distributed throughout coastal waters from Southern Africa through Southeast Asia to the East to the West/Northern Australia (Jefferson and Karczmarski, 2001; Jefferson and Leatherwood, 1997; Van Parijs and Corkeron, 2001b). The species in the Indo-Pacific area are believed to be either *Sousa plumbea* or *Sousa chinensis* where *S. plumbea* is recorded in the Western Indian Ocean along South Africa to Southeast coast of India and *S. chinensis* from the East coast of India to China and Australia (Schipper, 2008; Thompson, 2013). The species referred are inshore or near shore species inhabit coastal waters, bays, and estuaries typically within 0.5 km off the coast, in waters less than 20 m deep (Parsons, 2004; Sutaria and Jefferson, 2004; Wells, 2002). According to the current understanding of IPHD in the Gulf of Mannar, north of Puttalam Lagoon are believed to be members of the Western Indian Ocean subspecies, *S. plumbea* (Martenstyn, 2011; Parsons, 2004). However, DNA analyses of Humpback Dolphins from Australia (chinensis) are said to be highly distinct from other Indo-Pacific populations (Frère *et al.*, 2008) while phylogenetic analyses indicated that Hong Kong chinensis, South African plumbea, are more closely related each other than to the chinensis dolphins in Australia (Corkeron *et. al.*, 1997).

Bar reef marine sanctuary and associated waters of Puttalam Lagoon in Sri Lanka is known as a residential area of Indo-Pacific Humpback and Spinner dolphins. It is also reported that they frequently visit Puttalam Lagoon (Ilangakoon, 2006) with the high tide through the deeper part of the lagoon channel (Martenstyn, 2011; Parsons, 2004). Similarly, Karczmarski and Cockcroft were also noted that the *S. plumbea* type humpback dolphins in Algoa Bay, South Africa have a tendency towards an increase in feeding behavior at high tide. According to Centre for Research on Indian Ocean Marine Mammals (CRIOMM), subpopulation of IPHD in Puttalam Lagoon had declined from 15 in 2005 to just 5 in 2012, which shows they are critically in endanger. This was evident from photo identification. Ever increasing coastal development in Northwestern coast of Sri Lanka, mainly fisheries and water based recreational activities, may exert an impact on noise pollution. Marine mammals are being confronted with habitat degradation and destruction, due to noise pollution, harassment and over fishing of prey species

(Jefferson and Hung, 2004). Noise pollution hinders communication of cetacean, causing physiological and behavioral changes (Simmonds *et al.,* 2014). Banned-Dynamite fishing and '*laila*' net fisheries used in Sri Lankan waters are prime cause of reef damage and mass fish kills, demise of pods of dolphins that associate with the target fish species (Garcia *et al.,* 2003).

Recently, public knowledge and hence concern about the possible effects of anthropomorphic environmental noise, together with attempts to mitigate adverse effects on the humpback dolphin, have steadily grown within scientific and conservation communities (Jefferson *et al*., 2009; Jefferson and Hung, 2004; Parson, 2000; Würsig, *et al*., 2000). *S. chinensis* in Hong Kong waters feed mainly on a variety of fishes (Jefferson and Hung, 2004), while in Moreton Bay, Australia, it is recorded that humpback dolphins are associated with shrimp trawlers (Corkeron, 1990). Similarly, Ilangakoon (2006) had observed that the species in the Puttalam Lagoon allied with prawn fishing. Guissamulo (2004) suggested that the seasonal changes in river discharges and salinity, increased availabilities of humpback dolphin prey species in Maputo Bay, Mozambique.

According to the previous studies in Morton Bay and west Hong Kong, it is revealed that the Cetacean delphinids have evolved complex sound production and hearing abilities to effectively sense and communicate, forage and navigate within their three dimensional and often vision-limited environments (Van Parijs and Corkeron, 2001b). Delphinid sounds are generally categorized into clicks (used for echo-location), whistles (believed to be used for communication), grunts (associated with socializing) and burst-pulses, which are used for communication (Jefferson and Karczmarski, 2001). Later burst-pulses were divided into barks and quacks (Parsons, 2004). Grunts are low frequency, narrow band sounds of short duration, while quacks were low frequency broadband harmonic sounds of slightly shorter duration than barks (Van Parijs and Corkeron, 2001a).

However, in order to propose effective and scientific based measures for navigational noise mitigation and animal conservation of IPHD, it is necessary to study their vocalization and the possible effects of environmental noise on their hearing. Unfortunately, very few studies about the hearing sensitivity of the Humpback Dolphin in Sri Lankan waters have been reported. In this paper, recordings of Humpback Dolphins collected from Puttalam Lagoon were analyzed to fill the knowledge gaps that existed on the vocalization pattern of *S. plumbea* in Puttalam Lagoon with the primary objective of gathering baseline data for noise mitigation and animal conservation.

Fig. 1. External appearance of Indo-Pacific Humpback Dolphins (*S .plumbea*) in Puttalam Lagoon, Sri Lanka (Photograph by Gehan de Silva Wijeyethne)

Study Area

Puttalam Lagoon (Fig.2), on the West coast of Sri Lanka, is separated from the ocean by a long, permanent sand bar, which opens up in its Northern end. The surface area and mean depth of Puttalam Lagoon are 225 km^2 and 1.7 m, respectively (at MSL). Tides on the West coast of Sri Lanka are mixed semidiurnal, with a spring tidal range of 0.56 m. In Puttalam Lagoon, the horizontal mean, spring tidal range is about half that of the oceanic tide (Wijeratne and Rydberg, 2007).

The lagoon is fed by two rivers, namely the Kala Oya and Mi Oya, discharging at 2.2 and 8.1 m^3/s respectively. It is connected to Mundal Lake by a 15 km long canal, at the southern end. The most striking physical feature of the lagoon is salinity, while its seasonal variability is closely related to monsoon climate (Jayasiri, 2009). The salinity values were significantly reduced during the rainy seasons and the October rains imply rapidly decreasing salinities while the waters around Kalpitiya is more influenced by the discharge from Kala Oya (Arulananthan *et al.*, 1995). The salinity fluctuates from 36.58 PSU (August) to 13.46 PSU (December) in 2008 (Jayasiri, 2009).

Many studies had observed that the occurrence of *S. plumbea* in the northern part of the Puttalam Lagoon between Kalpitiya and Uchchimunai and in the shallows close to the shoreline (Ilangakoon, 2008). Even its year-round presence in the direct vicinity is confirmed by coastal communities, most of sightings of *S. plumbea* seemed to coincide with inter-monsoonal periods (August-October and February-April) when the sea is calm. However, as this species is somewhat subdued in its surface behavior, the likelihood of sightings was also higher during calm periods (Jefferson and Karczmarski, 2001).

Each of one passive acoustic surveys, on successive (two) days had been conducted, parallel with visual observation during the Northeast Monsoon period (January 2012) on the Western side of Kalpitya Lagoon (8°15'26.19"N, 79°46'50.51"E).

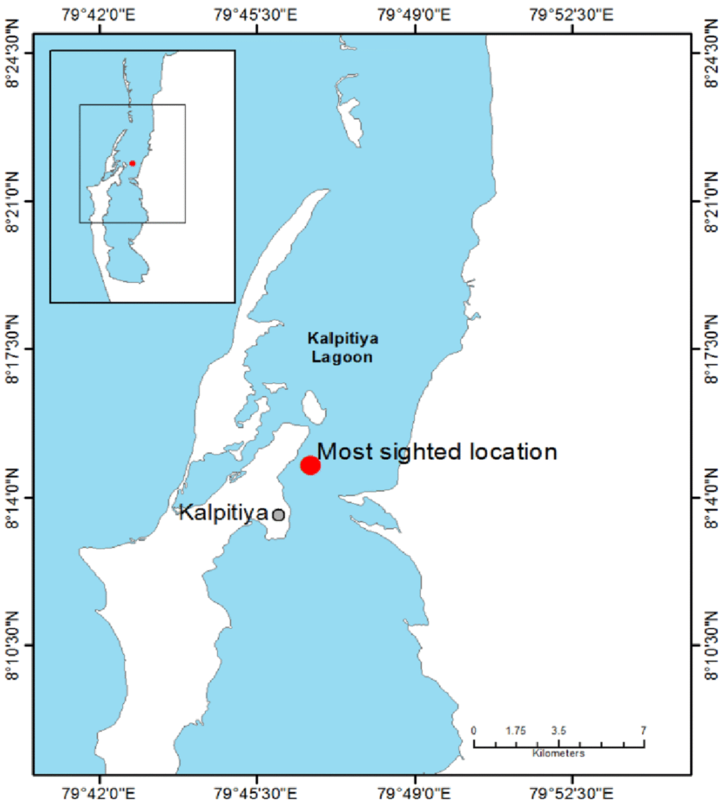

Fig. 2. Location of passive acoustic monitoring where underwater sound produced by Indo-Pacific Humpback Dolphins (*S. plumbea*)

Materials and Methods

A Multiday Fishing Boat, fixed with Ecologic Standard Acoustic Monitoring System (ESAMS) at its stern, was allowed to drift with current at the study area (Fig. 2) by switching off the engine. The sightings of *S. plumbea* were visually identified by NARA survey team. A pod of IPHD (pod of 5 humpback dolphins) were spotted at the proximity of the ESAMS hydrophone array. The Stereo Towed Hydrophone (HP-30 ST) of ESAMS holds a response range of 100 Hz to 48 kHz with a sampling rate of 96 kHz.

The preamplifiers had a low-cut filter designed to provide –3 dB gain at 512 Hz to limit low frequency tow and water noise. The hydrophone is fixed with a preamplifier signal conditioner (30 dB gain and LF cut – 3 dB @ 512 Hz). Measurements of the maximum frequency range were restricted by the upper limit (48 kHz) of the recording equipment.

The towed hydrophone array consists of two hydrophones, fit into a specialized cable, and was deployed for the recordings. The array is designed in such a way that the both hydrophones lie at a same water depth, in concurrence with the heading of the survey vessel.

Vocalizations were analyzed using RAVEN PRO 1.3 and PAMGUARD, on a HP Intel Core i5 running WINDOWS 7. PAMGUARD was used for data acquisition, visualization while RAVEN PRO 1.3 was applied for generating spectrogram of vocals. Each recording file was played back and analyzed in both wave and spectrogram forms with audio [Fast Fourier Transform (FFT), window size 512, window type: Hanning, overlap: 50%] to categorize and differentiate *S. plumbea* vocalizations. Initially each vocalization was separated into one of four categories broadband clicks, broadband burst pulses, whistles and grunts based on Van Parijs and Corkeron, 2001a. Click trains were identified by their logical click sequences (e.g. even spacing between clicks or a gradual increase/decrease in amplitude and/or spacing). RAVEN PRO 1.3 was intensively applied to measure minimum, maximum, start; end, center, and inter-quartile (IQR) frequencies (Hz), to measure inter-click intervals (ICIs), in seconds. For click trains with constant ICIs (non-fluctuating), we measured the start and end of the ICIs. Vocalizations were analyzed using spectrogram and waveform representations. Vocalizations that contained noise and/or vocalization overlap were not analyzed for center and IQR frequencies. Burst pulses were vocalizations with numerous and tightly spaced harmonics, are then classified into barks (highly variable harmonic structure) and quacks (more or less similar to barks but shorter in time). Whistles were identified based on Van Parijs and Corkeron (2001a) as sinusoidal frequency-modulated sounds of varying length, with a frequency range of 3-25 kHz, then separated into categories based on spectrogram form of RAVEN PRO. The grunt vocalizations are identified as low frequency narrow band sounds typically in the frequency of 0.5±2.6 kHz and duration of 0.06±2 s according to Van Parijs and Corkeron (2001b).

Results and Discussion

Vocalization pattern of IPHD in Puttalam Lagoon were compared to previous vocalization of Eastern Australia (Van Parijs and Corkeron, 2001b) and Western Hong Kong waters (Jefferson, 2004). Passive Acoustic Monitoring system (PAM), used in this study was capable of recording the frequencies up to 48kHz, whilst the studies in the off the west Hong Kong and Eastern Australia were capable of recording frequencies up to 22kHz. Broad band clicks, burst pulses, whistles and grunts were identified from the vocal of IPHD in Puttalam Lagoon and their interval(s), frequency range, frequency of highest intensity were compared with similar studies off West Hong Kong and Eastern Australia (Table 1).

Click variation

Click trains had a mean minimum frequency of approximately 8 kHz, a maximum frequency above 48 kHz and frequency of highest intensity lying between 32-42 kHz with click rate of approximately 10 clicks/second (Fig.3). The duration of each click train varied ranging from 0.05–0.1 s having 90-110 dB of click energy relative to 10^{-6} Pa. Individual click interval varies between 6-12 milliseconds.

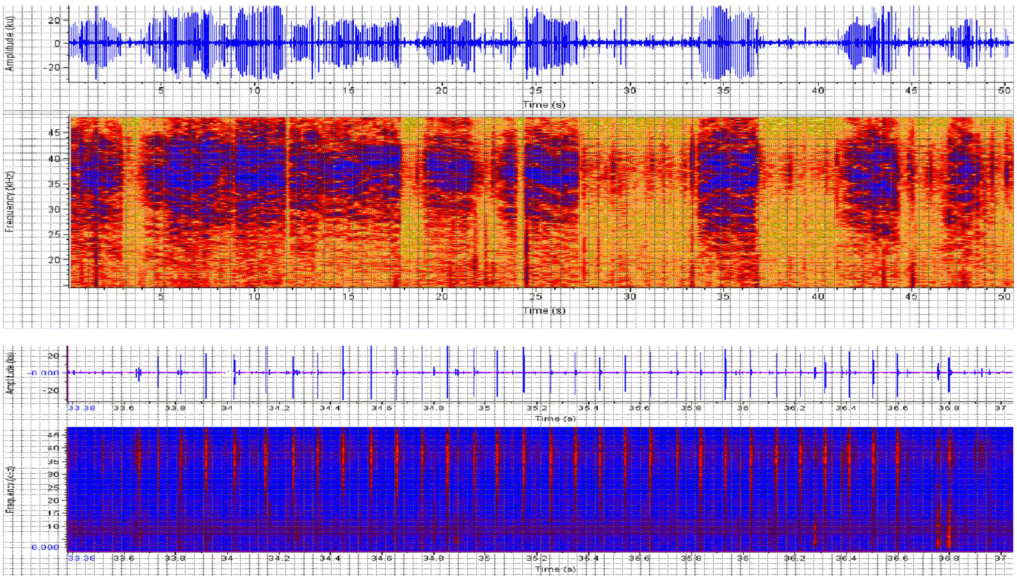

Fig. 3. A subset of the variations found in click vocalizations from recordings of IPHD. (FFT size: 512, Hanning window, overlap: 50%)

Whistle variations

Whistles are narrow band, frequency modulated sounds. Whistles ranging between 5.5 and 17 kHz whereas first harmonic is ranging between 7-9 kHz. Each whistle type varied in frequency and time duration. In present study, some whistles found in harmonics differed from those found in barks, having wider spacing and a lesser occurrence per vocalization. It is observed that the whistles are not frequently found such as clicks and most whistles were associated with clicks. The duration of whistles varied ranging from 0.6 – 1 s having 90 dB of click energy relative to 10-6 Pa. Most commonly found whistle type is shown in Fig. 4.

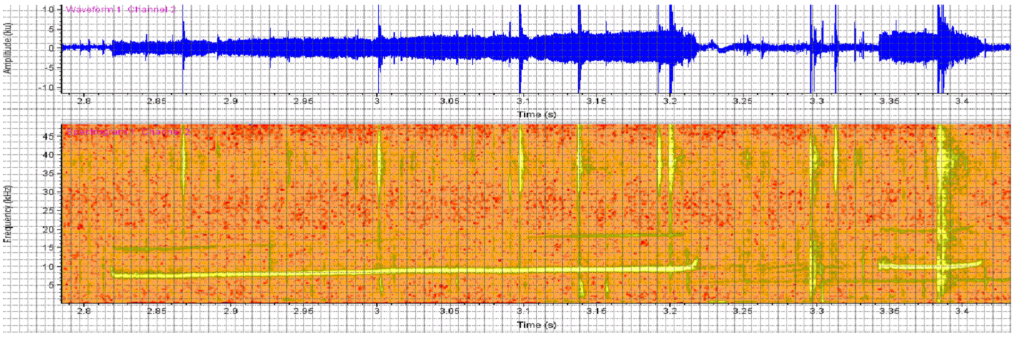

Fig. 4. A subset of the variations found in whistle vocalizations from recordings of IPHD. (FFT size: 16384, Hanning window, overlap (50%)

Grunt variations

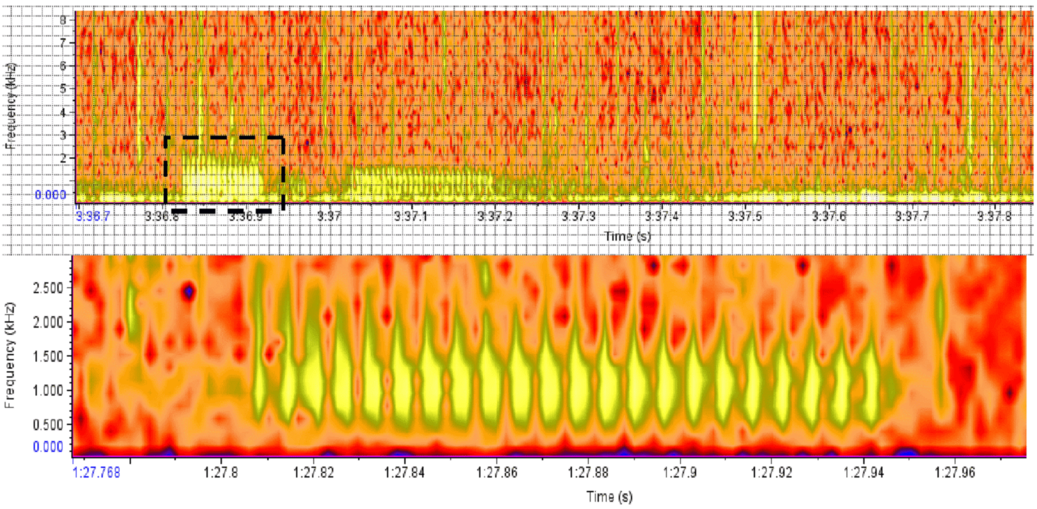

Fig. 5. A subset of the variation found in grunt vocalizations from recordings of IPHD. (FFT size: 512, Hanning window, overlap (50%)

Low frequency narrow band grunt vocalizations were identified in humpback dolphins (Fig.5). These vocalizations were low in frequency, with a minimum frequency of 0.4 kHz and maximum frequency of 2.5 kHz with duration of around 0.1 s.

Burst pulse variations

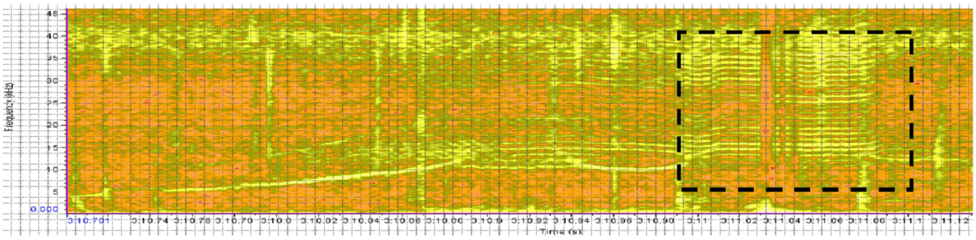

Fig. 6. A subset of the variation found in burst (barks) vocalizations from recordings of IPHD. (FFT size: 512, Hanning window, overlap:50%)

Few burst variations were identified and no quacks observed except few barks which has numerous harmonics that were closely spaced together. Most of barks were composed of harmonics (~20 s) the frequency range of barks varied between 12 to 42 kHz with duration of around 0.2 s (Fig 6).

Table 1. Comparison of humpback dolphins' vocalization pattern; Puttalam Lagoon, off Eastern Australia (Van Parijs and Corkeron 2001a) and western Hong Kong waters (Jefferson, 2004)

Vocalization	**West Hong Kong** (Jefferson, 2004)	**Eastern Australia** (Van Parijs and Corkeron, 2001a)	**Puttalam Lagoon, Sri Lanka**
Broad band clicks			
Interval (s)	0.02-0.06	0.1-10 (mean 4.3 s)	0.01-0.10
Frequency range	8 to > 22 kHz	8 to > 22 kHz	8 to > 48 kHz
Frequency of highest intensity	~ 30 KHz	-	~ 38 kHz
Whistles			
Interval (s)	<1.0	-	~ 0.6
Frequency range	3.0-8.5 kHz	5.5-15.5 kHz	5.5-17 kHz
Frequency of highest intensity	-	-	9 kHz
Barks			
Interval (s)	-	~0.1 to 7.4 (mean 2 s)	~0.1 to 1.0
Frequency range	4.1-24.9 kHz	0.6 to >22 kHz	12 to 42 kHz
Frequency of highest intensity	6 kHz	-	-

Quacks			
Interval (s)	-	0.08-2 (mean 0.6s)	-
Frequency range	-	0.6 to8 kHz	-
Frequency of highest intensity	-	-	-
Grunts			
Interval (s)	-	0.06-0.2 (mean 0.09s)	~0.10
Frequency range	-	0.9-1.4 kHz	0.4-2.5 kHz
Frequency of highest intensity	-	-	1 kHz

The humpback dolphins in Puttalam Lagoon communicate in frequencies as low as 400 Hz than the species in Eastern Australia, suggests that they have good hearing sensitivities at low frequencies which is primarily associated with socializing. Unfortunately, the vessel noise normally, which produces frequencies of 6 kHz or less (Parsons, 2004) would coincide with low frequency vocals (grunts) of IPHD. Moreover, it was observed that the rate of dolphin clicks and whistling were significantly increased, when boat entered an area of their feeding ground. Fig.7 shows that the feeding area of humpback dolphins of Puttalam Lagoon in Dutch Bay lies in fishing ground and vessel routes thus competing for the same resource. Deaths caused by blast fishing were also recorded in the same area (Rodrigo, 2011). According to the studies of blast test, more energy in high frequencies over 10 kHz for near blasting were recorded whilst distant blasts have less pronounced peak frequencies less than 5 kHz with sound levels exceed approximately 161 dB (Fernando *et al.,* 2014). Analysis of audiogram of the IPHD showed the direct impacts on the resident humpback dolphin population and the sound levels of blast fishing (Li *et al*., 2012).

Fig. 7. From left to right; Feeding on the fishing vessel routes. Fishing while feeding in Dutch Bay. Death caused by blast fishing (Rodrigo, 2011). Photograph from the Interim Report " Kalpitiya Humpback Dolphin Study" Howard Martenstyn (2011).

Aknowlegment

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