Sounds of Indo-Pacific humpback dolphins (*Sousa chinensis*) in West Hong Kong: A preliminary description

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Abstract: Vocalizations of Indo-Pacific humpback dolphins (*Sousa chinensis*) in west Hong Kong waters were described from 12 recordings in 2010. A broadband hydrophone system recorded sounds. Vocalizations were characterized as broadband click trains, burst pulses, and narrowband frequency modulated sounds, including whistles generally similar to those of some other delphinid cetaceans. A comparison of results to previous humpback dolphin sound descriptions for Moreton Bay, Australia found broad similarities except for the apparent absence of "quacks" and "grunts" in the present study, which are of low frequency and thus were possibly masked by anthropogenic and other low frequency noise in the Hong Kong habitat.

1. Introduction

Cetacean delphinids have evolved complex sound production and hearing abilities, which allow them to effectively sense and communicate within their three-dimensional and often vision-limited environment. Delphinid sounds are generally divided into the categories of clicks (often used for echolocation), burst-pulses (generally used for communication), and whistles (believed to always be used for communication), although some delphinids do not whistle (see Janik, 2009 for a review). For cetaceans that rely on acoustics for communication, foraging, and navigation, noise pollution is concerning since it can affect behavior, communication, and physiological health (National Research Council, 2005).

The Indo-Pacific humpback dolphin (*Sousa chinensis*) population in West Hong Kong waters is of particular interest due to its proximity to increasing anthropogenic

changes, e.g., noise pollution (Würsig and Greene, 2002). Previous characterizations of humpback dolphin sounds have been made in the Indus Delta (Zbinden *et al.*, 1977), Australia (Parijs and Corkeron, 2001), and Hong Kong (Goold and Jefferson, 2004), although the latter study only recorded clicks.

This study characterized humpback vocalizations from Hong Kong and compared them to a previous study conducted by Parijs and Corkeron (2001) in Moreton Bay, Australia. We suggest that differences in sound types may be attributed to environmental variation between the study sites, but population differences cannot be ruled out.

2. Materials and methods

Humpback dolphin vocalizations were recorded off Lantau Island in Hong Kong during 7 days in May–June, 2010. We recorded sounds from the stern of a 15 m diesel vessel, the "Standard 31516," with engine off and vessel drifting. Broadband humpback dolphin recordings were made with a Cetacean Research Technology spot-calibrated hydrophone (model: CR1; sensitivity: -197.7 dB, re. 1 V/μPa; usable frequency response listed as 4 Hz–68 kHz $+3/-12$ dB connected to a 1 MΩ input impedance; linear frequency range: 0.2–48 kHz $\pm$ 3 dB) and a Fostex digital recorder (model: FR-2; frequency response: 20 Hz–80 kHz $\pm$ 3 dB) with a preamplified signal conditioner (model: PC200-ICP; precision gain: $\times 0.1$–$\times 100$; frequency range: >100 kHz; system response: 1 Hz–100 kHz $\pm$ 0.25 dB) to prevent overloading. The hydrophone, suspended by a 2 m spar buoy to prevent excessive movement from waves, was lowered into the water at 3 and 7 m depths and recorded (sampling rate: 24 bit at 192 kHz) various durations in Broadcast Wave Format, ranging from 2 min 1 s to 8 min. Twelve recordings were taken over 6 days in the presence of humpback dolphins; however, these did not exclude the presence of boats or other anthropogenic noises.

Vocalizations were analyzed using Raven Pro 1.3 and Adobe Audition 2.0 software, on a Dell Optiplex 960 (Intel® Core™ 2 Duo desktop computer running Windows 7. 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 delphinid vocalizations from non-delphinid sounds. Each vocalization was separated into one of three categories—broadband clicks (in comparison to the other relatively narrowband sounds recorded), broadband burst pulses, and narrowband frequency modulated sounds. Click trains were defined as logical click sequences (e.g., even spacing between clicks or a gradual increase/decrease in amplitude and/or spacing). Burst pulses were vocalizations with numerous and tightly spaced harmonics. Whistles were downsampled to 48 kHz to better clarify their shape, then separated into categories based on spectrogram form. Vocalization locations were marked within each file for later analysis.

We used Raven Pro 1.3 to measure minimum, maximum, start, end, center, and inter-quartile (IQR) frequencies (Hz), and we used Adobe Audition to measure inter-click intervals (ICIs), in seconds. For click trains with constant ICIs (non-fluctuating), we measured the start and end 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. Results were saved as text files, recorded in Microsoft Excel 2008 for MacIntosh, and graphed using R statistical software (R Development Core Team, 2011).

3. Results and discussion

Vocalizations were analyzed from 12 files and categorized as broadband click trains ($N = 382$), burst pulses ($N = 19$), or narrowband whistles ($N = 195$). Click trains varied in ICI, ranging from constant intervals throughout the vocalization to fluctuations in interval length. Broadband click trains with constant ICIs had beginning and ending ICIs that increased proportionally to each other (Fig. 1). Click train frequencies extended above and below our flat frequency response range; as such, we excluded them from the frequency analyses. Burst pulses were classified as "barks" based on the
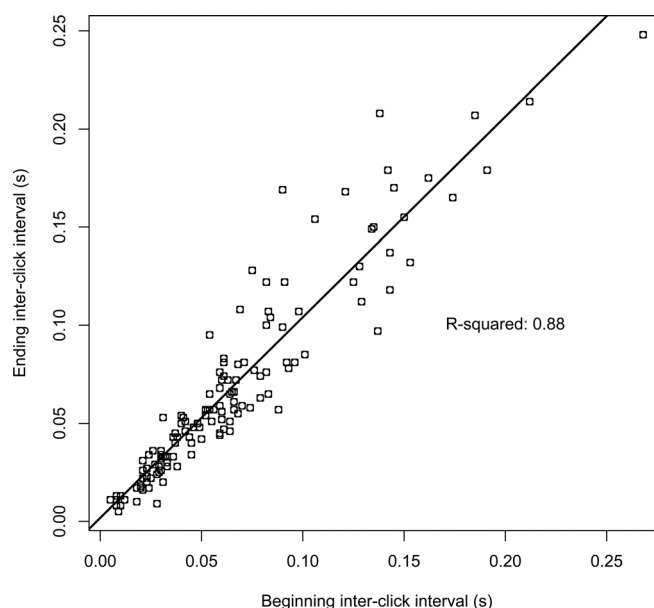
Fig. 1. A linear regression plot of ending inter-click intervals regressed on beginning inter-click intervals for click trains from recordings of Indo-Pacific humpback dolphins.

similarity of their spectrogram form, e.g., continuous horizontal form with multiple harmonics and frequency ranges ~0.6 to >22 kHz, to barks in Parijs and Corkeron's (2001) study, though none of our barks reached Parijs and Corkeron's (2001) full frequency ranges. We chose to classify the burst pulses as barks instead of quacks mainly due to their large frequency ranges (>22 kHz), a distinguishing characteristic of barks. Barks had minimum and maximum frequencies that were greater than whistles, ranging from a low of 4.1 kHz minimum frequency to a high of 24.9 kHz maximum frequency (Fig. 2). Barks had numerous harmonics that were closely spaced together. No "quacks" (described as "burst pulses similar to barks in shape, but of shorter duration") were found based on Parijs and Corkeron's (2001) frequency range. Whistles varied greatly in spectrogram form (Fig. 3), based on differences in frequency range, spectral contour, and number of harmonics. Present in some whistles, harmonics differed from those found in barks, having wider spacing and a lesser occurrence per vocalization. Whistle IQR bandwidth was much lower in comparison to barks; however, whistle center frequency was similar to that in barks (Fig. 2).

Based on differences in ICIs, there appearred to be two types of click trains, distinguished by ICI patterns of either constant intervals or fluctuating ones. These variations are similar to those found by Lammers *et al.* (2004) in Hawaiian spinner dolphins. For constant ICIs, the strong linear relationship between the first and last ICI ($R^2 = 0.88$, Fig. 1) indicates that there was little fluctuation within constant ICIs, consistent with our spectral observations. Within the fluctuating click trains, ICIs varied, some starting with closely spaced ICIs and ending with widely spaced ICIs, some vice versa, and still others with more variations, including sections of constant ICIs. It is possible that these differences are a result of optimal functionality, with constant ICIs used for orientation/navigation purposes if distance to objects is unknown, whereas fluctuating ICIs may be a function of distance to prey. In foraging bats, clicks begin as frequency modulated (wider spaced ICIs) when initially searching for prey and end in constant frequency (closely spaced ICIs) modulation in the prey capture stage (Griffin *et al.*, 1960). Similarly, humpback dolphins may alternate their click trains depending on their hunting strategy or stage in a prey capture. There is some
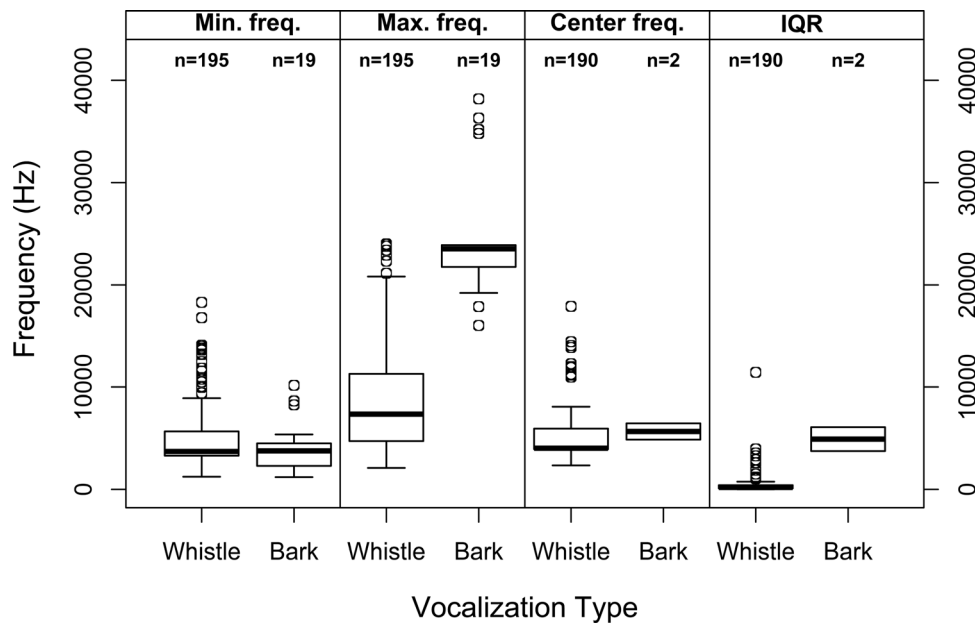
Fig. 2. Whistle and bark distributions for minimum (min), maximum (max), center, and IQR frequencies (Hz) for recordings of Indo-Pacific humpback dolphins. (FFT size: 512, Hanning window, overlap: 50%).
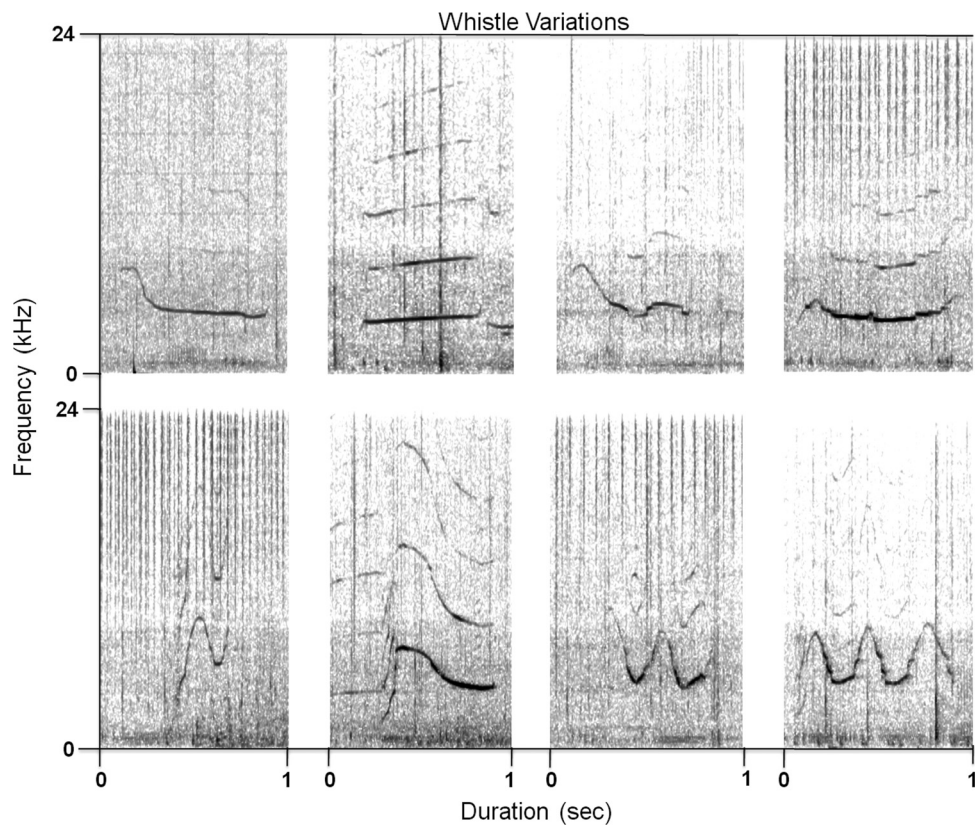

Fig. 3. A subset of the variation found in whistle vocalizations from recordings of Indo-Pacific humpback dolphins. (FFT size: 512, Hanning window, overlap: 50%).

evidence for this in several odontocetes, including bottlenose dolphins (*Tursiops* sp.), known to alter their ICI to compensate for hindering conditions, e.g., weather, ambient noise, distance to target, and target characteristics (Richardson and Thomson, 1995). Additionally, a study by Evans and Powell (1967) observed that clicks generally increased in repetition rate as a target was approached.

Whistles and barks differed in frequency range, and as a result their IQR bandwidth; however, they shared similar center frequencies. Barks were considered broadband sounds and spanned a broader frequency range, whereas whistles were more narrowband in range and were consequently downsampled. The IQR difference was a function of their frequency ranges. Larger frequency ranges, e.g., barks, had wider IQRs. The similarity found in center frequency may indicate that they are both used for communication. Sounds at lower frequencies travel farther underwater (National Research Council, 2000), which may be important for distinguishing whistles and barks from click trains.

Of the variety of whistles in our study, none were directly comparable to those in the Parijs and Corkeron (2001) study. Instead, the general contours of several whistles (Fig. 3) were similar to those found in the Zbinden *et al.* (1977) study of humpback dolphins, in addition to a few signature whistle variations from bottlenose dolphins (Janik *et al.*, 1994). Ding *et al.* (1995) showed that bottlenose dolphin whistles differ significantly in inflection points among five geographical locations, possibly because of differing levels of ambient noise. May-Collado and Wartzok (2008) highlighted significant whistle variation within multiple parameters found among common bottlenose dolphin (*T. truncatus*) populations in the Atlantic Ocean. Their study hypothesized that this intraspecific variation was due to local adaptation as a result of changes in acoustic habitat structure, which may be the cause of geographical differences. Likewise, it is possible that similar variation exists in different geographical locations for Indo-Pacific humpback dolphins. Recent DNA evidence also indicates that the Hong Kong and Australian populations of humpback dolphins are quite different genetically, and may even eventually be named as different species, which may further explain broad-scale differences in vocalizations (Frère *et al.*, 2008).

Complementing Parijs and Corkeron's (2001) results in Australia, this study further documented the frequency ranges of Indo-Pacific humpback dolphin burst pulses; however, we were unable to analyze (and thus compare) the frequencies of our click train data due to the frequency range of our equipment. Further work on click trains should be certain to use a flat frequency response that will encompass a potential full frequency range. In addition, our small sample of burst pulses ($N = 19$) requires greater numbers before descriptions of frequency range can be solidified. Parijs and Corkeron (2001) also found quack and grunt vocalizations in Moreton Bay, neither of which were present in Hong Kong. Both of these vocalizations occur at lower frequencies, at or below 3.7 kHz, and are used in a social context. Similar to the variation found in whistle contours, it is possible that this difference is a result of environmental differences between study sites, or simply due to different populations. Our absence of recording quacks and grunts may also be an artifact due to a "masking" effect, where vocalizations were unable to be separated from the background noise. West Hong Kong is noisy, with much of the sound concentrated in lower frequencies (Würsig and Greene, 2002). However, whether these sounds do not exist in Hong Kong dolphins, or whether we did not pick them up in our few recordings—either by chance or by masking—awaits further work.

Noise pollution is an important issue in marine environments due to the reliance of odontocete cetaceans on acoustic signaling for communication, foraging, and navigation (Laiolo, 2010). This is of particular concern with the Indo-Pacific humpback dolphin population in Hong Kong, where there are many sources of anthropogenic disturbances, e.g., dredging, heavy vessel traffic, chemical pollution, and noise pollution (Würsig and Greene, 2002; Jefferson *et al.*, 2009). This study characterized some of the vocalizations recorded from Indo-Pacific humpback dolphins in Hong Kong; however, more research is needed to more fully describe the sound repertoire of the Hong Kong population, and in assessing the impacts of anthropogenic activities.

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