PATTERNING IN NORTHERN BOTTLENOSE WHALE (*HYPEROODON AMPULLATUS*) CLICK TRAINS

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1 Introduction

Northern bottlenose whales (*Hyperoodon ampullatus*) are large toothed whales of the family Ziphiidae; the beaked whales. They are one of the few species of beaked whales whose vocalizations have been fairly well described and are known to produce several types of broadband impulsive vocalizations with spectral content ranging from 0.5 to > 50 kHz, including upswept frequency modulated (FM) pulses, buzz clicks, and more variable surface clicks [1-4]. [1] report a mean FM pulse duration of 0.276 msec, mean interclick interval (ICI) of 306 msec and mean centroid frequency of 47 kHz. This varies somewhat from the mean duration of 0.585 msec, mean ICI of 514 msec, and mean minimum and maximum frequencies of 10.5 and 47.5 kHz reported by [2]. These FM pulses correspond closely to the "deep-water clicks" described by [3], which had a mean duration of 0.35 msec, mean ICI of 400 msec and were heard when no whales were visible at the surface. FM pulses/deep-water clicks are likely used to echolocate prey [1,3]. Buzz clicks have shorter duration and ICI (< 14 msec), no FM structure, and are also likely used for foraging but when prey is at short range [1]. "Surface clicks" are described as clicks emitted in rapid succession with irregular timing with a mean duration of 2.02 msec and mean ICI of 70 msec, recorded when whales were visible at the surface or shortly after diving [3]. Surface clicks likely serve a different function such as echolocating on vessels or companions, or possibly social communication [3].

During northern bottlenose whale focused field studies in summer 2006 conducted in the Gully submarine canyon located offshore Nova Scotia, Canada, acoustic recordings made when northern bottlenose whales were observed at the surface revealed click trains occurring with unusual temporal patterns that have not been previously described. The objective of this study was to describe these atypical click trains in greater detail.

2 Methods

2.1 Data collection

Acoustic recordings of northern bottlenose whales were obtained from the Gully between 25 July and 3 Aug 2006. A 12-meter sailing vessel was used to approach northern bottlenose whales to within 100 m to collect data for photographic identification studies. Acoustic recordings were made on an opportunistic basis, typically when the vessel was stationary and when individuals were observed at the surface near the vessel or shortly after they dove. Length of the recording sessions varied from 1-66 minutes, and a total of 18.3 hours of recording were collected. Detailed notes on the number, sex and age class (if known) of the animals present, and their behavior while at the surface, were also collected throughout recording periods.

All recordings were made using a custom built towed hydrophone array consisting of two Benthos AQ4 hydrophones (frequency response ± 1 dB re 1 V/μPa from 5-30 kHz) spaced 1.8 m apart and housed in a fluid filled case at the end of a 100 m cable. The system contained custom built preamplifiers (which added 27 dB re 1 V/μPa to the incoming signal) and was connected to a custom built high-pass filter (set to 0.4-3.6 kHz, adjusted according to background noise levels) and a Kemo Pocketmaster 1600 lowpass filter (set to 48 kHz). The array was connected to a personal computer through a Creative Labs Audigy PCMCIA sound card with a sampling rate set to 96 kHz. The system was able to record signals up to 48 kHz.

2.2 Analysis of recordings

The recordings were visually and aurally scanned in Raven Pro 1.4 (© Cornell Lab of Ornithology) and click trains with unusual timing patterns were identified. The most frequent atypical timing pattern identified was a "doublet click train" which consisted of pairs of clicks with a typical ICI separated by longer ICIs (Figure 1). A quantitative analysis of this particular click train pattern was completed. Often multiple animals were recorded simultaneously; thus, only relatively loud clicks which were clearly part of the same click train (as determined by visually examining amplitude and frequency structure of the clicks) were included. Any echoes/reflections present were excluded from the analysis.

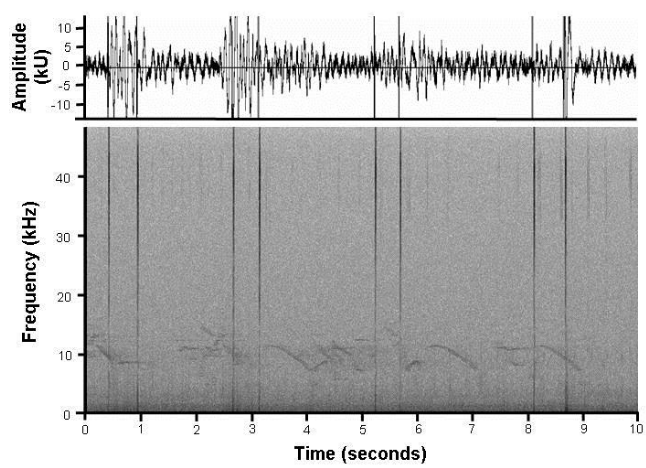

Figure 1: Waveform and spectrogram of a portion of a northern bottlenose whale doublet click train.

The start time of each click within the doublet click train was measured manually in Raven Pro. ICI durations were calculated by subtracting the start time of each click within the click train from the start time of the preceding

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click. The click trains consisted of both short ICI durations (between the two clicks of the click pair) and long ICI durations (between click pairs) (Figure 1). The mean, standard deviation and median ICI duration was calculated for short and long ICIs.

3 Results

Eighteen doublet click trains recorded on different days, and thus likely made by different individuals, were measured (Table 1). The mean long ICI duration was significantly longer than then the mean short ICI duration ($t_{0.05(2)} = -3.12$, df = 78, $p < 0.001$) and within a train the mean long ICI duration tended to be at least two times longer than the mean short ICI duration (Figure 2).

ICI type	Number of ICIs measured	Median (msec)	Mean (msec)	SD (msec)
Short	75	460.20	460.58	92.48
Long	57	1601.00	1486.68	617.4

Table 1: Median, mean and standard deviation of short and long ICIs within northern bottlenose whales doublet click trains.

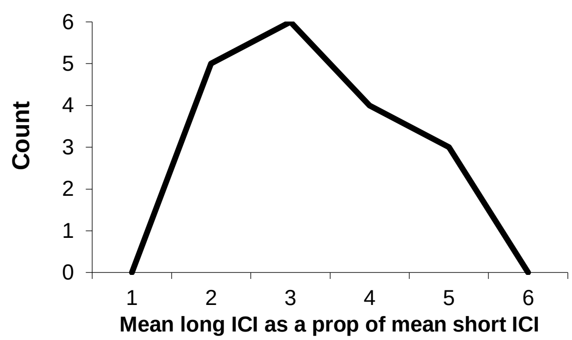

Figure 1: Histogram of the mean long ICI as a proportion of the mean short ICI for each doublet click train.

4 Discussion

The doublet click trains described here are the first click trains of this type reported for cetaceans. Click trains consisting of paired clicks have been observed in echolocating terrestrial species including swiftlets, owls and bats [5-7]. Several possible functions of this clicking pattern have been suggested including increasing signal-to-noise ratio of the clicks [8] and an anti-masking strategy used in group situations [9]. It is possible that the patterning in the doublet click trains produced by northern bottlenose whales allow individuals to distinguish their own clicks from those produced by others in the group. Another possible function is social communication. Non-click vocalizations such as the more typical social sounds produced by other odontocetes (e.g., whistles) do not appear to be a common feature of the vocal repertoire of northern bottlenose whales [1-4]. Sound production limited to clicks is known to occur in sperm whales, whose clicks serve both foraging (through echolocation) and communication functions (e.g., codas) [10]. The northern bottlenose whale doublet click trains examined in this study were recorded when groups ranging in size from 3-11 individuals were present, and often when the animals were displaying social behaviours at the surface.

5 Conclusion

Although the function of doublet click trains is not currently clear, this vocalization is extremely interesting and demands more investigation as it may be an important source of information for increasing our understanding of this species. Further research is required to determine the prevalence of these patterned click trains in the vocal repertoire of northern bottlenose whales and their function. This study highlights that there is still much to learn about the vocal behavior of northern bottlenose whales.

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References

[1] S.K. Hooker and H. Whitehead. Click characteristics of northern bottlenose whales (*Hyperoodon ampullatus*). *Mar. Mamm. Sci.*, 181: 69-80, 2002.

[2] B. Martin and H.B. Moors-Murphy. Analysis of Northern bottlenose whale pulses and associated reflections recorded from the Gully Marine Protected Area. *Proc. Meet. Acoust.*, 19: 010045, 2013.

[3] M. Wahlberg, K. Beedholm, A. Heerfordt and B. Møhl. Characteristics of bisonar signals from the northern bottlenose whale, *Hyperoodon ampullatus*. *J. Acoust. Soc. Am.*, 130: 2077-3084, 2011.

[4] H.E. Winn, P.J. Perkins, and L. Winn, Sounds and behavior of the northern bottle-nosed whale. 7th Annual Conference on Biological Sonar and Diving Mammals, Stanford Research Institute, Menlo Park, CA., 53-59, 1970.

[5] R.A. Suthers and D. H. Hector. Mechanism for the Production of Echolocating Clicks by the Grey Swiftlet, *CollocMia spodiopygia*. *J. Comp. Physiol.*, 148: 457-470, 1982.

[6] D. Crawford, J.W.H. Ferguson and A.C. Kemp. Why do grass owls (*Tyto capensis*) produce clicking calls. *J. Raptor Res.*, 33:134-142, 1999.

[7] H. Raghuram, N. Gopukumar and K. Sripathi. Presence of single as well as double clicks in the echolocation signals of a fruit bat, *Rousettus leschenaulti* (Chiroptera: Pteropodidae). *Folia Zool.*, 56:33-38, 2007.

[8] E.R. Buchler and A.R. Mitz. Similarities in design features of orientation sounds used by simpler, nonaquatic echolocators. In *Animal Sonar* Systems. Eds R.G. Busnel and J.F. Fish. Plenum Press, NY: 871-874, 1980.

[9] J.H. Fullard, R.M.R. Barclay. Echolocation in free-flying Atiu Swiftlets (*Aerodramus sawtelli*). *Biotropica.*, 25:334-339, 1993.

[10] W.A. Watkins and W.E. Schevill. Sperm whale codas. *J. Acoust. Soc. Am.*, 62: 1485-1490, 1977.