Variation in Right Whale Contact Calls with New Data From Auckland Island Southern Right Whales

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INTRODUCTION

Right whales consist of three different nominal species groups, North Pacific Right Whales (*Eubalaena japonica*), North Atlantic Right Whales (*E. glacialis*) and Southern Right Whales (*E. australis*) (Rosenbaum et al. 2000; Gaines et al. 2005). Recordings of vocalizations have been made from all species, although in southern right whales', call characteristics and contexts have only previously reported from one breeding ground location (*i.e.* Golfo San Jose, Argentina: Clark, 1982; Parks et al. 2007).

Calls from all right whales are generally similar and can be classified under the scheme of Clark (1982) for southern right whales, although some modifications to classifying these calls have been made (McDonald and Moore, 2002; Parks and Tyack, 2005). Calls are generally low frequency (peak frequencies < 500 Hertz), tonal, and may be easily separated out into discrete categories (i.e. 'Up', 'Down', 'Gunshots', 'Blows') or can fall into a continuum of sounds that are more difficult to classify. For Southern Right Whales some behavioral observations made in combination with sound recordings have indicated the potential behavioral function of some call types (Clark 1983).

One call classified as an 'Up' call consists of a simple, uniformly tonal upsweeping call with the major energy between 50-200 Hz and a frequency modulation rate between 20-100 Hz/Sec (Clark 1982). These calls are the most common southern right whale call (Clark 1983) and have been described as 'contact' calls (referred to as contact calls hereafter) since they appear to function as signals which bring whales together (Clark, 1983; Parks and Tyack, 2005). Because of their ease of recognition and the importance of their indicated biological function, upcalls have been the focus of a comparative study wishing to examine right whale response to the potential masking effects of anthropogenic noise in the ocean (Parks et al. 2007). This study undertook inter-specific comparisons of southern right whale and North Atlantic right whale contact calls as well as intra-specific comparisons between historic and contemporary recordings, within a framework of 'paired anthropogenic noise environments' (i.e. low V high anthropogenic noise).

We made recordings of southern right whale vocalizations in the Auckland Island breeding grounds in 2007 and 2008. This preliminary work describes the characteristics of contact calls from this population and compares them to contact calls from other right whales reported previously. The aims of this study were to: 1) Describe contact calls from this population of southern right whales; 2) To compare these calls to other right whale contact calls reported previously; and 3) to briefly consider the comparisons in relation to ambient anthropogenic noise and other potential physical/biological contributors to variation in vocalizations. This work is a preliminary presentation of a larger study examining vocalizations from this population of southern right whales.

METHODS

Recordings were conducted from both the *Evohe*, a 25m research vessel, and its tenders (4.5m rigid hull inflatable) during 2 Southern right whale research trips in 2007 and 2008 to the Auckland Islands. Recordings were made in Port Ross in late July and early August, generally in the presence of large numbers (upwards of 100; Childerhouse and Dunshea, 2007; Dunshea et al. 2008) of right whales within the greater Port Ross area and usually within 10's of meters of 1-5 smalls groups or cow-calf pairs. An HTI-SSQ-41B hydrophone (High Tech, Inc. Gulfport, MS, sensitivity -171 dBV re 1 V/uPa +/-2dB from 10Hz–32 kHz) was used to record sound onto a stereo digital audio tape (DAT) recorder Sony TCD-8 (frequency response flat +/-1 dB from 9 Hz to 22 kHz).

Recordings from both years were digitized and then downsampled in Matlab (www.mathworks.com) to 8kHz sampling rate files for ease of analysis. Recordings were scanned for high signal to noise southern right whale

contact calls, as defined by (Clark, 1982). Generally, due to the low noise environment, and proximity of the whales, the calls were of excellent quality. Raven 1.2 and 1.4 (Cornell University, Raven: Interactive Sound Analysis Software) was used for analysis. Calls of interest were bounded with the Raven selection window and chosen metrics saved to the selection table. Due to the differences in the output metrics of Raven and different metrics of interest, the bandwidth of 2007 and 2008 recordings were selected in slightly different ways. In 2007, only measurements on fundamental frequencies were made and the parameters measured were, *start* frequency, highest frequency and duration. In 2008, measurements were made with the newer version of Raven across the entire bandwidth of the call (fundamental frequency and harmonics). Call parameters measured for 2008 calls were *minimum* frequency, highest frequency, peak frequency and duration. For ease of comparison, we only included highest frequency metrics from 2008 calls with no harmonics, thus the highest frequency represented the highest frequency of the fundamental frequency as for 2007 measurements. Spectrogram settings of 2048 sample FFT size, 87.5% overlap, and a Hanning window were used to provide an analysis resolution for frequency of 5.6Hz (3dB filter bandwidth), and time window of 12.8ms.

We compared our *start* and *minimum*, highest and peak frequencies, as well as call duration with studies from the literature on other southern right whale populations and right whale species with comparable metrics. A summary of the studies to which these results were compared is presented in Table 1. Since null hypotheses would be generated *ad hoc* and we were not testing specific hypotheses, we did not evaluate our data with tests of significance; we simply compared mean values and confidence intervals between studies for inference (Johnson, 1999). Where confidence intervals are not reported in studies, they are calculated from standard deviations and sample sizes with the following formula: $1.96(S.D/\sqrt{n})$. Where S.D. = standard deviation and, n = sample size.

Table 1. Summary of the studies from which data was gathered for comparison of call metrics with the present study. Row colors indicate different species and are used throughout the remainder of figures.

Study	Species	Location	Recording Period	*n*
Parks et al. 2007	*E. australis*	Golfo San Jose, Argentina	2000	78
Parks et al. 2007	*E. australis*	Golfo San Jose, Argentina	1976-1977	846
This Study	*E. australis*	Port Ross, Auckland Islands	2007-2008	171
Parks et al. 2007	*E. glacialis*	Bay of Fundy, Canada, Cape Cod Bay, MA. Great South Channel, MA.	1999-2004	929
Parks et al. 2007	*E. glacialis*	Vineyard Sound, MA.	1956	19
Parks and Tyack, 2005	*E. glacialis*	Bay of Fundy, Canada	1999-2002	211
McDonald and Moore, 2002	*E. japonica*	Eastern Bering Sea	1999	436

RESULTS AND DISCUSSION

A total of 171 contact calls have been classified and analyzed thus far from these recordings; 123 from 2007 and 48 from 2008. We excluded some calls (n=3) that were initially classified as contact calls on the first pass since their start frequency was well above 300 Hertz. Although these calls were also tonal and uniformly upsweeping (i.e. their spectrograms were visually similar to upcalls), under the classification scheme of Clark (1982) these calls would fall into a 'high' call classification as opposed to an up call one.

Summary metrics for both recording years from this study are presented in Table 2. Average highest frequency shows inter-annual variation within the bounds expected given confidence intervals. Duration of 2008 calls is on average longer than 2007 calls.

Table 2. Summary statistics for measured metrics of Auckland Island Southern Right Whale contact calls. Values given are means, with 95% confidence intervals in parentheses. Sample size (*n*) is given to the right of each metric.

Year	Duration (s)	*n*	Start/Minimum frequency (Hz)	*n*	Highest frequency (Hz)	*n*	Peak Frequency (Hz)	*n*
2007	0.82 (0.04)	123	81.7 (2.5)*	123	140.9 (25)	123	-	-
2008	0.94 (0.08)	48	64.5 (5.5)*	48	169.3 (49.5)$	9	106 (10.4)	48
All	0.86 (0.03)	171	-	-	146.4 (8.6)	132	106 (10.4)	48

* In 2007 *start* frequency was measured and in 2008, *minimum* frequency was measured. $Only 2008 calls with no harmonics were included in this metric so that this value of highest frequency refers to the highest frequency of the calls' fundamental frequency.

When compared to other right whale studies, duration of Auckland Island southern right whale contact calls is not differentiated from other southern right whales, however they appear shorter than calls from one North Atlantic right whale study: (Parks and Tyack, 2005) and longer than those of North Pacific right whales (Fig. 1). Interestingly, duration of calls from North Atlantic right whales are different between different studies (e.g. Parks and Tyack, 2005; Parks et al. 2007; Parks et al. 2009), some data of which is from the same location and with overlapping time periods, suggesting that apparent variation in contact call duration may arise through a combination of real spatial and temporal differences along with varying analysis parameters used in different studies.

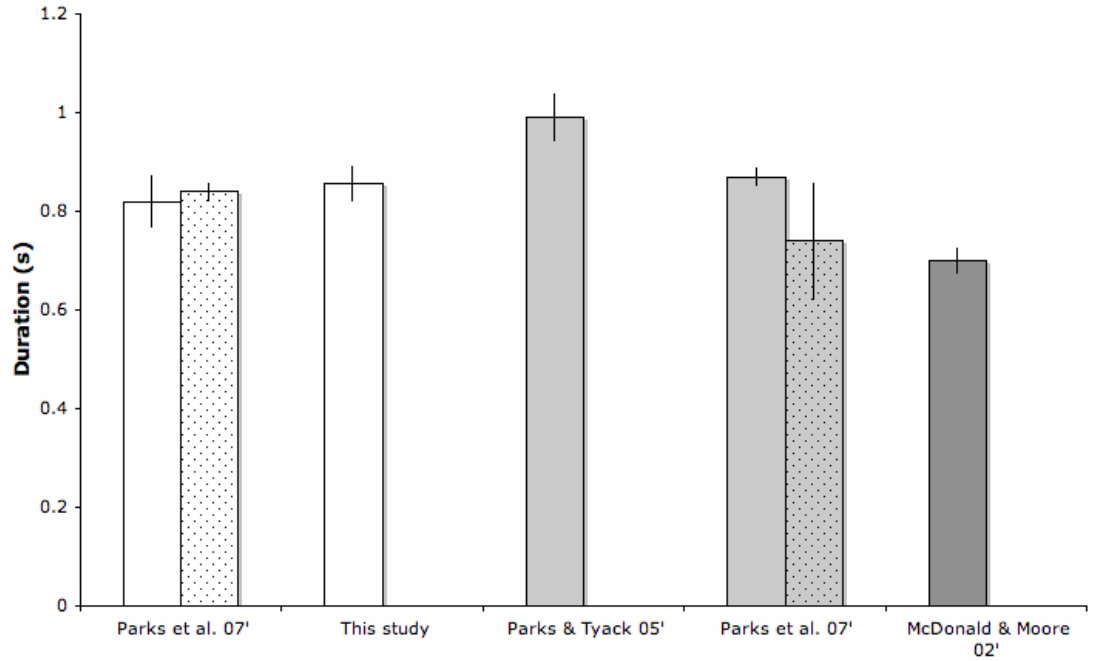

Figure 1. Average durations of right whale contact calls. Whiskers represent 95% confidence intervals. Data source is indicated on the x-axis labels, color/pattern key as follows: White: Southern right whales; Light grey: North Atlantic right whales; Dark grey: North Pacific right whales; Plain bars: Contemporary recordings; Dotted bars: Historical recordings. See Table 1 for details of studies and time periods of recordings.

Contact call start frequency of (2007) Auckland Island southern right whales is not differentiated from contemporary southern right whales from Golfo San Jose, although greater than that of all historical right whale recordings and lower than that of contemporary recordings of both northern right whale species (Fig. 2a.). Minimum frequency of (2008) Auckland Island southern right whale contact calls is considerably lower than that of North Atlantic right whales (Fig. 2b.). The maximum frequency of Auckland Island southern right whale contact calls is not differentiated from contemporary or historic recordings of southern right whales but is lower than that of all northern right whale species (Fig 2c.). The peak frequency of Auckland Island southern right whale calls is considerably lower than that of North Atlantic right whales (Fig 2d.).

It is not surprising that southern right whale calls are generally different from northern right whale calls considering they are different species that have been reproductively isolated for considerable periods of time (Rosenbaum et al. 2000). There are many influences by which call characteristics could diverge including but not limited to cultural drift and/or selection, genetic differences or environmental conditions.

Tthe Auckland Islands population of southern right whales is likely to be at the lowest end of the continuum of exposure to anthropogenic noise, given the isolation of the breeding ground and the likely southern ocean feeding areas of these animals. Recordings from these whales are therefore a valuable dataset with which to make comparisons to right whales in other acoustic environments. While their historical call characteristics are unknown, under the framework presented in Parks et al (2007), it may therefore be expected that their contact calls would be most similar to historic southern right whale calls. This does not appear to be the case and could illustrate the difficulties in making predictions of responses of species and populations to a particular parameter.

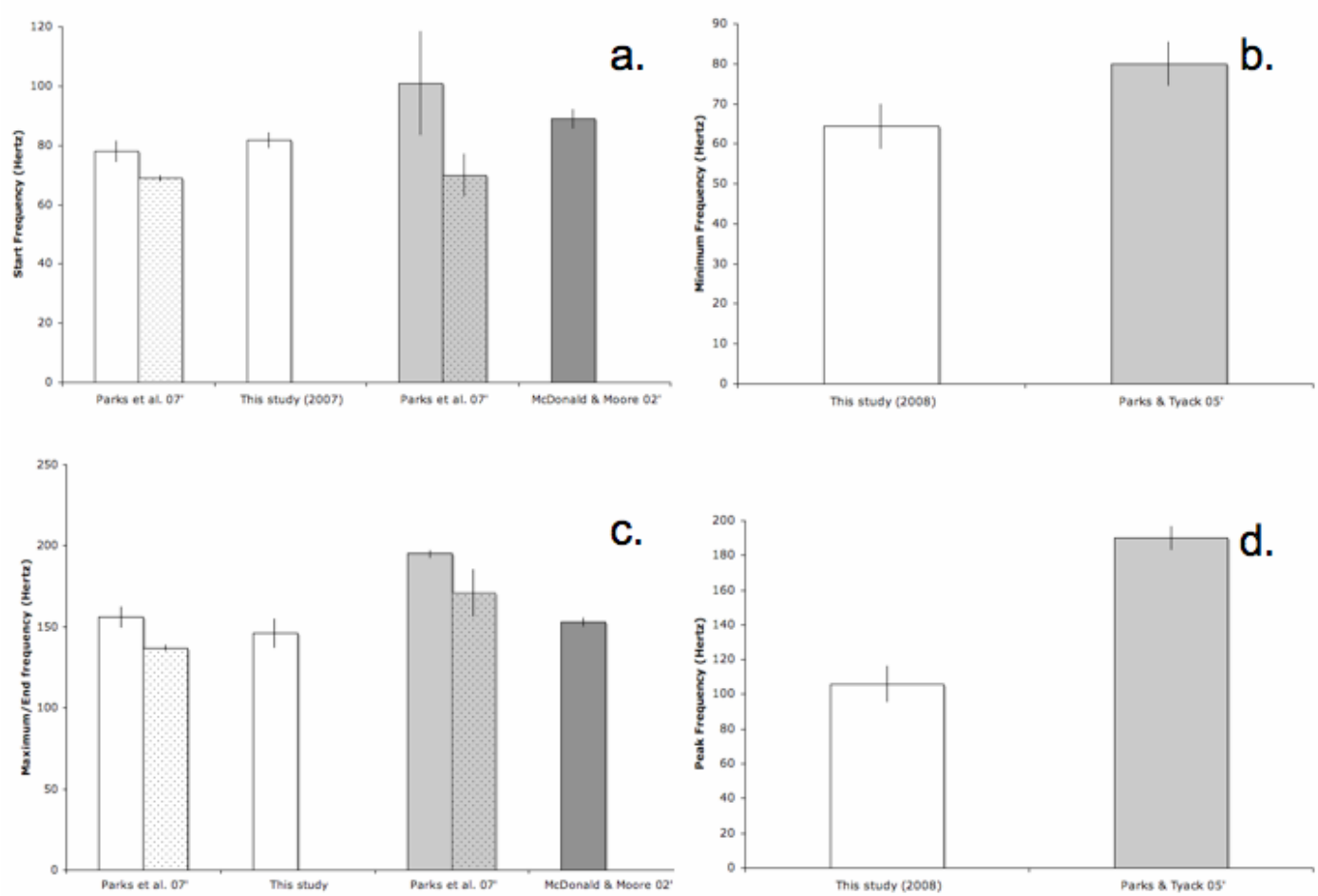

Figure 2. Average start frequency (**a.**), minimum frequency (**b.**), maximum/end frequency (**c.**) and peak frequency (**d.**) of right whale contact calls. Whiskers represent 95% confidence intervals. Data source is indicated on the x-axis labels, color/pattern key as follows: White: Southern right whales; Light grey: North Atlantic right whales; Dark grey: North Pacific right whales; Plain bars: Contemporary recordings; Dotted bars: Historical recordings. See Table 1 for details of studies and time periods of recordings.

With the different analysis parameters, variables measured and varying aims, comparing different acoustics studies is not particularly straightforward. The inherent subjectivity of analyzing spectrograms adds to the possible sources of error when comparing studies. For example, when examining a spectrogram to ascertain a

calls start frequency, the sample FFT window selected will have a large effect on the appearance of the start of the call on the spectrogram, since FFT sample size determines frequency resolution. Presumably if a study is interested in differences in frequency between subject groups, an FFT sample size that maximizes the frequency resolution of the spectrogram is desirable. The trade-off of course, is that this sacrifices temporal resolution. A detailed and standardized framework for measurements of different call characteristics and call comparisons would be beneficial in this regard.

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