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First acoustic recordings of critically endangered eastern South Pacific southern right whales (*Eubalaena australis*)

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Southern right whales (*Eubalaena australis*) were historically numerous off the coast of southern Chile until whaling efforts from the late 18th century to the 20th century decimated the population to near extinction (Pastene and Quiroz 2010). Over 2,000 southern right whales were taken by the French off the coast of Chile in the 19th century, and some 14,600 more were taken by Americans in the South Pacific at undetermined locations (Du Pasquier 1986, Best 1987). Today, eastern South Pacific southern right whales are recognized by the International Union for the Conservation of Nature (IUCN) as a critically endangered subpopulation, likely consisting of fewer than 50 mature individuals (Reilly *et al.* 2013, Galletti Vernazzani *et al.* 2014). This distinct subpopulation is known to range from Chilean Golfo de Penas, at 47°S, to as far north as the coast of Chorillos in Lima, Peru, at 12°S (Aguayo and Torres 1986, Orihuela and Cortegana-Arias 2013). Despite many studies documenting gradual recovery of other southern right whale populations, the eastern South Pacific subpopulation shows no signs of population increase (Galletti Vernazzani *et al.* 2014).

Mitigation of anthropogenic threats is vital to the survival of this critically endangered subpopulation, but further research into behavior and habitat use is

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necessary to make sure these measures are as effective as possible. A Conservation Management Plan (CMP) that includes both range states, Chile and Peru (IWC 2016a), has been implemented through the International Whaling Commission (IWC) since 2012. In 2016 the IWC Scientific Committee decided to support the project “Acoustic monitoring of the eastern South Pacific population of southern right whales, a key to increase the results of the CMP,” with the aim of facilitating identification of potential breeding areas along the coasts of Chile and Peru (IWC 2016b). Current knowledge of the subpopulation is drawn solely from sighting records, both historically from whalers and from current collaborations between researchers and the Chile National Marine Mammal Sighting Network. Our recordings of eastern South Pacific southern right whales are the first known acoustic data from this subpopulation and signal the potential for new research and mitigation techniques. Our recordings provide valuable information about call parameters and patterns, which can be used to document spatial and temporal patterns of occurrence as well as possibly generate acoustic-based density estimations.

Data were recorded on a marine acoustic recording unit (MARU, Cornell University; sensitivity: -168 dB, depth: 200 m, sampling rate: 2 kHz, gain: 23.5 dB, low-pass filter: 800 Hz, high-pass filter: 10 Hz) off the southwestern tip of Isla de Chiloe (43.53°S , 74.44°W) from 29 January to 17 June 2012 (Fig. 1). Spectrograms were visually audited for upsweep calls using Raven Pro 1.5 (Charif *et al.* 2010; Cornell Lab of Ornithology, Ithaca, NY), with the following display settings: 3 min time axis, 500 Hz frequency axis, 2,048 sample DFT, 1,400 sample window, and 50% overlap.

The full 139 d deployment was initially subsampled by analyzing four out of every 24 h. Subsampled days with the most upsweep calls, as well as days near those with many upsweeps, were selected to maximize the number of calls for this initial analysis. This resulted in analysis of 46 of 139 d (6 in February, 15 in March, 17 in April, 7 in May, and 1 in June), yielding a total of 4,313 right whale upsweep calls. A more exhaustive analysis of the full deployment, including seasonal and diel trends, is forthcoming.

Average duration of each call was 1.2 ± 0.6 s and the average frequency range was 68 ± 17 Hz to 136 ± 25 Hz, with an average frequency sweep of 68 ± 20 Hz (Fig. 2). This is consistent with descriptions of right whale upsweep calls from other populations of northern and southern right whales (Argentina: Clark *et al.* 1982, North Pacific: McDonald and Moore 2002, North Atlantic: Mussoline *et al.* 2012).

Temporal patterns of occurrence of upsweep calls also support their attribution to southern right whales. Calls were considered to be in bouts if they occurred within 2 min of another call. This criterion accounted for 87% of all calls, with an average of 40 ± 15 s between calls (Fig. 3). Number of calls per bout ranged from 2 to 33, with a mean of 8 ± 6 calls per bout. This varied slightly from McDonald and Moore’s (2002) findings of 10–15 calls per bout for North Pacific right whales; however, some variation in number of calls per bout can potentially be attributed to a difference in the number of whales calling at any particular time.

Some upsweep calls were classified as unidentified or humpback (*Megaptera novaeangliae*) calls. Unidentified calls were distinguished by their lower start and end frequencies (ranging from an average of 40 ± 10 to 70 ± 10 Hz) and smaller frequency sweeps (spanning an average of 29 ± 7 Hz) than have been documented for right whale calls (Mussoline *et al.* 2012). Humpback upsweeps generally contain higher frequencies and stronger harmonics than right whale upsweeps, and consistently occur in sequences with intercall intervals less than 10 s (McDonald and

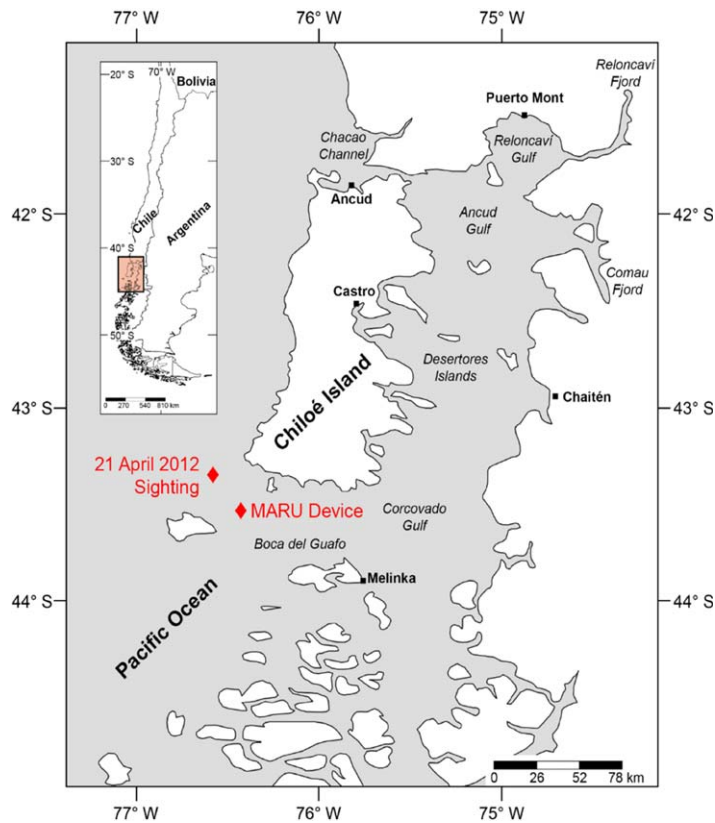


Figure 1. Location of MARU recorder near the southwestern tip of Isla de Chiloe in southern Chile (43.53°S, 74.44°W). Also shown is the location of a southern right whale sighting on 21 April 2012 (see text).

Moore 2002, Mellinger *et al.* 2004, Munger *et al.* 2008, Mussoline *et al.* 2012). However, to be certain that we were not confusing right whale and humpback whale calls, we did not include in our analysis any sections of recordings that contained higher frequency calls attributed to humpback whales.

Attribution of upsweep calls to eastern South Pacific southern right whales is further supported by the simultaneous occurrence of upsweep calls and a visual sighting near the recording device on 21 April 2012. A right whale was observed by Chilean NGO Centro de Conservacion Cetacea on an aerial survey on a Chilean Navy aircraft (43.32°S, 74.63°W), near the southwestern corner of Isla de Chiloe (Fig. 1), about 28 km from where the hydrophone was located. Upsweep calls characteristic of right whales were recorded on 21 April 2012 as well as 27 other days in April, as shown from initial subsampling of data (not yet all included in this analysis).

Upsweep calls are the most common call in the southern right whale repertoire and are thought to serve as contact calls, as they are the only call type known to be made by males, females, and calves (Clark 1982, 1983). Clark (1983) recorded more upsweep calls while groups of whales were traveling rather than resting, and even

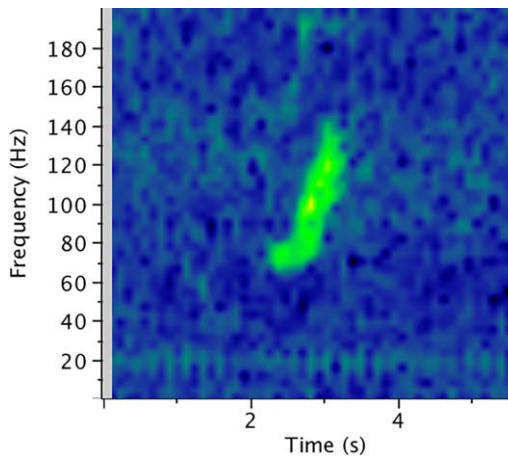


Figure 2. Spectrogram of an eastern South Pacific southern right whale upsweep call. Spectrogram parameters included a 2,048 sample DFT, 450 sample window, and 50% overlap. Spectrogram for above click has 450 sample window.

more calls while single whales were traveling, supporting Clark's (1982) idea that they function as long-distance communication calls. Due to their intensity and frequency modulation, upsweep calls are optimally suited to contrast with ambient noise conditions for increased range of detectability. It has also been proposed that these frequency upsweeps could degrade in a predictable manner with range, allowing an estimation of distance from the caller by the listener (Clark 1983).

The breeding season of southern right whales generally occurs from June to October (Best 1994). In Chile, most sightings recorded from 1964 to 2011 also occurred between June and October (approximately 88%, Galletti Vernazzani *et al.* 2014). However, two records occurred in April, one on 17 April 2009 near the same location of the April 2012 sighting reported here (south of Chiloe, $43^{\circ}28'S$, $74^{\circ}17'W$; Galletti Vernazzani *et al.* 2014). Furthermore, additional sightings have been recently documented from around Isla de Chiloe on 25 February 2014 ($42^{\circ}18'S$ – $74^{\circ}16'W$), on 12 March 2016 ($43^{\circ}29'S$ – $74^{\circ}11'W$) (BGV, personal observation) and on 9 February 2017 ($41^{\circ}52'S$ – $74^{\circ}04'W$) of an entangled individual that died

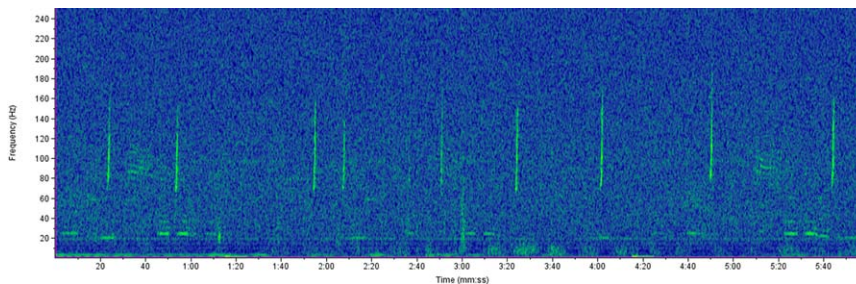


Figure 3. Spectrogram of a portion of a bout of eastern South Pacific southern right whale upsweep calls. Spectrogram parameters included a 2,048 sample DFT, 1,400 sample window, and 50% overlap. Blue whale calls are occurring in the background.

afterward (Galletti Vernazzani *et al.* 2017). This recent information provides increasing evidence that southern right whales are using waters off Isla de Chiloe not only during the breeding season but also likely during the feeding season for possible foraging activities. The waters of southern Chile are very productive, and the area off Isla de Chiloe is an important feeding habitat for blue whales from late January to early May (Galletti Vernazzani *et al.* 2012).

An acoustic presence of eastern South Pacific southern right whales has significant implications for conservation of this critically endangered subpopulation. Visual surveys depend on weather conditions and can be costly, requiring vessels and manpower. In contrast, passive acoustic monitoring can be used to collect large amounts of data with minimal labor, as recorders can be left for months at a time. Thus, this method lends itself well for working with subpopulations encountered as infrequently as eastern South Pacific southern right whales. Future work can be modeled after studies of critically endangered North Pacific right whales in the Bering Sea (Wiggins *et al.* 2017, Wade *et al.* 2006, Munger *et al.* 2008, Marques *et al.* 2011), in which acoustic data have been used to learn about habitat usage, seasonal and diel call patterns, and population density. Our data showing widespread calling behavior of eastern South Pacific southern right whales will contribute to the ongoing IWC acoustic monitoring project on this population (IWC 2016b), and provide promise for the use of passive acoustic monitoring in the conservation of this fragile subpopulation.

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