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# Discovering sounds in Patagonia, characterizing sei whale (*Balaenoptera borealis*) downsweeps in the south-eastern Pacific Ocean.

**Running title: Sei whale vocalizations in Chile**

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12 Abstract

13 Sei whales (*Balaenoptera borealis*) is the least known whale species. Information on sei
14 whale´s vocalizations in the south-eastern Pacific Ocean and its regional variability are
15 even more scarce than that from other ocean areas. This research presents the first
16 characterization of sei whale sounds recorded in Chile during austral autumn of 2016
17 and 2017. A total of 41 calls have been attributed to sei whale's downsweeps. In 2016,
18 calls ranged from an average maximum frequency of 105.3 Hz down to an average
19 minimum 35.6 Hz over 1.6 s with a peak frequency of 65.4 Hz. During 2017, calls ranged
20 from an average maximum frequency of 93.3 Hz down to 42.2 Hz (over 1.6 s) with a peak
21 frequency of 68.3 Hz. The absolute minimum frequency recorded was 30 Hz and the
22 absolute maximum frequency was 129.4 Hz. Calls generally occurred in pairs, but triplets
23 or singles were also registered. These low frequency sounds share characteristics with
24 recordings of sei whales near the Hawaii Islands, but with differences in the maximum
25 frequencies and duration. These calls distinctly differ from sounds previously described
26 for sei whales in the Southern Ocean and are the first documented sei whale calls in the
27 South-eastern Pacific.

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## 1. Introduction

The sei whale (*Balaenoptera borealis*; Lesson 1828) is the third largest rorqual in the Balaenopteridae family, after the blue whale (*B. musculus*) and the fin whale (*B. physalus*). It is also one of the least unknown whales. The sei whale is a cosmopolitan species found in temperate oceans and subpolar areas (Mackintosh, 1942; Gambell, 1968; Rice, 1998; Horwood, 2002; Reeves *et al*., 2002; Jefferson *et al*., 2008). It prefers deep offshore waters with temperatures below 20°C and avoids semi enclosed bodies of water (Omura and Nemoto, 1955; Gambell, 1985). North Atlantic, North Pacific and Antarctic populations are separated and probably subdivided into geographic stocks (Horwood, 1987); genetics studies, however, have not clarified the separation between populations by hemisphere (Kanda *et al*., 2006). In terms of functional populations (based on different biological characteristics and migration patterns) for management purposes, there are eight populations in the North Atlantic, two or three in the North Pacific and at least six populations in the Southern Hemisphere (Donovan, 1991). In the Southern Hemisphere, sei whale's sightings were recorded from the Subtropical Convergence to the Antarctic Convergence, but the only observation record of adult animals come from the austral summer in south of the Antarctic Convergence (Gambell, 1974; Lockyer, 1977). In general, sei whales migrate seasonally from the reproduction areas in low latitudes in winter to their feedings areas in high latitudes in summer (Reeves *et al*., 1998). Reproduction areas are poorly known (Perry *et al*., 1999) and feeding areas show great variability between years (Jonsgård and Darling, 1977). Population`s boundaries and migratory patterns are also poorly understood. In austral summer there are concentrations of sei whales between 40 and 50 °S; older, larger

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individuals tend to travel to northern Antarctic, while smaller, younger individuals tend to stay at lower latitudes (Rice, 1998; Acevedo *et al*., 2017).

Because of their smaller size, speed and elusiveness, sei whales were comparatively less important as target species for hunting until the early 1960s. After the decline of the most profitable species such as blue whales, fin whales and humpback whales, the whaling industry increased the hunting pressure on sei whales (Gambell, 1985). Thirty years ago, between the Antarctic and the North Pacific, many whales were taken from the coasts of Perú and Chile (Tonnessen and Johnsen, 1982). Most captures were carried out by the pelagic fishery in the Antarctic, which hunted more than 110,000 sei whales between 1960 and 1970 (Horwood, 2002). The International Whaling Commission estimated the size of the sei whale populations in the South Hemisphere to be 37,000 individuals after the cessation of the commercial captures in 1984, while this number was estimated 191,000 in the 1940s (Gambell, 1985). Between 1929 and 1983 sei whales captures represented 17.3% of the total catch of whales in Chile. It was the third most hunted species with approximately 1,664 individuals captured principally on the north and central coasts (Aguayo-Lobo, 1974; Aguayo-Lobo *et al*., 1998), although these include an unknown number of Bryde whales (Valdivia *et al*., 1981; Gallardo *et al*., 1983; Aguayo-Lobo *et al*., 1998). After the whale-hunting moratorium imposed by the International Whaling Commission in 1980, several research projects focused on the populations and recovery status of the large whales such as right whales, humpback whales, blue whale and fin whales (Reeves *et al*., 2002). Since 1976, sei whales have been listed as endangered (IUCN 2018). Today, sei whales are the least studied of the large whales and there has been a lack of data since the end of the commercial hunting (Prieto *et al*., 2011).

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In Chile, there are opportunistic sightings and stranding's of sei whales from Antofagasta (in the north) to the Magellan Straight (in the south), including the islands of Juan Fernandez (Gallardo *et al*., 1983; Schlatter, 1987; Aguayo-Lobo *et al*., 1998; Findlay *et al*., 1998; Pastene and Shimada, 1999; Guzmán, 2006; Acevedo *et al*., 2017). Many sightings in Central Chile and Northern Patagonia (33°-48°S) have been reported since 1966, when 286 whales were sighted in March of 1966 (between 43° and 45°S); 114 in October of the same year (between 46° and 48°S), all between 30 and 190 km off the shore (Aguayo-Lobo, 1974). In March 1968 Japanese whalers reported the sightings of several hundreds of sei whales between 46° 40' and 48°S, and peak concentration 30 km off the coast of the Tres Montes Peninsula at the northern limit of The Penas Gulf (Pastene and Schimada, 1999). In 2015, at Penas Gulf the largest recorded baleen whale mass mortality event was reported with 363 registered carcasses of baleen whales (Häussermann *et al*., 2017). Genetic and morphological analysis confirmed that the examined animals were sei whales (Häussermann *et al*., 2017). These historical sightings support the hypothesis of Guzman (2006) about the presence of sei whales feeding in Chilean Patagonia between Chiloe island and the Magellan Strait (Acevedo *et al*., 2017).

Since the sei whale is endangered and poorly known, population studies are crucial as a support for its conservation. Autonomous passive acoustic monitoring devices facilitate the monitoring of cetaceans through emitted vocalizations with the aim to characterize and understand their acoustic behavior and determine their distribution patterns in time and space (Clark and Ellison, 1989; Richardson *et al*., 1995).

Acoustic signals produced by sei whales are poorly known (Prieto *et al*., 2011), with vocalizations described from six different geographic areas: New England (USA), Florida

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(USA), Nova Scotia (Canada), Hawaii (USA), Antarctic Peninsula and Azores (Portugal) (Thompson *et al*., 1979; McDonald *et al*., 2005; Rankin and Barlow, 2007; Baumgartner *et al*., 2008; Calderan *et al*., 2014; Romagosa *et al*., 2015). There is no record of sei whale vocalizations from the South-eastern Pacific Ocean. The aim of this work is to describe sei whale vocalizations based on opportunistic recordings at the Penas Gulf, Chile, to establish a soundscape baseline for the South-eastern Pacific Ocean.

## 2. Methods

After the mass mortality event in 2015, two cruises to the Tres Montes Gulf (46.2-48.0º S, 74.0-75.4º W) aboard the motor sailing vessel Saoirse (fig 01) were carried out in May 2016 and May 2017 during which biological, oceanographic and acoustics studies were carried out.

Two different hydrophones were used for the recordings: a HF 200 kHz hydrophone (sensitivity -171 dBV re 1 µPa with pre-amp; frequency response 10–20000Hz from Ocean Sonic, Canada); and a ST 202 STD hydrophone (sensitivity -205 dBV re 1 µPa; frequency response 60000Hz ±3 dB from Ocean Instruments, New Zealand). Opportunistic and planned recordings were carried out depending on the weather conditions and the vessel location. The hydrophones were deployed for 2 to 5 days from the stationary vessel during the day or night at a depth of 5 and 10 meters. The supporting vessel was anchored in shallow waters (less than 40 meters) on rocky bottom. The hydrophones recorded for different time intervals depending on the weather conditions.

Audio data were analyzed visually using Audacity 2.2.2 (Audacity® software © 1999-2018 Audacity Team). Low and high frequency (Hz), frequency range (Hz), peak

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121 frequencies (the frequency at which the maximum power occurred within a call) and
122 duration (s) for all calls found and attributed to sei whales were measured using Raven
123 Pro 1.5 (Cornell University, Ithaca, NY).

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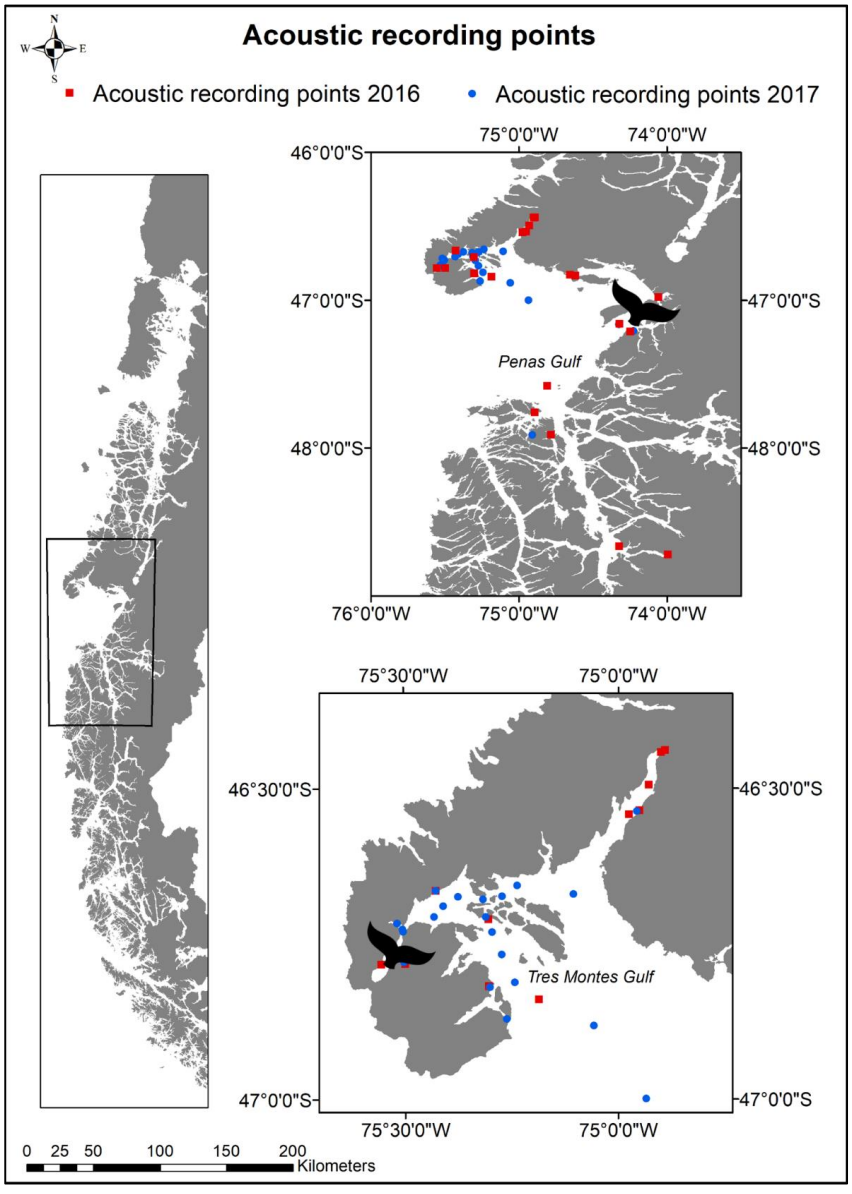
124 Figure 01. Study areas including sighting and recording locations. The whale tail indicates

125 the area where sei whale vocalizations were identified.

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## 3. Results

Sound was recorded during 16 days in 2016 and during 19 days in 2017 for a total of 363 hours, 136 hours in 2016 and 227 hours in 2017. Sei whale calls were found only for 3 days, on 7 May 2016 and 10-11 May 2017, at two locations (one in 2016 and other in 2017) (fig 01). Most activity was recorded during the night until early dawn (20:00 until 08:00 h) (n=36).

Only high-quality (i.e., high signal to noise ratio) calls were measured. All vocalizations reported in this study were recorded with the ST202STD hydrophone; all were identified as downsweep calls (fig 02). We identified a total of 41 calls; 5 calls in 2016 and 36 in 2017. In 2016, calls ranged from an average maximum frequency of 105.3 Hz (SD=18.3 Hz) down to an average minimum frequency of 35.6 Hz (SD=4.6 Hz) over 1.6 s (SD=0.1 s) with a peak frequency of 65.4 Hz (SD=14.1 Hz) (Table 1). In 2017, calls ranged from an average maximum frequency of 93.3 Hz (SD=10.9 Hz) down to 42.2 Hz (SD=5.6 Hz) over 1.6 s (SD=0.3 s) with a peak frequency of 68.3 Hz (SD=14.2 Hz). The minimum frequency was 30 Hz and the maximum frequency was 129.4 Hz. Calls occurred in pairs (n=12), singles (n=5) or triplets (n=4) (Table 1).

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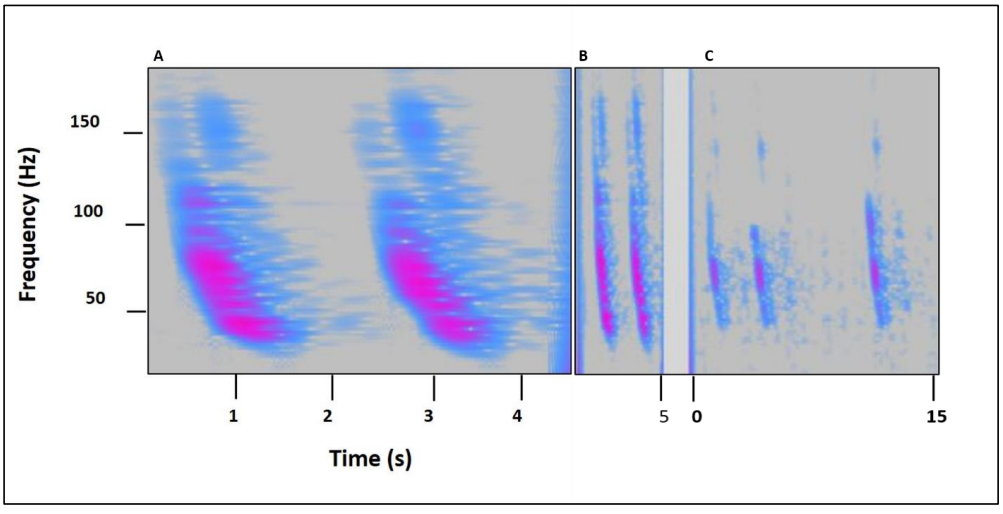
143 Figure 02. Spectrogram of sei whale vocalization recorded with the hydrophone (32768
144 FFT, Hamming window). A. five seconds spectrogram zoomed in of a pair of calls. B. five
145 seconds spectrogram of a pair of call. C. A pair and a single call of sei whale call within
146 15 seconds.

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149 Table 1. Comparison of the frequency and timing of recorded calls in the present study
150 with studies in other areas. Values are mean value ± standard deviation. ND = no data
151 (the study did not include that information)

| Source | Location | Year/nº vocalizations | High Frequency (Hz) | Low frequency (Hz) | Peak frequency (Hz) | Duration (s) |
|---|---|---|---|---|---|---|
| Present study | Chile, South-eastern Pacific | 2016/5 | 105.3±18.3 | 35.6±4.6 | 65.4±14.1 | 1.6±0.1 |
| | | 2017/36 | 93.3±10.9 | 42.2±5.6 | 68.3±14.2 | 1.6±0.3 |
| Romagosa et al. (2015) | Azores, Northern Atlantic Ocean | 2012/53 | 99.8±13.6 | 37.4±8.4 | 52.0±11.4 | 1.21±0.33 |
| Calderan et al. (2014) | Auckland Islands, Southern Atlantic Ocean | 2013/4 | 78.0±2.0 | 69.0±08 | 73.8±0.5 | 1.1±0.0 |
| | | 2013/4 | 83.3±4.1 | 53.8±4.9 | 78.3±3.1 | 1.2±0.0 |
| | | 2013/30 | 66.3±10.7 | 36.6±2.1 | 45.8±11.0 | 1.2±0.3 |
| Johnson et al. (2010) | Florida, Northern Atlantic Ocean | 2010/ND | 100 | 40 | ND | ND |
| Gedamke and Robinson (2010) | East Antarctica, Southern Ocean | 2006/ND | 570 | 170 | ND | ND |
| Baumgartner et al. (2008) | New England, North western Atlantic Ocean | 2006-2007/108 | 82.3 ±15.2 | 34.0±6.2 | ND | 1.38±0.37 |
| Rankin and Barlow (2007) | Hawaii, Pacific Ocean | 2002/2 | 100.3±11.1 | 44.6±2.9 | ND | 1.2±0.007 |
| | | 2002/105 | 39.4±3.4 | 21±2.4 | | 1.2±0.11 |
| McDonald (2005) | West Antarctica, Southern Ocean | 2003/50 | 433 | 192 | ND | 0.45±0.3 |
| Knowlton et al. (1991) | Canada, Northern Atlantic Ocean | 1986-1989/ND | 3500 | 1500 | ND | 0.5-0.8 |
| Thompson (1979) | Canada, Northern Atlantic Ocean | ND | 3000 | ND | ND | 0.7 |

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## 4. Discussion

Given that recordings from this project were opportunistic, we cannot prove the origin of the calls. However, we can confirm with reasonable certainty that vocalizations recorded off The Penas Gulf were produced by sei whales, due to the reported presence of this species during the expedition and the lack of sightings of other baleen whales. In addition, sei whale vocalizations described here show very similar characteristics to those described off Azores Islands by Romagosa *et al.* (2015), off Florida by Johnson *et al.* (2010), off New England by Baumgartner *et al*. (2008) and off Hawaii by Rankin and Barlow (2007). In these areas, sei whale vocalizations are characterized by low frequency downsweeps. However, sweeps recorded off Nova Scotia by Thompson (1979) and Knowlton et al. (1991) or in Antarctic waters by McDonald (2005), Gedamke and Robinson (2010) are very different from our recording and are characterize by higher frequencies.

Rankin and Barlow (2007) describe two ranges for the low frequency downsweeps, 100-44 Hz and 39-21 Hz with durations of 1.0 s and 1.3 s, respectively. In the present study, the minimum frequency was 30 Hz, being the average calls in the superior range defined by those authors. The range of frequencies described here are similar to what Baumgartner *et al*. (2008), Newhall *et al*. (2012), Johnson *et al.* (2010) and Romagosa *et al*. (2015) reported, although the maximum frequency reported in the present study is higher. The higher frequency calls recorded in the North Pacific (Hawaii) and in the present study are similar, but our results showed higher frequencies in the top range (maximum off 111.4 Hz versus 129.4 Hz, respectively) and a longer duration (maximum 1.27 s versus 2.27 s, respectively). The similarities could be expected due to the

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176 possibility of there being a stereotypical call used in feeding grounds, as suggested by
177 Romagosa *et al*. (2015). However, sei whales recorded off southern Chile have shown a
178 different call with higher frequencies and longer durations than those detected from
179 North Atlantic or North Pacific waters.

180 In the sub-Antarctic Auckland Islands, a series of four calls is predominant (Calderan *et*
181 *al.*, 2014), but the calls recorded at Penas Gulf occurred principally in pairs, although
182 single calls and triplets were also detected. There are not record off series of four calls
183 in this area such in North Atlantic or Pacific waters (Baumgartner *et al*., 2008, Newhall
184 *et al*., 2012, Romagosa *et al*., 2015).

185 Sei whale calls from Antarctic waters are characterized by broadband, tonal, frequency
186 modulated vocalizations between 100 and 600 Hz with durations between 1 and 3 s
187 (McDonald 2005, Gedamke and Robinson, 2010). These calls do not present similarities
188 with the calls recorded here. This may be due a geographic separation of the
189 populations, suggesting that different sei whale populations produce different
190 stereotypic calls. The structure of the calls of sei whales is more variable between whales
191 than within an individual whale (Baumgartner *et al.*, 2008). This suggests that sei whales
192 present in Antarctic waters do not transit through southern Chile in their migration to
193 the breeding grounds in lower latitudes. Thus, the sei whales found in Chile might
194 represent a different population. Visual observations, tagging efforts and genetic studies
195 are needed to verify this hypothesis.

196 In the present study, most acoustic activity was recorded during the night, while
197 Baumgartner and Fratantoni (2008), Newhall *et al.* (2012) and Romagosa *et al*. (2015)
198 recorded calls mostly during the day. These darkness patterns coincide with results from

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199 humpback whale's songs reported from Chile (Español-Jiménez and van der Schaar,
200 2018). However, low frequency sei whale downsweeps may have a different function
201 from the stereotyped humpback vocalizations considered as songs (Edds-Walton 1997).
202 Though the behavior of sei whales is poorly studied, most studies on this species state
203 that sei whales prefer offshore waters, but these new records and sightings along the
204 coast of Penas and Tres Montes Gulf (Aguayo-Lobo, 1974; Pastene and Schimada 1999;
205 Häussermann *et al.* 2017), demonstrated a wide habitat range, with the whales probably
206 following productive feeding areas. If this is true, it is reasonable to assume that the calls
207 of sei whale's calls are influenced by the feeding conditions (as proposed by
208 Baumgartner and Fratantoni (2008) and have communicative functions, e.g.
209 cooperatively searching for prey as suggested Newhall *et al*. (2012). Baumgartner and
210 Fratantoni (2008) hypothesize that calling rates are reduced at night while the whales
211 are feeding, but increase with social activity during the day when copepods are either
212 more difficult or less efficient to capture at depth. Our data could not support this
213 hypothesis since calls were recorded at night and it was not possible to observe what
214 activities the whales were engaged in. Other factor could be important in the discussion
215 about the acoustic behavior is the background noise, which masking biological
216 important signals and impede the communications between individuals (Clark *et al.,*
217 2009).

218 This new description of sei whale calls add knowledge to the vocalizations and
219 distribution of an endangered species (IUCN, 2018) red-listed under criteria A-1. It is also
220 listed in Appendix I ("Endangered migratory species") and II ("Migratory species with
221 unfavorable conservation status which require international agreements for their
222 conservation and management") in the Convention on the Conservation of Migratory



Species of Wild Animals (Bonn Convention 1979). Satellite tracking of the Chilean sei whale population, individual photo identification, distribution and characteristics of the prey species, behavioral, genetic and oceanographic studies are necessary to test some hypotheses and improve our understanding of this species.

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241 References

242 Acevedo, C., Aguayo-Lobo, A., González, A., Haro, D., Olave, C., Quezada, F., Martínez,
243 F., Garthe, S., and Cáceres, B.: Occurrence of sei whales (*Balaenoptera borealis*) in the
244 Magellan Strait from 2004-2015, Chile, Aquat. Mamm., 43 (1), 63, 2017.

245 Aguayo-Lobo, A.: Baleen whales of continental Chile, Pp: 209 – 217. William E. Schevill,
246 Editor. The Whale Problem: A Status Report. Harvard University Press, 419 pp, 1974.

247 Aguayo-Lobo, A., Torres, D., and Acevedo J.: Los mamíferos marinos de Chile: I. Cetacea,
248 Serie Científica INACH, 48, 19–159, 1998.

249 Baumgartner, M.F., and Fratantoni, D.M.: Diel periodicity in both sei whale vocalization
250 rates and the vertical migration of their copepod prey observed from ocean gliders,
251 Limnol. Oceanogr., 53, 2197–2209, 2008.

252 Baumgartner, M.F., Van Parijs, S.M., Wenzel, F.W., Tremblay, C.J., Carter Esch, H., and
253 Warde, A.M.: Low frequency vocalizations attributed to sei whales (*Balaenoptera*
254 *borealis*) J. Acoust. Soc. Am., 124 (2), 1339-1349, 2008.

255 Calderan, S., Miller, B., Collins, K., Ensor, P., Double, M., Leaper, R., and Barlow, J.: Low-
256 frequency vocalizations of sei whales (*Balaenoptera borealis*) in the Southern Ocean, J.
257 Acoust. Soc. Am., 136 (6), EL418-EL423, 2014.

258 Clark, C.W., and Ellison, W.T.: Numbers and distributions of bowhead whales, *Balaena*
259 *mysticetus*, based on the 1986 acoustic study off Pt Barrow Alaska, Report of the
260 International Whaling Commission, 39, 297-303, 1989.

261 Clark, C.W., Ellison, W.T., Southall, B.L., Hatch, L., Van Parijs, S.M., Frankel, A., and
262 Ponirakis, D.: Acoustic masking in marine ecosystems: Intuitions, analysis, and
263 implication, Mar. Ecol. Prog. Ser., *395*, 201-222, 2009.

264 Donovan, G.P.: A review of IWC stock boundaries. International Whaling Commission,
265 Special Issue, 13, 39-68, 1991.

266 Edds-Walton, P.L.: Acoustic communication signals of mysticete whales, Bioacoustics 8,
267 47–60, 1997.

268 Español-Jiménez, S., and van der Schaar, M.: First record of humpback whale songs in
269 Southern Chile: Analysis of seasonal and diel variation, Mar. Mam. Sci., 2018.

270 Findlay, K., Pitman, R., Tsurui, T., Sakai, K., Ensor, P., Iwakami, H., Ljungblad, D., Shimada,
271 H., Thiele, D., Van Waerebeek, K., Hucke-Gaete, R., Sanino-Vattier, G.P. :1997/1998 IWC-
272 Southern Ocean whale and ecosystem research (IWC/SOWER) blue whale cruise, Chile,
273 Report presented to the International Whaling Commission, Muskat, Oman, 1998.

274 Gallardo, V.A., Arcos, D., Salamanca, M., and Pastene, L.A.: On the occurrence of Bryde's
275 whale (*Balaenoptera edeni* Anderson 1878) in an upwelling area off Central Chile, Report
276 of the International Whaling Commission, 33, 481-488, 1983.

277 Gambell, R.: Seasonal cycles and reproduction in sei whales of the Southern
278 Hemisphere, Discovery Reports, 35, 31-134, 1968.

279 Gambell, R.: A review of population assessments of Antarctic sei whales, Report of the
280 International Whaling Commission, Special Issue 1, 44-49, 1974.

281 Gambell, R.: Sei whale, *Balaenopera borealis*, Lesson 1828, Pp: 155 – 170. In: Sam H.
282 Ridgway and Richard Harrison Editors. Handbook of Marine Mammals. Vol 3. The
283 Sirenian and Baleen whales. Academic Press, London, 369 pp., 1985.

284 Gedamke, J., and Robinson, S.M.: Acoustic survey for marine mammal occurrence and
285 distribution off East Antarctica (30–80_E) in January-February 2006, Deep Sea Res., II 57,
286 968–981, 2010.

287 Guzmán, A.: Avistamientos de ballena azul *Balaenoptera musculus* (Linnaeus, 1758) y sei
288 *B. borealis* Lesson, 1828 en la costa nor-occidental de la isla de Chiloé, Chile, Boletín del
289 Museo Nacional de Historia Natural, Chile, 55, 51-60, 2006.

290 Häussermann, V. Gutstein, C.S., Bedington, M., Cassis, D., Olavarria, C., Dale, A.C.,
291 Valenzuela-Toro, A.M., Perez-Alvarez, M.J., Sepúlveda, H.H., McConnell, K.M., Horwitz,
292 F.E., and Försterra, G.: Largest baleen whale mass mortality during strong El Niño event
293 is likely related to harmful toxic algal bloom, PeerJ, 5, e3123, 2017.

294 Horwood, J.W.: The sei whale: Population biology, ecology and management, London:
295 Croom Helm, 1987.

296 Horwood, J.W.: Sei whale *Balaenoptera borealis*, In W. F. Perrin, B. Würsig, and J. G. M.
297 Pp. 1069-1070. Thewissen (Eds.), Encyclopedia of marine mammals. San Diego:
298 Academic Press, 1352 pp., 2002.

299 IUCN 2018. The IUCN Red List of Threatened Species. Version 2018-1.

300 Jefferson, T.A., Webber, M.A., and Pitman, R.L. (Eds.).: Marine mammals of the world: A
301 comprehensive guide to their identification, San Diego: Academic Press., 616 pp., 2008.

302 Johnson, S. C. Johnson, S.C., Širović, A., Buccowich, J.S., Debich, A.J., Roche, L.K., Thayre,
303 B., Wiggins, S.M., Hildebrand, J.A., Hodge, L.E.W., and Read, A.J.: Passive acoustic
304 monitoring for marine mammals in the Jacksonville Range Complex, Marine Physical
305 Laboratory Technical Memorandum 548, Scripps Institution of Oceanography,
306 University of California San Diego, La Jolla, CA. 2010.

307 Jonsgård, Å., and Darling, K.: On the biology of the eastern North Atlantic sei whale,
308 *Balaenoptera borealis* Lesson, Reports of the International Whaling Commission, 1, 124–
309 129. Special issue, 1977.

310 Kanda, N., Goto, M. and Pastene, L.A.: Genetic characteristics of western North Pacific
311 sei whales, *Balaenoptera borealis*, as revealed by microsatellites, Marine Biotechnology,
312 8, 86–93, 2006.

313 Knowlton, A., Clark, C. W. and Kraus, S. D.: Sounds recorded in the presence of sei whales
314 *Balaenoptera Borealis*, Abstract Book of The Ninth Biennial Conference on the Biology
315 of Marine Mammals., 40 pp. Chicago, Illinois, USA. [abstract only], 1991.

316 Lockyer, C.: Some possible factors affecting the age distribution of the catch of sei
317 whales in the Antarctic, Reports of the International Whaling Commission, Special Issue,
318 1, 63-70, 1977.

319 Mackintosh, N.A.: The southern stocks of whalebone whales, Discovery Reports, XXII,
320 197-300, 1942.

321 McDonald, M. A., Hildebrand, J. A., Wiggins, S. M., Thiele, D., Glasgow, D. and Moore, S.
322 E.: Sei whale sounds recorded in the Antarctic, J. Acoust. Soc. Am., 118, 3941–3945,
323 2005.



324 Newhall, A.E., Lin, Y.-T., Lynch, J.F., Baumgartner, M.F., and Gawarkiewicz, G.G.: Long
325 distance passive localization of vocalizing sei whales using an acoustic normal mode
326 approach, J. Acoust. Soc. Am., 131 (2), 1814–1825, 2012.

327 Omura, H., and Nemoto, T.: Sei whales in the adjacent waters of Japan. III. Relation
328 between movement and water temperature, Sci. Rep. Whale Res. Inst., 10, 79–87, 1955.

329 Pastene, L.A., and Shimada, H.: Report of a sighting survey in Chile's exclusive economic
330 zone with comments on sei whale distribution, Anales del Instituto de la Patagonia, Serie
331 Ciencias Naturales (Chile), 27, 51-62, 1999.

332 Perry, S.L., DeMaster, D.P. and Silber, G.K.: The great whales: history and status of six
333 species listed as endangered under the U.S. Endangered Species Act of 1973, Mar. Fish.
334 Rev., 61, 1–74, 1999.

335 Prieto, R., Janiger, D., Silva, M.A., Waring, G.T., and Gonçalves, J.M.: The forgotten
336 whale: A biblio-metric analysis and literature review of the North Atlantic sei whale
337 *Balaenoptera borealis*, Mammal Rev., 42 (3), 235-272, 2011.

338 Rankin, S., and Barlow, J.: Vocalizations of the sei whale *Balaenoptera borealis* off the
339 Hawaiian Islands, Bioacoustics, 16, 137–145, 2007.

340 Richardson, W.J., Greene, C.R.J., Malme, C.I., and Thomson, D.H. Pp: 33–58. Marine
341 mammals and noise: Measurement procedures in. Academic Press, San Diego, CA. 576
342 pp., 1995.

343 Reeves, R.R., Silber G., and Payne, P.M.: Draft recovery plan for the fin whale
344 *Balaenoptera physalus* and sei whale *Balaenoptera borealis*, prepared for the Office of
345 Protected Resources, National Marine Fisheries Service, Silver Spring, MD, 1998.

346 Reeves, R.R., Stewart, B.S., Clapham, P.J., and Powell, J.A. (Eds.).: Marine mammals of
347 the world, New York: Alfred A. Knopf/Chanticleer Press, 2002.

348 Rice, D.W.: Marine mammals of the world: Systematics and distribution, (Special
349 Publication Number 4). Lawrence, KS: The Society for Marine Mammalogy. 231 pp.,
350 1998.

351 Romagosa, M., Boisseau, O., Cucknell, A. C., Moscrop, A., and McLanaghan, R.: Source
352 level estimates for sei whale (*Balaenoptera borealis*) vocalizations off the Azores, J.
353 Acoust. Soc. Am., 138 (4), 2367-2372, 2015.

354 Schlatter, R.: Avistamientos de mamíferos marinos durante SIBEX-Fase 2, en el estrecho
355 de Bransfield y aguas adyacentes (Sightings of marine mammals during SIBEX-Phase 2,
356 in the Bransfield Strait and adjacent waters), Serie Científica INACH, 36, 167-174, 1987.

357 Thompson, T.J., Winn, H.E., and Perkins, P.J.: Mysticete sounds. Behaviour of Marine
358 Mammals, Cetaceans, edited by H. E. Winn and B. L. Olla (Plenum, New York), 3, 403–
359 431, 1979.

360 Tonnessen, J.N. and Johnsen, A.O.: The history of modern whaling, University of
361 California Press. Berkeley, California. 798 pp., 1982.

362 Valdivia, J., Ramirez, P., and Franco, F.: The exploitation of Bryde's whales in the
363 Peruvian Sea, Report of the International Whaling Commission, 31, 441-448, 1981.