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2 **Southeast Pacific blue whale song recorded off Isla Chañaral, Northern Chile**

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26 * **Text:**

27 Determining the distribution and seasonal movements of baleen whales is fundamental
28 to the development of conservation strategies and marine spatial planning, which ensure
29 their continued protection (e.g., Pompa, Ehrlich, and Ceballos (2011), Mullen, Peterson,
30 and Todd (2013), Redfern et al. (2013a, 2013b)). One method widely used to monitor
31 distribution and movements of cetaceans is Passive Acoustic Monitoring (PAM) (e.g.,
32 Mellinger, Stafford, Moore, Dziak, and Matsumoto (2007), Van Parijs et al. (2009)). The
33 loud, repetitive, low-frequency songs of baleen whales make these animals particularly
34 good candidates for acoustically determining their occurrence and in turn their
35 distribution (e.g., Stafford, Nieukirk, and Fox (1999a, 1999b), Cerchio, Jacobsen, and
36 Norris (2001), Širović, Hildebrand, Wiggins, and Thiele (2009), Buchan, Huckle-Gaete,
37 Rendell, and Stafford (2015)). Endangered (<https://www.iucn.org/>) blue whales
38 (*Balaenoptera musculus*) produce distinct song types recorded in different oceanic
39 regions with largely distinct spatial and temporal distributions (e.g., McDonald,
40 Mesnick, and Hildebrand (2006) and references therein, Stafford, Chapp, Bohnenstiel,
41 and Tolstoy (2011), Samaran et al. (2013), Buchan, Huckle-Gaete, Rendell, and Stafford
42 (2014), Buchan et al. (2015), Balcazar et al. (2017)). Song in blue whales is assumed to
43 serve some reproductive function as it is believed to be produced only by males (Oleson
44 et al., 2007a) and is produced throughout the animals' migratory range (Stafford et al.
45 (1999a), Stafford, Nieukirk, and Fox (2001)). Blue whale song remains relatively stable
46 over time, although there is some intra-annual variation in song production (Oleson,
47 Wiggins, and Hildebrand, 2007b) and a decrease in the frequency of tonal song
48 components has been reported over decadal timescales (McDonald, Hildebrand, and
49 Mesnick (2009), Gavrilov, McCauley, and Gedamke (2012)). Therefore, PAM offers a

50 very useful method to monitor the distribution of blue whale acoustic groups
51 worldwide.

52

53 The predominant song type of Southeast Pacific blue whales, known as the Southeast
54 Pacific 2, (SEP2) (Buchan et al., 2014) has been recorded in Chilean Patagonia (Buchan
55 et al., 2014, and 2015), off Juan Fernandez (Truong, Širović, Tripovich, and Rogers,
56 2016), and in the eastern Tropical Pacific (Stafford et al. (1999b), Buchan et al. (2015)).
57 This acoustic presence supports a migratory range for this group between Chilean
58 Patagonia and the eastern Tropical Pacific. This migratory range is also supported by
59 genetic sampling of the individuals within this range (Torres-Florez, Hucke Gaete, and
60 LeDuc, 2014), photo-identification (Torres-Florez et al., 2015), and studies using
61 satellite tags (Hucke-Gaete et al., 2018). Placed within the migratory corridor of south
62 Pacific blue whales, Isla Chañaral is part of the Humboldt Archipelago, a series of
63 coastal islands within the productive Humboldt Current System (Thiel et al., 2007)
64 (Figure 1). The waters surrounding Isla Chañaral, which lies 3.5 nautical miles from the
65 mainland, are a known summer feeding ground primarily for fin whales (*Balaenoptera*
66 *physalus*) (Pérez-Álvarez et al. (2006), Toro, Vilina, Capella, and Gibbons (2016),
67 Sepúlveda, Santos, and Pavez (2017), Sepúlveda, Pérez-Álvarez, and Santos-Carvallo
68 (2018)), but also blue whales, humpback whales (*Megaptera novaeangliae*), sei whales
69 (*Balaenoptera borealis*), and minke whales (*Balaenoptera bonaerensis*) have also been
70 sighted (Capella, Vilina, and Gibbons (1999), Sepúlveda pers. Comm.). This area has
71 long since been the focus of a Marine Protected Area proposal. The acoustic identity of
72 the blue whales that visit this area is unknown. In this study, we report the analysis of
73 new PAM data from Northern Chile to examine whether there is evidence of southeast
74 Pacific blue whales (SEP2 song type) in this area.

75

76 Passive acoustic data were collected within the Isla Chañaral channel, between the Isla
77 Chañaral and the mainland, at 29°00'44" S and 71°31'26" W (Figure 1) during three
78 periods of two weeks in January and February 2017 (see Patris, Malige, and Glotin
79 (2017) for details). A 'BOMBYX II', which includes a Cetacean Research C57
80 hydrophone (sensitivity of $-187 \text{ dB re } 1 \text{ V } \mu\text{Pa}^{-1}$, flat response down to 20 Hz,
81 omnidirectional at frequencies less than 10 kHz), powered by a 9V source and high-pass
82 filtered ($C=47\mu\text{F}$, frequency cut 0.15 Hz) and a commercial SONY PCM-M10 recording
83 device (gain 6, $R_{in} = 22 \text{ k}\Omega$) equipped with a 256 GB memory card, set up in a
84 specialized tube made by OSEAN SA (France) able to resist high pressure, was
85 deployed between 15 and 20 m below the surface on a mooring where the maximum
86 water column depth was 70 m. The 'BOMBYX II' was deployed by the University of
87 Toulon and CNRS (DYNI team, LIS).

88

89 Recording was done at a sample rate of 48 kHz so as to record a vast diversity of
90 cetaceans, ranging from large whales to dolphins, and at 16-bits, allowing for high
91 sensitivity without saturating the memory¹. No low-pass filter (such as an anti-aliasing
92 filter) was used for this recording, since it was not considered necessary for our purpose.
93 Acoustic data were recorded between the 16 January and the 27 February 2017. No data
94 were recorded during the 30 and 31 January and during the night between the 13 and 14
95 February because of instrument redeployment.

96

97 The SEP2 song is made up of a four-unit phrase (A, B, C, D, see Figure 2) lasting 60 s
98 that is repeated every two minutes, in long series lasting for hours. All units are long
99 and stable pulsed sounds; thus their power spectra show a set of discrete frequencies

100 (Patris, Malige, Glotin, Asch, and Buchan, 2019). The energy of the spectra is generally
101 concentrated around the 24 Hz peak. Unit A has an average duration of 22 s, unit B of
102 13 s, unit C of 5 s, and unit D an average duration of 13 s. Usually, not all units are
103 visible due to low signal to noise ratio (SNR) and units C and D contain most of the
104 signal's energy. In this study SEP2 song phrases were annotated whenever at least the 24
105 Hz-frequency peak of units C and D were visible. The SEP2 songs of Southeast Pacific
106 blue whales were annotated manually, i.e., a box was drawn around the C and D units of
107 the SEP2 song phrase, on the spectrogram visible in Raven Pro 1.5 (Bioacoustics
108 Research Program, 2012). The following parameters were used: 8,192 sample FFT, 50%
109 overlap, Hann window, with a Raven scale set to view 60 Hz over 200 s. Herein, we
110 refer to all phrases with at least C and D units as SEP2 song phrases.

111

112 A nonsystematic double check of the data by another analyst showed that few phrases
113 (with only unit B visible) were not counted by the first analyst (missed detections).
114 Units C and D were not visible due to noise or propagation effects that mask low
115 frequencies. Furthermore, unit A and the pair C-D are sometimes confoundable (having
116 similar characteristics in duration and peak frequency). Thus, in some cases, unit A and
117 the pair C-D of the same phrase were counted as two distinct occurrences of a phrase
118 (false positive). As the second analysis was not systematic on all data but only on a
119 portion of it (one third), it served to evaluate the importance of errors during the
120 counting of the first analysis. Based on this double check, we estimate the error in
121 counting SEP2 occurrences to be less than 3%.

122

123 A total of 913 h of acoustic recordings were analyzed, over which 1,981 SEP2 song
124 phrases were identified, annotated and counted by the first analyst (Figure 3). As

125 presented in these studies, we also noted the presence of two short high frequency
126 precursors before units A (around 430 Hz) and D (around 350 Hz) (see Figure 2). Two
127 faint downsweeps are identified in phrases with high signal-to-noise ratio: in unit A
128 (duration of 5 s from 150 Hz to 120 Hz) ($n = 10$) and in unit B (duration of 12 s from
129 450 Hz to 300 Hz) ($n = 10$), see Figure 2. This sound may be a byproduct of the pulsed
130 low frequency sound, a resonance artefact or sound made independently. In the latter, no
131 mechanism of sound production has been proposed to explain this superposition of two
132 sounds, called two-voiced sounds (Brown, 2008) and this has not been described for
133 other blue whale's song types (McDonald et al., 2006).

134

135 There was no noticeable trend in the total number of SEP2 song phrases counted over
136 the study period although, overall, more phrases were counted in January (64
137 phrases/day in average) compared to February (36 phrases/day) (See Figure 3). No
138 significant difference was found between day and night in the number of phrases.
139 Although this is a short period study, these results show low but consistent acoustic
140 presence of Chilean blue whales throughout the months of January and February off Isla
141 Chañaral.

142

143 From the Raven Pro selection tables, we calculated the time between SEP2 phrases, i.e.,
144 the inter-phrase interval (IPI), (Fig. 4). The peaks at 2 and 4 min are characteristic of
145 SEP2 individual song (Buchan, Rendell, and Hucke-Gaete, 2010) and suggest that
146 phrases could be produced by single singers rather than multiple overlapping singers.
147 There is only one instance of song phrase overlap on January 28, 2017, reflected by
148 shorter IPIs of 50-70s, which might suggest the presence of two singers. This is
149 consistent with limited opportunistic sighting observations: A single blue whale

150 performing circular dives and fluking, consistent with foraging behavior (Buchan and
151 Quiñones, 2016), was observed by S. Buchan on February 15-17 and 23, 2017 within
152 the Chañaral Channel and to the South of Isla Chañaral; and sightings of two blue
153 whales together on January 16, 2017 (observed by J. Patris, S. Buchan, and F. Malige).

154

155 The number of phrases per day reported remains low compared to acoustic studies from
156 Chilean Patagonia, where over one thousand SEP2 phrases were automatically detected
157 per day between the months of March and May 2012-2013, which is thought to be the
158 time of maximum abundance of animals in this region (Hucke-Gaete, Osman, Moreno,
159 Findlay, and Ljungblad (2003), Buchan et al. (2015), Galletti-Vernazzani, Jackson,
160 Cabrera, Carlson, and Brownell Jr (2017)). Since there is not yet year-round data off Isla
161 Chañaral, it is impossible to compare seasonal trends in acoustic presence of Chilean
162 blue whales at both sites. However, sighting data off Isla Chañaral (Sepulveda et al.,
163 2017) and in Chilean Patagonia (Hucke-Gaete et al. (2013), Galletti-Vernazzani et al.
164 (2017)) still suggest much higher abundance in Chilean Patagonia, which is considered
165 the primary feeding ground for Chilean blue whales.

166 During visual inspection of the data set, no Antarctic blue whale song type (Ljungblad,
167 Clark, and Shimada (1998), Matsuoka, Murase, Nishiwaki, Fukuchi, and Shimada
168 (2000)) has been detected, although it has been recorded in the Chilean Patagonia
169 (Buchan, Hucke-Gaete, Stafford, and Clark, 2018) and also in low-latitude East Pacific
170 Ocean (Stafford et al., 2004). No SEP1 blue whale's song type (Cummings and
171 Thompson, 1971) has been detected in this data set. SEP1 has been recorded in Chilean
172 Patagonia, off Juan Fernandez Archipelago and in the East Tropical Pacific (Cummings
173 and Thompson (1971), Truong et al. (2016), Stafford et al. (1999b)) but is the least

174 common of the two Southeast Pacific song types (Buchan et al. (2015), Saddler et al.
175 (2017)).

176

177 This is the first report of Southeast Pacific blue whale song (or any baleen whale call) in
178 the coastal waters off Northern Chile and in the Humboldt Current System. Given the
179 high levels of productivity of this system, and considering that Southeast Pacific blue
180 whales are known to migrate between wintering grounds near Galapagos and summer
181 feeding grounds in Chilean Patagonia (Hucke-Gaete et al. (2003 and 2018), Buchan et
182 al. (2015), Torres-Florez et al. (2015), Buchan and Quinones (2016)), it would make
183 sense that some animals would take advantage of the available prey in the Humboldt
184 Current System. In particular, the dense patches of Humboldt Current krill (*Euphausia*
185 *mucronata*) known to be exploited by fin whales off Isla Chañaral (Toro et al., 2016)
186 would also offer foraging opportunities for blue whales that are on their way to or from
187 their primary feeding ground in Chilean Patagonia. The presence of southeast Pacific
188 blue whales off Isla Chañaral is further evidence of the importance of this area for the
189 conservation of endangered baleen whale populations.

190

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201 **REFERENCES**

202 Balcazar, N. E., Klinck, H., Nieu Kirk, S. L., Mellinger, D. K., Klinck, K., Dziak R. P.
203 and Rogers, T. L. (2017) Using calls as an indicator for Antarctic blue whale occurrence
204 and distribution across the southwest Pacific and Southeast Indian Oceans. *Marine*
205 *Mammal Science*,33,172–186.

206

207 Bioacoustic Research Program. (2012) Raven Pro: Interactive Sound Analysis Software
208 (version 1.5) [Computer Software]. Ithaca, NY: *The Cornell Lab of Ornithology*.
209 Available from: <http://www.birds.cornell.edu/raven>.

210

211 Brown, J. C. (2008). Mathematics of pulsed vocalizations with application to killer
212 whale biphonation, *Journal of the Acoustical Society of America* 123(5), 2875-2883.

213

214 Buchan, S.J., Rendell L.E. and Hucke-Gaete R., Preliminary recordings of blue whale
215 (*Balaenoptera musculus*) vocalizations in the Gulf of Corcovado, northern Patagonia,
216 Chile (2010), *Marine Mammal Science*, 26(2), 451–459

217

218 Buchan, S. J., Hucke-Gaete, R., Rendell, L. E. and Stafford, K. M. (2014). A new song
219 recorded from blue whales in the Corcovado Gulf, Southern Chile, and an acoustic link
220 to the Eastern Tropical Pacific. *Endangered Species Research* 23,241–252.

221

222 Buchan, S. J., Hucke-Gaete, R., Rendell, L. E. and Stafford, K. M. (2015). Seasonal
223 occurrence of Southeast Pacific blue whale songs in southern Chile and the eastern
224 tropical Pacific. *Marine Mammal Science* 31,440–458. NOTES 227

225

226 Buchan, S. J., and Quiñones, R. A. (2016). First insights into the oceanographic
227 characteristics of a blue whale feeding ground in northern Patagonia, Chile. *Marine*
228 *Ecology Progress Series* 554,183–199.

229

230 Buchan, S.J., Stafford, K., Hucke-Gaete, R., Clark, C.W., Balcazar-Cabrera, N.,
231 Gutierrez, L., Patris, J., Malige, F., Neira, S., Sepulveda, M., Santos-Carvalho, M., and
232 Olavarría, C. (2017). A review of blue and fin whale acoustically-inferred seasonal
233 movements in the eastern South Pacific, *Poster in the Society for Marine Mammalogy's*
234 *22nd Biennial Conference on the Biology of Marine Mammals*.

235

236 Buchan, S.J., Hucke-Gaete, R., Stafford, K.M., and Clark, C.W. (2018). Occasional
237 acoustic presence of Antarctic blue whales on a feeding ground in southern Chile.
238 *Marine Mammal Science* 34(1),220–228.

239

240 Capella, J., Vilina, Y., and Gibbons, J. (1999). Observación de cetáceos en la isla
241 Chañaral y nuevo registros para el área de la reserva nacional Pinguino de Humboldt,
242 norte de Chile, observación of cetaceans at Isla Chañaral and new records at the
243 Humboldt Penguin national reserve, northern Chile. *Estudios Oceanológicos* 18, 57-
244 64.

245

246 Cerchio, S., Jacobsen, J.K., and Norris, T.F. (2001). Temporal and geographical
247 variation in songs of humpback whales, *Megaptera novaeangliae* : synchronous change
248 in Hawaiian and Mexican breeding assemblages. *Animal behaviour*, 62, 313–329

249

250 Cummings, W.C., and Thompson, P.O. (1971). Underwater sounds from the blue whale,
251 *Balaenoptera musculus*. *Journal of the Acoustical Society of America* 50,1193–1198.

252

253 Eaton, J.W., Bateman, D., and Hauberg, S. (2009). GNU Octave version 3.0.1 manual:
254 a high-level interactive language for numerical computations (CreateSpace Independent
255 Publishing Platform, 2009). Available from
256 <http://www.gnu.org/software/octave/doc/interpreter>, 11ISBN 1441413006.

257

258 Galletti-Vernazzani, B., Carlson, C.A., Cabrera, E. and Brownell Jr, R.L. (2012).
259 Chilean blue whales off Isla Grande de Chiloé, 2004-2010: distribution, site-fidelity and
260 behavior. *Journal of Cetacean Research and Management* 12, 353–360.

261

262 Galletti-Vernazzani, B., Jackson, J.A., Cabrera, E., Carlson, C.A. and Brownell Jr, R.L.
263 (2017). Estimates of abundance and trend of Chilean blue whales off Isla de Chiloé,
264 Chile. *PLOS ONE* 12(1), e0168646.

265

266 Gavrilov, A. N., McCauley, R.D. and Gedamke, J. (2012). Steady inter and intra-annual
267 decrease in the vocalization frequency of Antarctic blue whales. *Journal of the*
268 *Acoustical Society of America* 131, 4476–4480.

269

270 Huckle-Gaete, R., Osman, L.P, Moreno, C.A., Findlay K.P. and Ljungblad, D.K. (2003).
271 Discovery of a blue whale feeding and nursing ground in southern Chile. *Proceedings*
272 *of the Royal Society London B (Supplement)* 271, S170–S174.

273

274 Huckle-Gaete, R. (2004). Distribución, preferencia de hábitat y dinámica espacial de la
275 ballena azul en Chile: 1997-2004 [Distribution, habitat preference and spatial dynamics
276 of the blue whale in Chile: 1997–2004]. Ph.D. thesis, Universidad Austral de Chile,
277 Valdivia, Chile.

278

279 Huckle-Gaete, R., Haro, D., Torres-Florez, J., Montecinos, Y., Viddi, F., Bedriñana-
280 Romano, L., Nery, M. and Ruiz, J. (2013). A historical feeding ground for humpback
281 whales in the eastern South Pacific revisited: The case of Northern Patagonia, Chile.
282 *Aquatic Conservation Marine and Freshwater Ecosystems*. 23. 10.1002/aqc.2343.

283

284 Huckle-Gaete, R., Bedriñana-Romano, L., Viddi, F.A., Ruiz, J.E., Torres-Florez, J.P. and
285 Zerbini, A.N. (2018). From Chilean Patagonia to Galapagos, Ecuador : novel insights on
286 blue whale migratory pathways along the Eastern South Pacific. *PeerJ* 6, e4695,

287

288 Ljungblad, D. K., Clark, C.W. and Shimada, H. (1998). A comparison of sounds
289 attributed to pygmy blue whales (*Balaenoptera musculus breviceuda*) recorded south of
290 the Madagascar Plateau and those attributed to ‘true’ blue whales (*Balaenoptera*
291 *musculus*) recorded off Antarctica. *Report of the International Whaling Commission* 48,
292 439–442.

293

294 Matsuoka, K., Murase, H., Nishiwaki, S., Fukuchi, T. and Shimada, H. 2000.
295 Development of a retrievable sonobuoy system for whale sounds recording in polar
296 region. *Paper SC/52/O7 presented to the IWC Scientific Committee*, (2000), in Adelaide,
297 Australia (unpublished).

298

299 McDonald, M. A., Mesnick, S.L. and Hildebrand, J.A. (2006). Biogeographic
300 characterisation of blue whale song worldwide: Using song to identify populations.
301 *Journal of Cetacean Research Management* 8, 55–56.

302

303 McDonald, M. A., Hildebrand, J.A. and Mesnick, S. (2009). Worldwide decline in tonal
304 frequencies of blue whale songs. *Endangered Species Research* 9, 13–21.

305

306 Mellinger, D.K., Stafford K.M., Moore S.E., Dziak R.P. and Matsumoto H. (2007) An
307 overview of fixed passive acoustic observation methods for cetaceans. *Oceanography*.
308 20(4), 36–45.

309

310 Mullen, K.A., Peterson, M.L., and Todd, S.K. (2013) Has Designating and Protecting
311 Critical Habitat Had an Impact on Endangered North Atlantic Right Whale Ship Strike
312 Mortality? *Marine Policy* 42, 293–304.

313

314 Oleson, E. M., Calambokidis, J., Burgess, W.C., McDonald, M.A., LeDuc, C.A. and
315 Hildebrand, J.A. (2007a). Behavioural context of call production by eastern North
316 Pacific blue whales. *Marine Ecology Progress Series* 330, 269–284.

317

318 Oleson, E. M., Wiggins, S.M. and Hildebrand, J.A. (2007b). Temporal separation of
319 blue whale call types on a southern California feeding ground. *Animal Behaviour* 74,
320 881–894.

321

322 Piñones, A. and Fedorov, A.V. (2016). Projected changes of Antarctic krill habitat by the
323 end of the 21st century. *Geophysical Research Letters* 43, 8580–8589.228

324

325 Patris, J., Malige, F., and Glotin, H. (2017). Construction et mise en place d’un système
326 fixe d’enregistrement à large bande pour les cétacés “bombyx 2” isla de chañaral, été
327 austral 2017. *Technical Report 2017-03, LSIS CNRS*.

328

329 Patris, J. (2019). Contribution en méthodes pour le suivi de mysticètes par acoustique
330 passive, *PhD thesis, Université de Toulon, France. Available from*
331 <http://www.theses.fr/2019TOUL0016>

332

333 Patris, J., Malige, F., Glotin, H., Asch, M. and Buchan, S. (2019). A standardized
334 method of classifying pulsed sounds and its application to pulse rate measurement of
335 blue whale southeast Pacific song units. *The Journal of the Acoustical Society of*
336 *America*. 146, 2145-2154.

337

338 Perez-Alvarez, M., Thomas, F., Uribe, F., Sepúlveda, M., Flores, M. and Moraga, R.
339 (2006). Fin Whales (*Balaenoptera physalus*) Feeding on *Euphausia mucronata* in
340 Nearshore Waters off North-Central Chile. *Aquatic Mammals*. 32, 109-113.

341

342 Pompa, S., Ehrlich, P.R., and Ceballos G. (2011). Global Distribution and Conservation
343 of Marine Mammals. *Proceedings of the National Academy of Sciences of the United*
344 *States of America* 108 (33), 13, 600–605.

345

346 Redfern, J.V., McKenna, M.F., Moore, T.J., Calambokidis, J., Deangelis, M.L., Becker,
347 E.A., Barlow, J., Forney, K.A., Fiedler, P.C., and Chivers, S.J. (2013a) Assessing the
348 Risk of Ships Striking Large Whales in Marine Spatial Planning. *Conservation Biology*
349 27 (2), 292–302.

350

351 Redfern, J.V., Hatch, L.T., Caldow, C., DeAngelis, M.L., Gedamke, J., Hastings, S.,
352 Henderson, L., McKenna, M.F., Moore, T.J., and Porter, M.B. (2013b). Assessing the
353 risk of chronic shipping noise to baleen whales off Southern California, USA.
354 *Endangered Species Research*. 32, 53–167.

355

356 Saddler, M.R., Bocconcelli, A., Hickmott, L.S., Chiang, G., Landea-Briones, R.,
357 Bahamonde, P.A., Howes, G., Segre, P.S. and Sayigh, L.S. (2017) Characterizing
358 Chilean blue whale vocalizations with DTAGs: a test of using tag accelerometers for
359 caller identification, *Journal of Experimental Biology* (220), 4119-4129

360

361 Samaran, F., Stafford, K.M., Branch, T.A., Gedamke, J., Royer, J.R., Dziak, R.P. and
362 Guinet, C. (2013). Seasonal and geographic variation of the southern blue whale
363 subspecies in the Indian Ocean. *PLoS ONE* 8(8), 1–10.

364

365 Sepúlveda, M., Santos, M. and Pavez, G. (2017). Whale-watching en la Reserva Marina
366 Isla Chañaral: Manejo y planificación para una actividad sustentable. *Primera Edición*
367 2017, ISBN: 978-956-368-225-0

368

369 Sepúlveda, M., Pérez-Álvarez, M.J., and Santos-Carvallo, M. (2018) From whaling to
370 whale watching: Identifying fin whale critical foraging habitats off the Chilean coast.
371 *Aquatic Conservation Marine and Freshwater Ecosystems* 018, 1–9.

372

373 Širović, A., Hildebrand, J. A., Wiggins, S.M. and Thiele, D. (2009). Blue and fin whale
374 acoustic presence around Antarctica during 2003 and 2004. *Marine Mammal Science*
375 25, 125–136.

376

377 Stafford, K. M., Nieukirk, S.L. and Fox, C.G. (1999a). An acoustic link between blue
378 whales in the eastern tropical Pacific and the northeast Pacific. *Marine Mammal*
379 *Science* 15, 1258–1268.

380

381 Stafford, K. M., Nieukirk, S.L. and Fox, C.G. (1999b). Low-frequency whale sounds
382 recorded on hydrophones moored in the eastern tropical Pacific. *Journal of the*
383 *Acoustical Society of America* 106, 3687–3698.

384

385 Stafford, K. M., Nieukirk, S.L. and Fox, C.G. (2001). Geographical and seasonal
386 variation of blue whale calls of the North Pacific. *Journal of Cetacean Research*
387 *Management* 3, 65–76.

388

389 Stafford, K. M., Bohnenstiehl, D. , Tolstoy, M., Chapp, E., Mellinger, D. and Moore, S.
390 (2004). Antarctic-type blue whale calls recorded at low latitudes in the Indian and
391 eastern Pacific Oceans. *Deep Sea Research Part I: Oceanographic Research Papers*.
392 51. 1337-1346. 10.1016/j.dsr.2004.05.007.

393

394 Stafford, K. M., Chapp, E., Bohnenstiel, D.R and Tolstoy M.. (2011). Seasonal detection
395 of three types of “pygmy” blue whale calls in the Indian Ocean. *Marine Mammal*
396 *Science* 27, 828–840.

397

398 Thiel, M., Macaya, E., Acuna, E., Arntz, W., Bastias, H., Brokordt, K., Camus, P.,
399 Carlos Castilla, J., Castro, L., Cortes, M., Dumont, C., Escribano, R., Fernandez, M.,
400 Gajardo, J.A., Gaymer, C., Gomez, I., Gonzalez, A.E., González, H.E, Haye, P. and
401 Vega, A. (2007). The Humboldt Current System of Northern and Central Chile.
402 *Oceanography and marine biology*. 45, 195-345

403

404 Toro, F., Vilina, Y.A., Capella, J. and Gibbons, J. (2016) Novel Coastal Feeding Area
405 for Eastern South Pacific Fin Whales (*Balaenoptera physalus*) in Mid-Latitude
406 Humboldt Current Waters off Chile, *Aquatic Mammals* 42(1), 47-55.

407

408 Torres-Florez, J.P., Hucke Gaete, R., and LeDuc, R. (2014). Blue whale population
409 structure along the eastern South Pacific Ocean: Evidence of more than one population.
410 *Molecular Ecology* 23(24), 5998–6010.

411 Torres-Florez, J.P., Olson, P.A., Bedriñana-Romano, L., Rosenbaum, H.C.R., Ruiz, J.,
412 LeDuc, R. and Hucke Gaete, R. (2015) First documented migratory destination for
413 eastern South Pacific blue whale. *Marine Mammal Science*, 31(4), 1580–1586

414

415 Truong, G., Širović, A., Tripovich, J., and Rogers, T. (2016). Seasonal patterns in
416 Chilean blue whale call detections between 2003 and 2015. SC/66b/SH/25,
417 *International Whaling Commission*.

418

419 Van Parijs, S.M., Clark, C.W., Sousa-Lima, R.S., Parks, S.E., Rankin, S., Risch, D.,and
420 Van Opzeeland, I.C. (2009). Management and research applications of real-time and
421 archival passive acoustic sensorsover varying temporal and spatial scales. *Marine*
422 *Ecology Progress Series* 395, 21–36.

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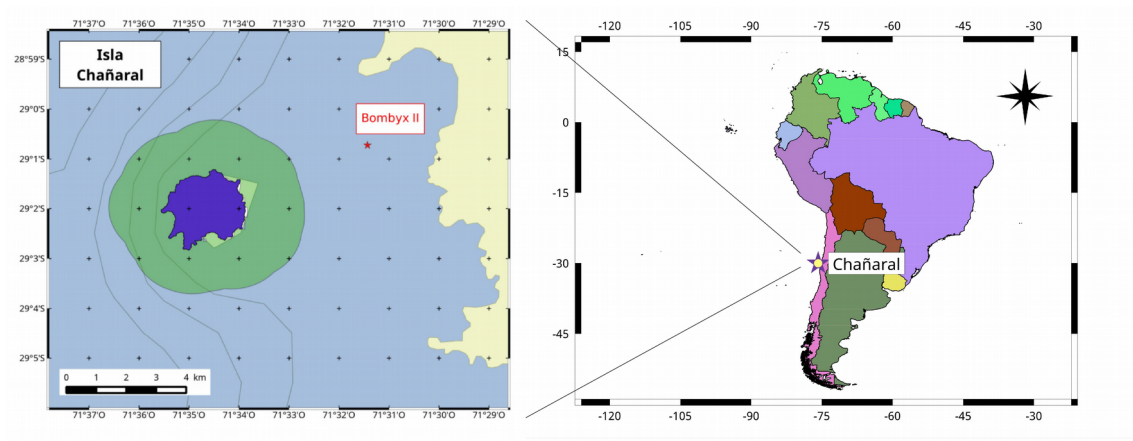
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448 **Figure captions and captions**



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450 Figure 1. Map of the deployment zone of the BOMBYX II device (left). The green zone

451 around the Island is a marine protected area (Reserva Marina Isla Chañaral). General

452 location in South America (right).

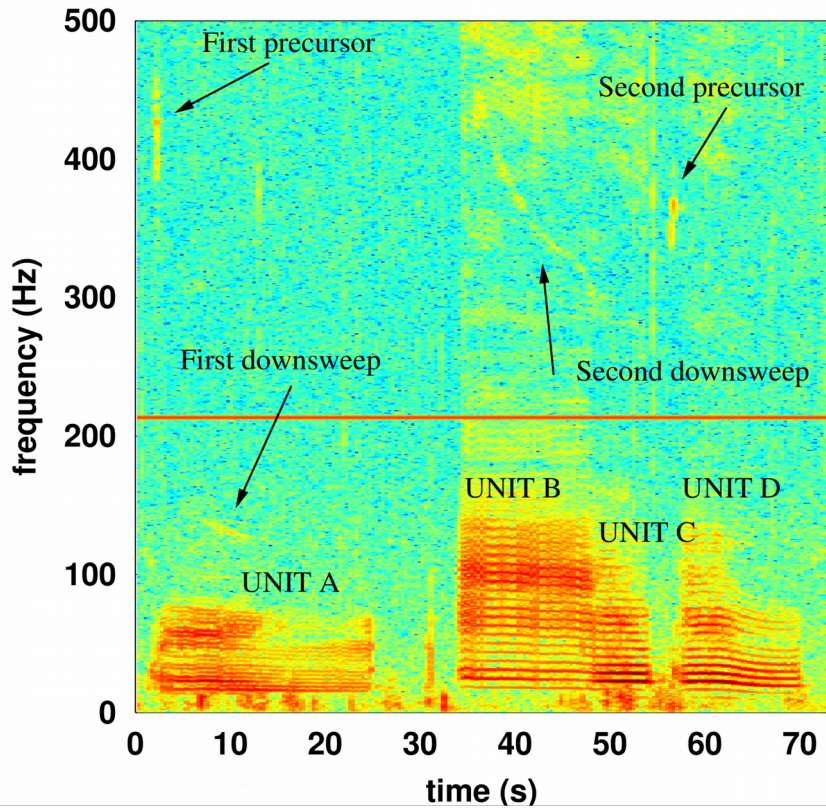
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459 Figure 2. Time frequency representation of a SEP2 song recorded off Isla Chañaral, on
460 February 2, 2017 (Fast Fourier transform, Blackman window of 65,536 points,
461 overlapping 75%) using Octave software (Eaton, Bateman, and Hauberg, 2009). The
462 line at 213 Hz is a constant electronic noise coming from the coupling between the
463 hydrophone and the recording device. Units A, B, C, D are clearly visible as well as
464 precursors and downsweeps belonging to the song.

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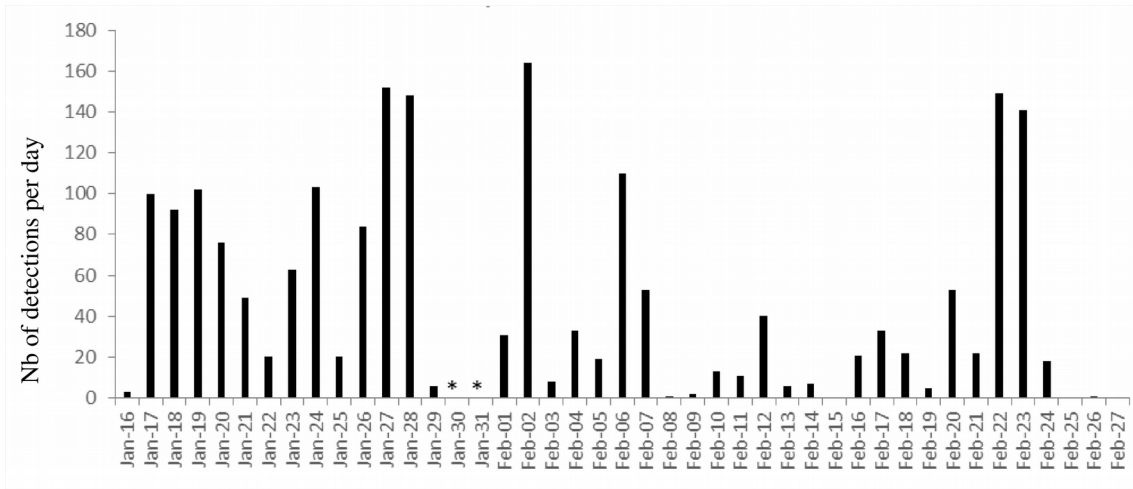
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473 Figure 3. Number of SEP2 phrases counted in the first season of recording off Isla
474 Chañaral. The device was off duty during January 30 and 31 (asterisks) and the
475 February 13 and 14.

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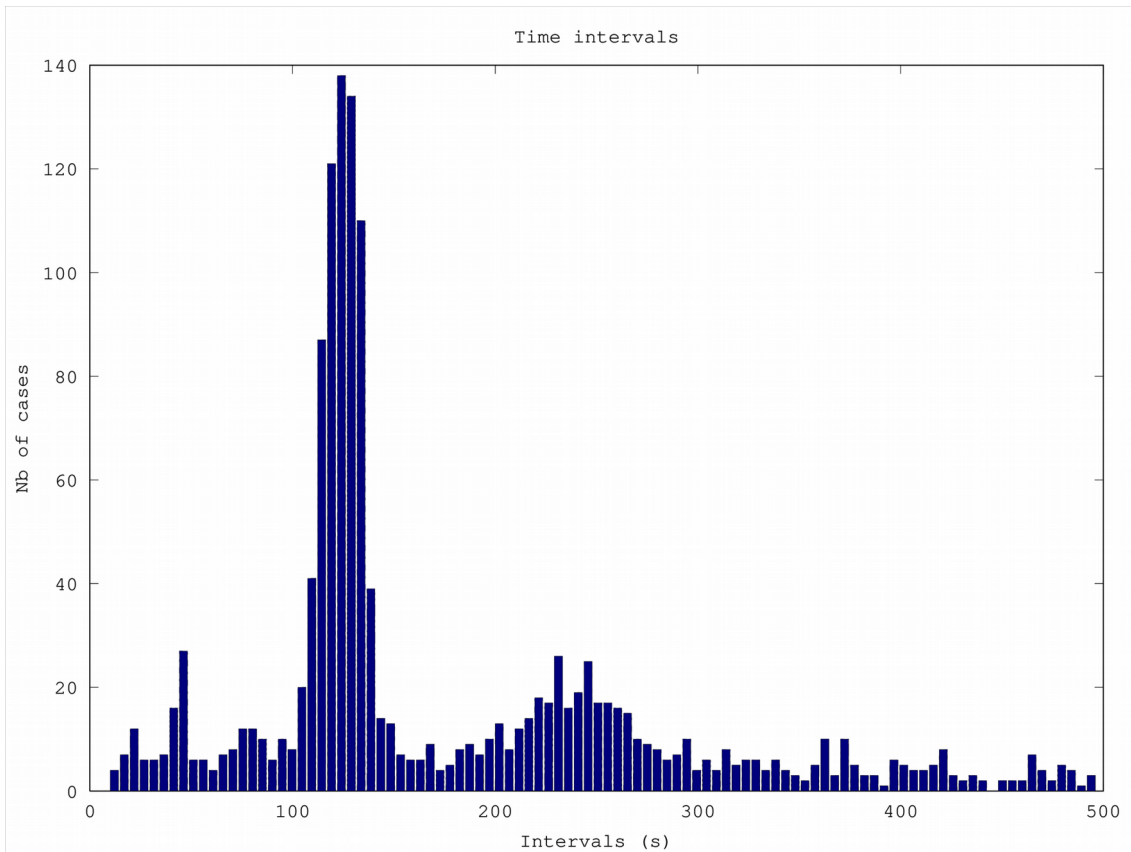
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484 Figure 4. Histogram of the inter-phrase intervals (IPIs) between two occurrences of
485 SEP2 phrases, from the Raven Pro selection table.

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1 i During the analysis, other vocalizations were found: blue whale “D-calls”, fin whale
2 (*Balaenoptera physalus*) vocalizations, bottlenose dolphins' (*Tursiops truncatus*) echolocation
3 clicks, whistles and low-frequency vocalizations, and dusky dolphin (*Lagenorhynchus obscurus*)
4 burst of pulses (see Patris, 2019). This dataset can be obtained asking the authors.