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Author-formatted, not peer-reviewed document posted on 05/10/2022

DOI: <https://doi.org/10.3897/arphapreprints.e95906>

Reencounter with the past: occurrence of sei whale (*Balaenoptera borealis*) in an old hunting area in the south-eastern Pacific Ocean

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1 **Running page head: Occurrence of sei whale**

2

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5

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25 **Abstract**

26

27 The sei whale (*Balaenoptera borealis*) was intensively exploited throughout its range, with about
28 110.000 individuals hunted by pelagic fleets in Antarctic waters between 1960 and 1970. In
29 addition, basic information on its distribution, migratory routes, and feeding grounds in the
30 southeastern Pacific, has been poorly documented. In the case of Chile, recent information consists
31 mainly of accidental records. This research presents the first sei whale photo-identification catalog
32 for south-central Chile. From November 2019 to January 2020, 88 individuals were recorded from
33 land-based and boat surveys at Caleta Chome. Of this, 12 individuals were photo-identified through
34 scars or distinctive notches in the dorsal fins. The peak of sightings occurred during December
35 2019; two individuals were sighted on more than one occasion.

36

37 **Keywords**

38 Sei whale, *Balaenoptera borealis*, Caleta Chome, Chile, South-eastern Pacific

39 **Introduction**

40 The sei whale (*Balaenoptera borealis*) is an Endangered mysticete (Cooke 2018) and the third
41 largest whale after the blue whale (*Balaenoptera musculus*) and the fin whale (*Balaenoptera*
42 *physalus*; Horwood 2018). This species presents a cosmopolitan distribution and pelagic with
43 temperatures below 20 °C (Omura & Nemoto 1955, Gambell 1968, 1985). It migrates to the
44 southern hemisphere during summer, from areas near the subtropical convergence where it
45 reproduces, to areas near the Antarctic convergence (50 ° S-60 ° S) for feeding (Horwood 1987,
46 Reeves et al. 1998, Rice 1998). Feeding zones are unpredictable, with a sudden influx into an area,
47 followed by disappearance and subsequent absence for years (Gambell 1985, Reeves et al. 2002,
48 Jefferson et al. 2008). During the summer there are high concentrations of sei whales between 40 °
49 and 50 ° S with adult individuals reaching polar waters while juveniles or sub-adults staying north
50 of the Antarctic convergence (Lockyer 1977, Acevedo et al. 2017). Six populations have been
51 assumed for the southern hemisphere for management purposes; however, the scarce evidence have
52 failed to identify separate populations within ocean basins (Kanda et al. 2006, Horwood 2018).

53 The International Whaling Commission estimated that by the 1940s the population declined
54 from 191.000 to 37.000 individuals after the cessation of commercial catches (Gambell 1985).
55 Although the sei whale was not a target species for hunting until the early 1960s (Acevedo et al.
56 2017, Español-Jiménez et al. 2019) the decrease in the most profitable whales (*B. musculus*, *B.*
57 *physalus*, *Megaptera novaeangliae* and *Eubalaena australis*) led to an increase in the hunting effort
58 of this species. In South America, this species was heavily exploited throughout its range (Zerbini et
59 al. 1997, Aguayo-Lobo et al. 1998a) where about 110.000 individuals were hunted by pelagic fleets
60 in Antarctic waters between 1960 and 1970 (Horwood 2018). In Chile, it was the third most hunted
61 whale species between 1929 and 1979 with at least 1,664 individuals captured (Aguayo 1974);
62 however, due to the difficulty of differentiating from Bryde's whale (*Balaenoptera edeni*), its
63 hunting numbers are probably overestimated since many Bryde whales would have been reported

64 as sei whales (Valdivia et al. 1981, Gallardo et al. 1983, Aguayo-Lobo et al. 1998a). There were
65 about 25 years (between 1974 and 1999) in which there was no research on sei whales, and the few
66 studies that were conducted during this period did not consider the sei whale as an object of study
67 (Gallardo & Pastene 1983, Gallardo et al. 1983, Guerra-Correa et al. 1987, Aguayo-Lobo et al.
68 1998b). Since the moratorium on whaling there has been a considerable reduction in sei whale
69 research (Reeves et al. 2002), currently this species is one of the least known baleen whales in the
70 world (Prieto et al. 2012, Horwood 2018, Acevedo et al. 2017).

71 Caleta Chome was founded by the Macaya Hnos. whaling industry on 1948 (Quiroz &
72 Carreño 2019). By 1954 the sei whale was already within the productivity of the whaling plant in
73 Caleta Chome and was the first documented records of sei whales for this region. The sei whale
74 catch data for this area were for a long time under the name "S + B", since they considered the
75 bryde (B) and sei (S) whales together due to the similarities that existed between them, therefore
76 there are no clear records of the number of individuals of sei whales caught in this area (Pastene
77 1982). In Caleta Chome, between 1951 and 1983, an active whaling was carried out by the Trinidad
78 Whaler owned by the Macaya Family (Quiroz & Carreño 2019). Given that the sei whale is
79 Endangered studies of its populations are crucial to support its conservation. This study presents the
80 first sei whale photo-identification catalog in south-central Chile and information on sightings.

81

82 **Materials and methods**

83

84 *Study area*

85

86 The sightings were in Caleta Chome in the Biobio region of Chile (36°40'S; 73°15'W; Fig. 1).
87 Waters rich in nutrients from the Humboldt Current fertilize the coasts of this region in the spring
88 and summer season when the winds are favorable to coastal upwelling (Sobarzo et al. 2007,

89 Simpkins 2018), generating an increase in primary productivity and higher trophic levels (Thiel et
90 al. 2007, Escribano et al. 2012, Anabalón et al. 2016). South of Caleta Chome, the freshwater
91 discharge from the Biobío River provides nutrients, organic matter, and terrigenous particles to the
92 adjacent coastal area, positively influencing phytoplankton biomass and primary production
93 (Masotti et al. 2018). Bathymetric accidents such as the Biobío canyon (Sobarzo et al. 2016) and an
94 irregular coastline (Figueroa & Moffat 2000) are essential factors in the coastal dynamics of the
95 area.

96

97 *Sighting and data base*

98 The sighting records were collected during November 2019 to January 2020 two days per week for
99 a total of 25 days (41 hours and 15 min) of monitoring. The surveys (search of whales) were during
100 the morning between 08:00-12:00 AM (14 surveys) and afternoon between 06:00-09:00 PM (11
101 surveys). The sightings were made from a) land from a hill of 50-55 m of height using 10x42
102 binoculars and spotting scopes 15-45x65 (16 surveys); and b) aboard the boat El Felipe I (7.8m in
103 length) that periodically sails in Caleta Chome (9 surveys). The number of observers varied from 2
104 to 4 observers. From the boat, the sightings were at a distance no greater than 20 m and the
105 identification of the species was carried out with photographic records using a Canon EOS77D
106 camera with 100-400 mm zoom lens, and Canon SX530 semi-professional camera. The morphology
107 of the dorsal fin, characterized by a prominent falcate fin that rises at a steep angle from the rear and
108 central ridge along the head, allowed species identification (Acevedo et al. 2017). The individuals
109 were individualized based on photographs by identifying the distinctive scars, notches, or holes in
110 the dorsal fin (Würsig & Jefferson 1990). Only images of medium to high quality (> 4608 x 3456
111 pixels) that allowed to highlight their distinctive characteristics were used.

112 Daily Sea Surface Temperature (SST) between November 2019 and January 2020 data were
113 obtained from Multi-Scale Ultra High Resolution (MUR, <https://podaac.jpl.nasa.gov/dataset/MUR->
114 [JPL-L4 - GLOB-v4.1](https://podaac.jpl.nasa.gov/dataset/MUR-JPL-L4-GLOB-v4.1)) with a spatial resolution of 1 km². The SST for each sei whale sighting at
115 sea was obtained from the near pixel to the sighting coordinate.

116

117 *Data analysis*

118 To have a better visualization of the results of the sightings, a detection index (Di) was established
119 which was calculated based on the sum of the sightings made during intervals of 10 days (i.e.,
120 maximum interval between monitoring) and the effective sampling effort within that interval of
121 days:

$$122 \quad Di = \text{sightings during 10 days} / \text{sampling effort for 10 days}$$

123

124 **Results**

125 Between November 3 and January 18, we made 88 sei whale sightings. The number of sightings
126 varied from November to January, registering a peak of sightings during December 11 and 20
127 (Figure. 2). We identified 17 groups of sei whale of 2 to 9 individuals (median = 4), most of these
128 groups were registered during the month of December (10 groups). The SST range from 12,7°C to
129 15,1°C during the sightings, and the estimated depth of the sightings range from 16 to 137 m. On
130 the other hand, sei whale sightings were made at mean distance of 3.6 km from the coast. We
131 highlight one event, where the distance was c.a 0.1 km. (Table 1).

132 Twelve individuals were photo-identified through distinctive scars or notches on the dorsal
133 fins (Figure. 3), 83% of the individuals have some notch and one of them have a broken fin (# 002)
134 and other two had laceration (# 007 and # 009). Most individuals (see photographic sequence from
135 # 009 to # 012 in Fig. 3) were photographed in December 2019. Two individuals (# 003 and # 009)
136 were sighted more than one day in the area, individual # 003 was sighted 7 days after the first

137 sighting and individual # 009 on the seventh and tenth day after the first sighting. The presence of a
138 mother with a calf was registered for 5 different days.

139

140 **Discussion**

141 With the moratorium established by the International Whaling Commission (IWC) in 1983, the
142 cetacean records associated with hunting decreased and the only records of the sei whale for central
143 Chile were only three reports and one scientific publication (Pastene 1982, Gallardo & Pastene
144 1983, Gallardo et al. 1983, Aguayo-Lobo et al. 1998a). Although there are records of sightings of
145 this species for previous years (F. Silva obs. Pers.), a high abundance of individuals had not been
146 recorded in this area and neither the presence of mothers with young.

147 The sei whale is described as predominantly found in deep waters, occupying mainly pelagic
148 habitats at distances greater than 110 km from the coast (Best & Lockyer 2002, Prieto et al. 2012);
149 however, many of our sightings occurred near the coast at distances no greater than 6 km (see Table
150 1) consistent with what was observed for populations of sei whales in the South Atlantic (Weir et al.
151 2020). This greater abundance of sei whale near the coast and the feeding activity during the day,
152 agree with the results obtained by Español-Jiménez et al. (2019) on the coast of the Gulf of Penas
153 and Tres Montes. Another data to highlight are the sightings of the same individual on more than
154 one occasion, this suggests a stay of at least 7-10 days. In addition, the presence of mothers with
155 young during the observation season may be giving signs of safety and good environmental
156 conditions for rearing. More than 50% of the identified individuals had scars on their fins. Among
157 the possible natural threats that could have damaged its dorsal fin, is predation by killer whales
158 (*Orcinus orca*) which are considered its only significant natural predator (Jefferson et al. 1991,
159 Springer et al. 2006).

160 The occurrence of sei whales in the coastal upwelling system of Chile was reported by
161 Gallardo & Pastene (1983), who associated high primary productivity with the concentration of
162 sightings, proposing that the coasts of the Biobío region they can be feeding areas for some

163 cetaceans during their migrations. The continental shelf off Biobío is an important upwelling zone
164 and has been described as one of the most productive areas within the Humboldt Current System
165 (Montecino et al. 1998, Montero et al. 2007, Thiel et al. 2007, Daneri et al. 2012, Iriarte et al.
166 2012). Bathymetric features such as underwater canyons generate foraging areas for a variety of
167 cetaceans, contributing to primary productivity and biodiversity (Moors-Murphy 2014). Croll et al.
168 (2005) mention that bathymetric ruptures and the coastal upwelling process are important factors in
169 the density of euphausiids, contributing to the formation of feeding areas. The high occurrence of
170 individuals in Caleta Chome could be related to a migratory route close to the Biobío Canyon
171 located to the south of the study area.

172 The oceanographic conditions in the distribution of this species are variable in relation to the
173 migratory routes and the permanence in feeding and / or reproduction sites (Omura & Nemoto
174 1955, Gregr & Trites 2001, Sasaki et al. 2013, Murase et al. 2014). On the coasts of Chile, the
175 presence of sei whales has been reported in areas with sea surface temperatures of 14.5 °C in spring
176 (Clarke et al. 1978). In the Magellan Strait Acevedo et to (2017) reported a thermal range between
177 5.7 and 10.9 °C. Our sightings are also within this temperature range, agreeing with the values
178 reported for this species in other parts of the world.

179 Acevedo et al. (2017) reported sei whales in the Magellan Strait from November to May,
180 with a peak of sightings (83.6%) occurring during December and January. They suggest that
181 although there are records that support the hypothesis that whales forage in southern Chile, none of
182 them provide information on systematic annual occurrences in these same areas, but this in turn can
183 be supported by the fact that sei whales are known for their unpredictable presence in an area
184 followed by their subsequent disappearance, as well as having a greater variation in distribution in
185 their feeding grounds than most species of baleen whales (Tønnessen & Johnsen 1982, Horwood
186 1987). All these records that support the presence of the sei whale on Chilean coasts are at the same
187 time of the year (January-May) within relatively small latitudes and although they are not in
188 consecutive years there is a certain periodicity that could support the hypothesis that the sei whale

189 forages in Chilean waters but their foraging areas change over the years (Pastene & Shimada 1999,
190 Guzmán 2006, Aguayo-Lobo et al. 2006; Acevedo et al 2017, Español-Jiménez et al. 2019. In this
191 work, the occurrence of the sei whale off the Chilean coast shows the existence of a passage zone
192 and possible feeding area within the waters near the coast. Ecological knowledge about sei whales
193 along the Chilean coast is scarce, therefore we highlight the importance of increasing sighting
194 efforts around the Hualpén Peninsula Nature Sanctuary during upwelling events to understand if the
195 presence of sei whales follows some seasonal pattern or corresponds to sporadic events.

196 **Acknowledgements**

197 We thank the Turismo Chome Aventura company for the navigation services in Caleta Chome and
198 the information provided through verbal communication of sei whale sightings and navigation
199 routes commonly used by whales. A.C.C thanks the COPAS-coastal center, Universidad de
200 Concepción, Chile and the Agencia Nacional de Investigación y Desarrollo de Chile (ANID).

201

202 **Authors' contributions**

203 AC-C, CC-Q and FS-A contributed to the conception and design of the study. AC-C performed the
204 literature search and/or organized the database. AC-C and RM produced the figures and/or tables.
205 AC-C, RM and HVN wrote the first draft of the manuscript. CC-Q and FS-A wrote sections of the
206 manuscript. Authors reviewed and/or analyzed the literature and contributed to manuscript revision,
207 read, and approved the submitted version.

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340

LEGENDS OF TABLE AND FIGURES

341

342

343 Table 1. Summary of sightings of sei whales (*Balaenoptera borealis*) in Caleta Chome during the
344 seasons from November 2019 to January 2020.

345

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348 Chome. The red point shows the position of the sightings in the sea. The associated sampling
349 number is indicated on each point (see Table 1). The black point shows the position of Caleta
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354 Figure. 2. Frequency in the detection index of the *Balaenoptera borealis* sighted during November
355 and December 2019 and January 2020. The detection rate was calculated based on the effective
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359

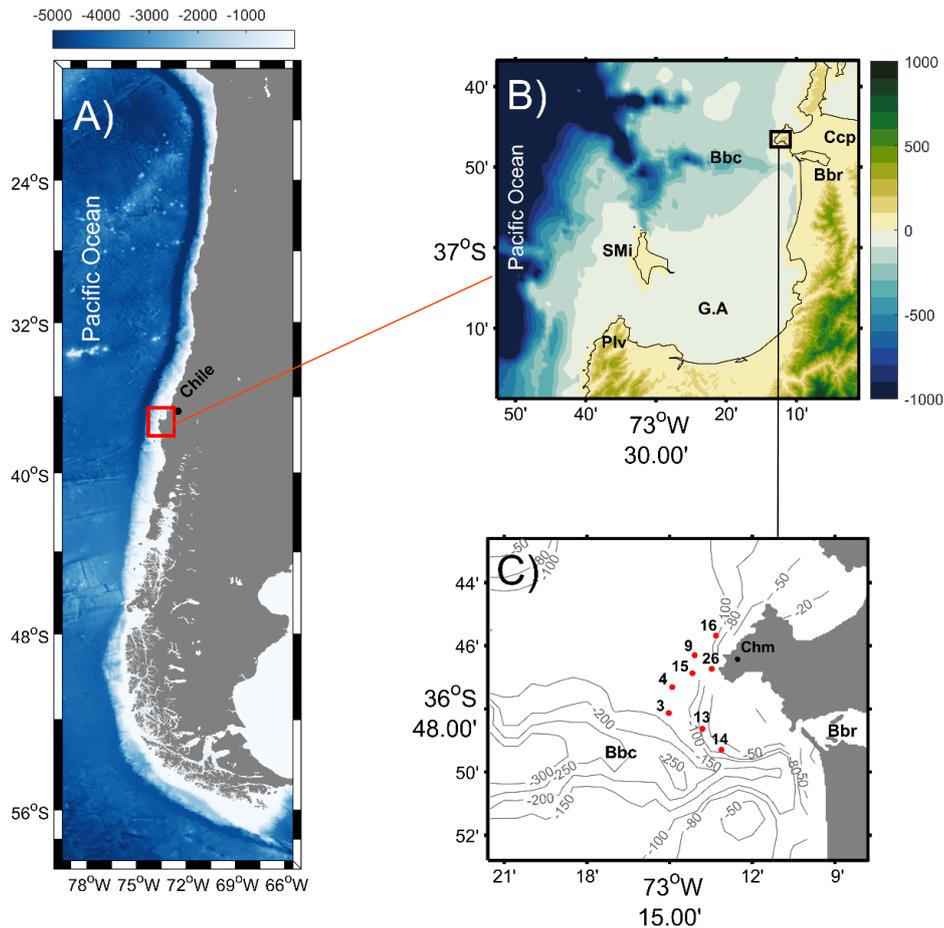
360 Figure. 3. Dorsal fin photographs of 12 identified sei whales (*Balaenoptera borealis*) at Caleta
361 Chome, during the seasons from November 2019 to January 2020.

362 Table 1. Summary of sightings of sei whales (*Balaenoptera borealis*) in Caleta Chome during the
 363 seasons from November 2019 to January 2020.

No.	Date (d/m/y)	Latitude (S)	Longitude (W)	Number of individuals	Sighting place	Distance from shore (km)	SST (°C)	Depth (m)
1	03-11-2019	-	-	1	Coast	-	-	-
2	06-11-2019	-	-	3*	Coast	-	-	-
3	09-11-2019	36°48'10.64"	73°13'45.58"	1	Boat	4.4	12.9	113
4	17-11-2019	36°47'18.55"	73°14'54.26"	4*	Boat	5.6	15.1	137
5	18-11-2019	-	-	5	Coast	-	-	-
6	28-11-2019	-	-	6	Coast	-	-	-
7	29-11-2019	-	-	4*	Coast	-	-	-
8	30-11-2019	-	-	4	Coast	-	-	-
9	01-12-2019	36°46'17.00"	73°13'40.75"	6	Boat	1.6	13.5	122
10	02-12-2019	-	-	1	Coast	-	-	-
11	05-12-2019	-	-	3	Coast	-	-	-
12	06-12-2019	-	-	2	Coast	-	-	-
13	07-12-2019	36°48'35.88"	73°13'30.39"	8	Boat	4.6	12.7	103
14	08-12-2019	36°49'17.70"	73°13'7.15"	4	Boat	5.4	12.8	122
15	13-12-2019	36°46'44.59"	73°13'41.02"	9*	Boat	1.1	13.3	105
16	14-12-2019	36°45'40.66"	73°13'18.85"	8	Boat	2.4	12.9	116
17	22-12-2019	-	-	3	Coast	-	-	-
18	23-12-2019	-	-	1	Coast	-	-	-
19	30-12-2019	-	-	4*	Coast	-	-	-
20	31-12-2019	-	-	4	Coast	-	-	-
21	06-01-2020	-	-	1	Coast	-	-	-
22	08-01-2020	-	-	1	Coast	-	-	-
23	09-01-2020	-	-	2	Coast	-	-	-
24	10-01-2020	-	-	1	Coast	-	-	-
25	13-01-2020	-	-	1	Coast	-	-	-
26	18-01-2020	36°46'40.98"	73°12'54.39"	1	Boat	0.1	12.7	16

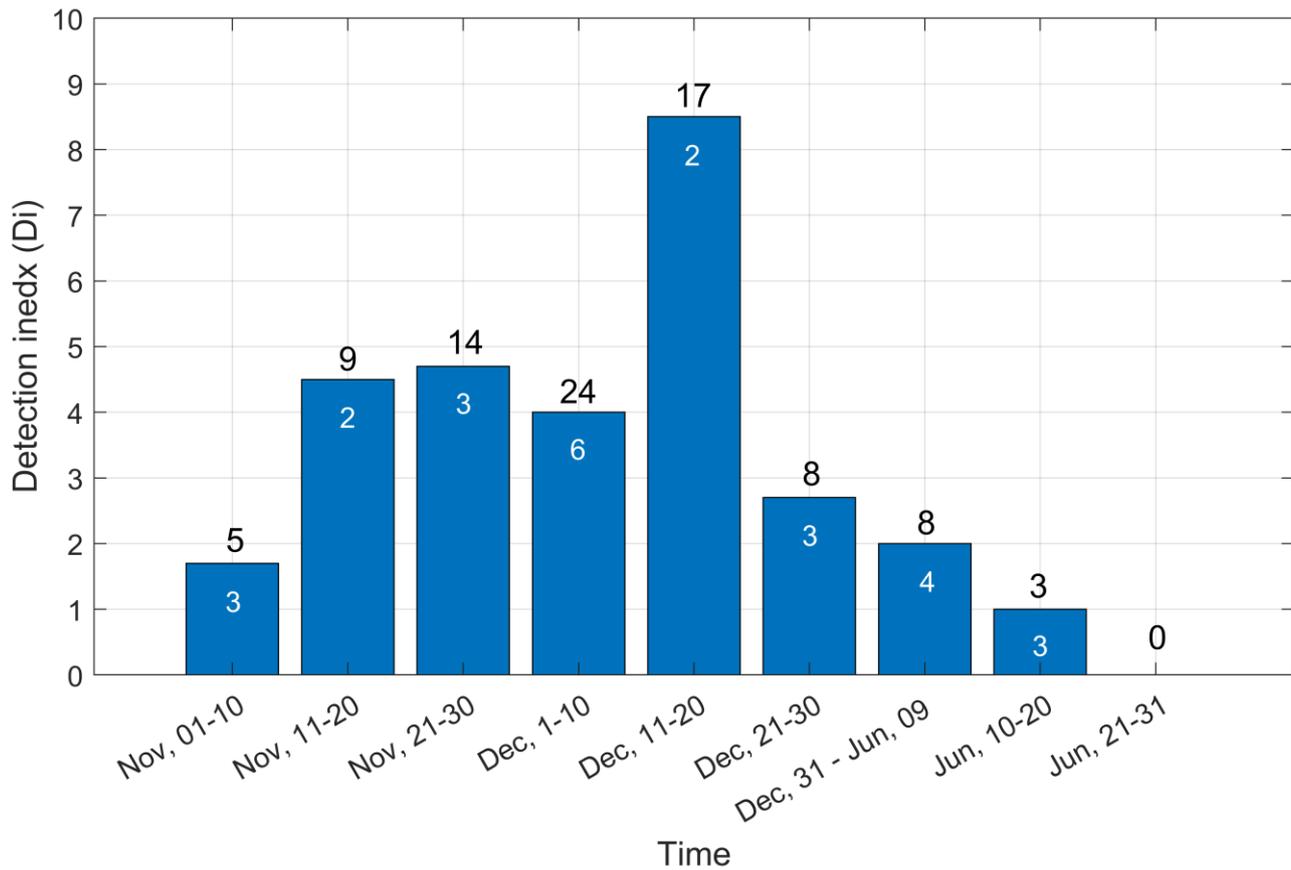
364 Note: the number of individuals with * represents those sightings in which mothers with young were recorded.

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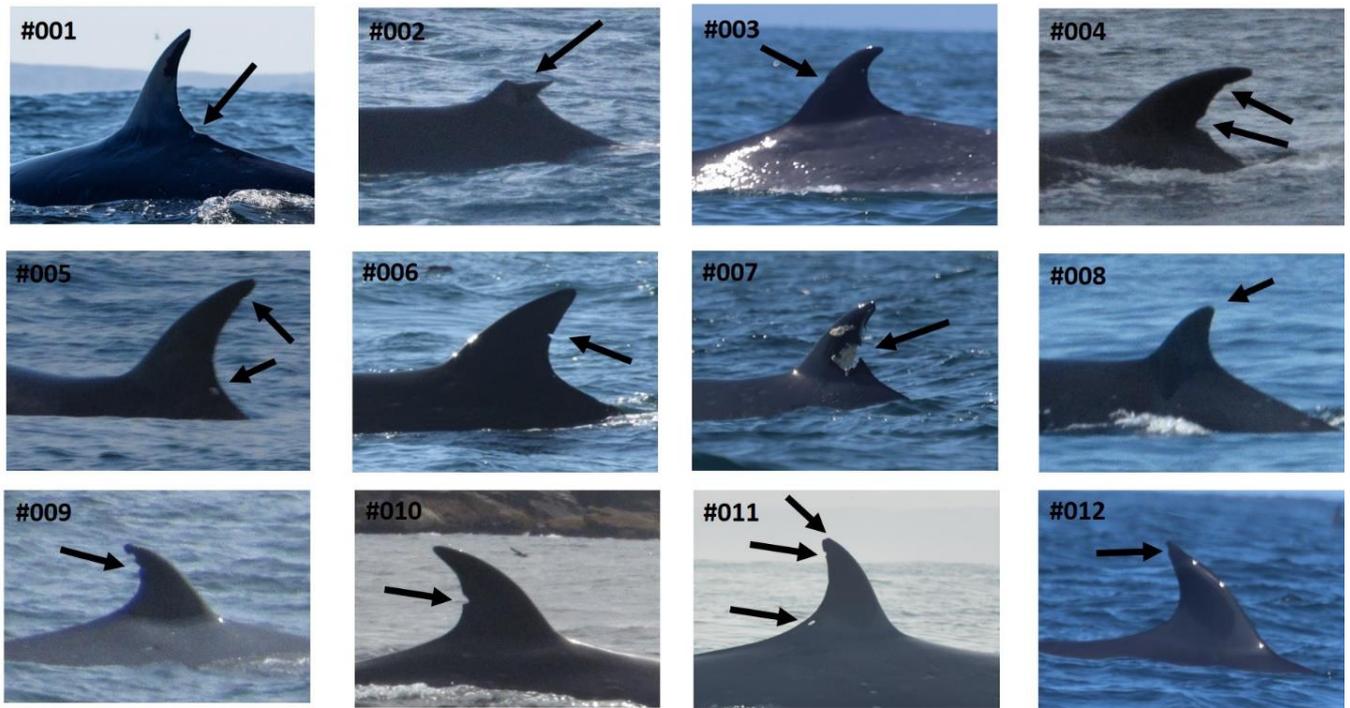


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