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Novel Coastal Feeding Area for Eastern South Pacific Fin Whales (*Balaenoptera physalus*) in Mid-Latitude Humboldt Current Waters off Chile

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Abstract

Southern Hemisphere feeding grounds for fin whales (*Balaenoptera physalus*) are known to be located in Antarctic and subantarctic waters. Specific feeding areas outside of these waters were unknown. Fin whales were first reported from inshore Chilean waters in 1993. New spatial and temporal distribution records of these whales in coastal waters of northern Chile are reported for a 28-y study period from 1988 to 2015. Records of a total of 519 animals comprise 179 sightings of which 170 are new and nine are previous reports from the region obtained since 1993. Fin whales were sighted either solitarily or in groups of up to 14 individuals. They have been observed throughout the year, though more often in summer than winter months. Photographic databases reveal repeated observation of certain unique individuals among years, and residence of several individuals over summer months for periods up to 3 mo. The occurrence and re-sighting of fin whale feeding in this area identifies this habitat as a coastal foraging area for these whales, which is the first documented feeding ground for the eastern South Pacific in waters north of the Antarctic. Individuals recorded in Chilean waters are primarily adults; very few juveniles and no calves have been reported. Fin whale presence in coastal areas maximizes vulnerability to human activities like increasing nonregulated whale watching and collisions with vessels transiting the close maritime route to Coquimbo harbor.

Key Words: fin whale, *Balaenoptera physalus*, Chile, eastern South Pacific, feeding ground, Humboldt Current, seasonal occurrence

Introduction

The fin whale (*Balaenoptera physalus*, Linnaeus, 1758) is an endangered cosmopolitan and primarily offshore species that inhabits temperate to subpolar waters in all main ocean basins and the Mediterranean Sea (Aguilar, 2008; Archer et al., 2013). The Southern Hemisphere population dwindled as a consequence of whaling. In line with declining Southern Ocean stocks, fin whale catches in the eastern South Pacific (ESP) (Chile and Peru mainly) also declined from the mid-1960s (Clarke, 1980).

Southern Hemisphere fin whales migrate seasonally from Antarctic and subantarctic feeding grounds into low-latitude breeding and calving areas (Mackintosh, 1966; Aguilar, 2008). However, despite the large size of this species, its charismatic nature, and threatened status, its migratory routes, breeding areas, and calving locations are poorly known (Aguilar, 2008; Mizroch et al., 2009), and feeding areas outside of Antarctic waters have not earlier been reported for inshore Southern Hemisphere waters (Bérubé et al., 1998; Jefferson et al., 2008).

In the ESP, fin whales have been sighted in offshore waters off Chile, Peru, and Ecuador, including waters of the Galapagos Islands (Clarke, 1962; Loesch, 1966; Aguayo, 1974; Denkinger et al., 2011), with records from further north being comparatively rare (Gerrodette & Palacios, 1996; Palacios et al., 2012). The majority of reports of fin whales in Chilean waters are from sightings made in excess of 100 km from shore from Arica (18° 28' S, 70° 18' W) to Cape Horn (55° 58' S, 67° 16' W) (Aguayo et al., 1998b), but usually between latitudes 20° S and 34° S (Clarke, 1962; Clarke et al., 1978; Aguayo et al., 1998a). Acevedo et al. (2012) reported 50 to 100 individuals along

a stretch of 120 nmi from 21° 27' S, 97° 34' W, 1,500 nmi to the west of Chile and suggested this region may represent an offshore breeding area, though no calves were observed. Instead, inshore records of fin whales in Chilean waters are scarce, limited to waters of a coastal island system (29° 09' S) (Capella et al., 1999; Pérez et al., 2006).

Reports of fin whales observed over a 28-y period spanning 1988 to 2015 obtained from dedicated surveys in a mid-latitude coastal archipelago in the Humboldt Current System, northern Chile, are compiled and evaluated. These data and concurrent behavioural observations indicate inshore waters surrounding this island system represent a hitherto unknown feeding area for fin whales outside of Antarctic or subantarctic regions.

Methods

The study area includes coastal waters around an insular cluster in the Humboldt Current System central-north of Chile. This archipelago includes four medium-sized islands: Gaviotas, Chañaral, Choros, and Damas—the last three occurring within the Pingüino de Humboldt National Reserve (PHNR) islands system (Figure 1). The survey area extends to 10 to 12 km offshore and along 40 km of coastline between 29° 00' and 29° 20' S, and it covers approximately 400 km^2 of waters over 200-m depth. Sea surface temperature (SST) ranges from 11 to 18° C annually (Aravena et al., 2014). The study area is located in the northern edge of the Coquimbo Bay (30° S) coastal upwelling centre (Montecino et al., 1996; Marín & Delgado, 2003; Thiel et al., 2007), a highly productive seasonal area with common occurrence of euphausiid concentrations such as *Euphausia mucronata,* the most abundant and endemic species in the Humboldt Current System (Antezana, 1978, 2002; Escribano et al., 2000). In addition to the fin whales recorded in this work, the study area also supports significant concentrations of other high-level predators such as seabirds (mainly Humboldt penguin [*Spheniscus humboldti*], brown pelican [*Pelecanus thagus*], and Peruvian booby [*Sula variegata*]), marine otter (*Lontra felina*) (Vilina et al., 1995), South American sea lion (*Otaria flavescens*) (Sepúlveda et al., 2009), and other cetacean species (González et al., 1989; Capella et al., 1999).

Surveys were conducted between 1988 and 2015, with sampling undertaken each year in 1988-1995, 1998-2000, 2004 and 2005, 2007 and 2008, and 2010-2015. In total, 2,685 h of surveys were conducted over 455 d spread over 57 mo spanning 21 y, of which 320 d (70.3% of survey effort) occurred during summer months (January-March), averaging 12.3 d/mo (SD = 9.2; range 1 to 28).

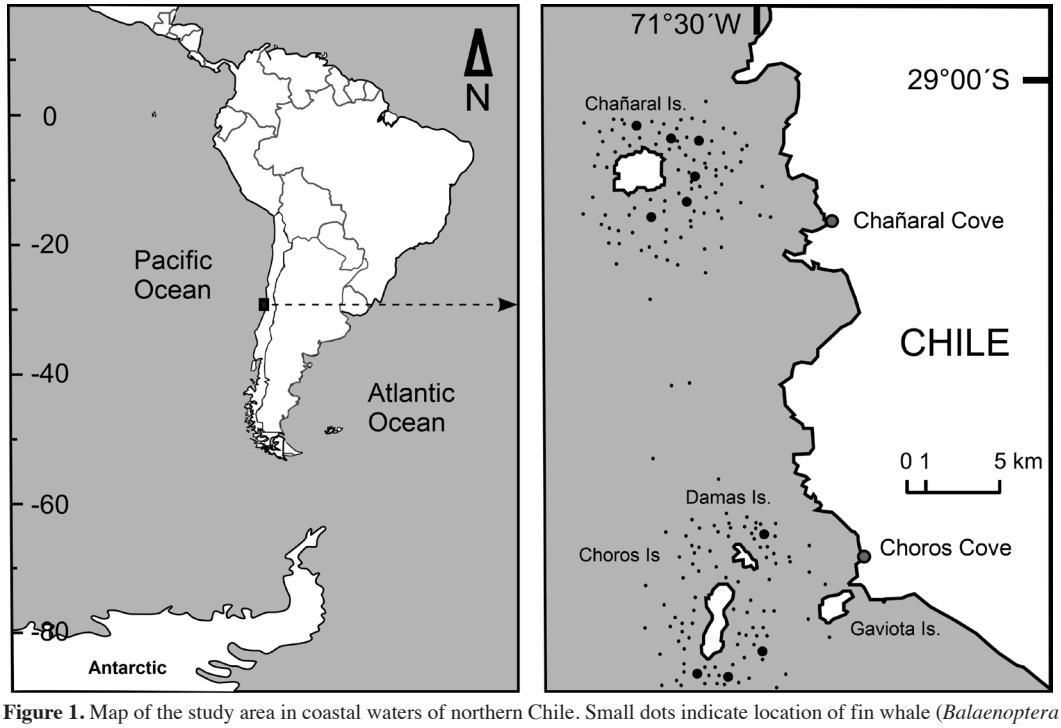

Figure 1. Map of the study area in coastal waters of northern Chile. Small dots indicate location of fin whale (*Balaenoptera physalus*) sightings, and black dots indicate feeding events.

Results were standardized and expressed as sighting rates (# sightings/100 h) per year and season to compensate for heterogeneous effort within and among years and seasons. To evaluate the occurrence of fin whales along time periods, we compared the sighting rates of two 8-y periods with survey effort and whale presence—the first from 1993 to 2005 against the second from 2007 to 2015.

Random surveys were undertaken aboard small outboard-motor-powered boats of 5.5- to 8-m length departing from Chañaral and/or Punta de Choros cove (Figure 1). At least two observers took part in each survey. Navigation was performed in sea conditions below Beaufort 3 and with adequate visibility or better.

Animals were identified as fin whales by a combination of asymmetrical lip pigmentation (white on the right side and "dark"' on the left); a light grey, forward-pointing V-shaped "chevron" on the back behind the head; and a rear-pointing dorsal fin (Aguilar, 2008). Sighting data included date, location, group size, class of individual, and behavior (e.g., surface activity, swimming direction, breathing/diving pattern, and feeding). Foraging events were recognized when fin whales were observed moving slowly near the surface and emerging with their mouth opened engulfing prey by lateral (Figure 2), dorsal, or ventral surface down. This is described as lunge feeding (Tershy & Willey, 1992). In some, the presence of schooling fish and euphausiid swarms was obvious at surface and, whenever possible, prey were collected and identified. On sighting, each group of fin whales was monitored for 15 to 45 min during which there were vessel approaches at 5 to 80 m, so it was possible to assign individuals to one of two size classes to approximate maturity (adult or juvenile): over 17 m (adult) and between 10 to 17 m (juvenile) (Agler et al., 1993). Whenever possible, photographs of dorsal fins were taken using appropriate camera and telephoto lenses (to 400 mm) to identify individuals by shape and scars to establish a catalogue for the area.

Results

A total of 179 sightings were recorded for the coastal insular system study area, comprising 170 new records from 1995 to 2015 and nine records from 1993 to 1995 (*fide* Capella et al., 1999) (Figure 1). The number of individuals per group ranged from 1 to 14. Pairs and trios were the most frequent group sizes with 69 (40.6%) and 40 (23.5%) sightings, respectively, while the sum of individuals from all sightings amounts to 519 individuals (Figure 3).

Fin whales were observed in 12 of a total of 21 y with effort between 1988 and 2015. No fin whales were observed between 1988 and 1992 in spite of the high survey effort, nor in the years 1998, 2000, 2004, and 2010, though survey effort was lower during those years (Figure 4). The effort-adjusted sighting rates was significantly higher for the period 2007 to 2015 (166 sightings) than for the 1993 to 2005 period (13 sightings) (one-way ANOVA, $F = 6.84$, $p = 0.020$).

Fin whale sightings occurred throughout the year; significant differences in sighting rates between seasons were not apparent (Kruskal-Wallis test, $H = 6.43$, $p = 0.092$), but differences between summer (14.1 mean sighting rate, January-March) and winter (3 mean sighting rate,

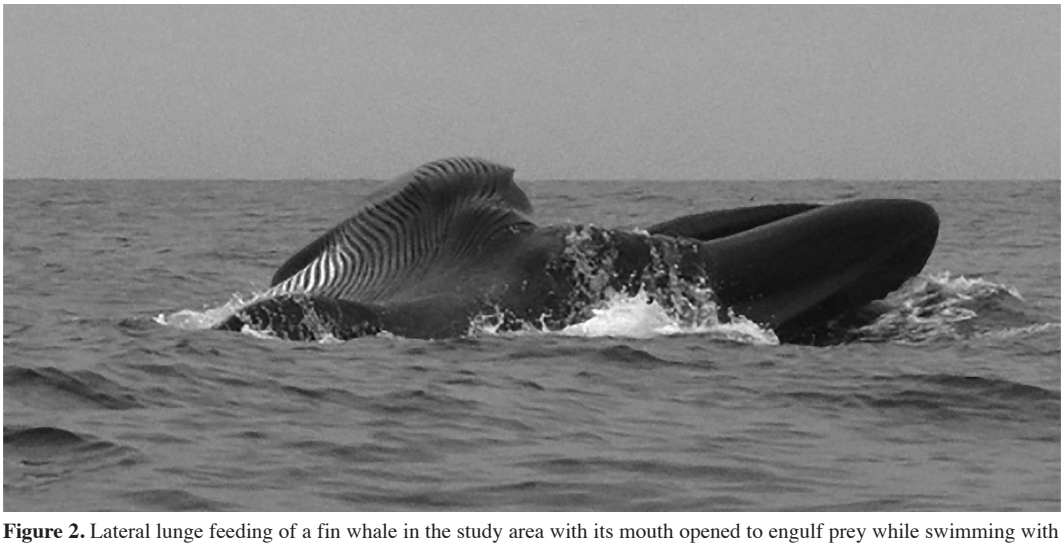

Figure 2. Lateral lunge feeding of a fin whale in the study area with its mouth opened to engulf prey while swimming with its right flank downwards, mostly inside the water

July-September) months alone were more than fourfold and significant (Mann-Whitney test, U = 10.5, $p = 0.028$). Both winter sightings occurred at the beginning of July. Somewhat intermediate effort-adjusted values of sighting frequency were recorded for fall (9.3) and spring (6.9) (Figure 5).

Of the 519 animals sighted, all but 17 were adults. Seventeen juveniles were reported, and no calfs were seen. Photographic records enabled nine unique individuals to be recognized among the fin whales sighted between 1993 and 1995; during the period 2011 to 2015, 32 unique individuals were recognized. No fin whales were deemed common to the two photographic datasets. Between 2011 and 2015, 15 individuals showed fidelity to the area: two individuals returned in 5 y (#006 and #013; Figure 6), one in 4 y (#012), four in 3 y (#001, #005, #009, and #014), and eight in 2 y. Ten fin whales appeared resident over summer from a 1 wk to 3 mo duration.

Feeding groups ranged from one to five whales (Figure 3). Ten sightings of lateral lunge feeding events were recorded (5.6% of total sightings): one each in 1993, 1994, and 2011; three in 2012; and two in 2014 and 2015. Except for the feeding event of 1993, which was on Peruvian anchovy (*Engraulis ringens*), all the rest were on euphausiids (unidentified species of krill). A small krill sample collected during feeding events on 3 February 2012 was identifiable to genus level as *Euphausia* spp., based on mid-dorsal spiniform processes on an abdominal segment (Antezana et al., 1976). Surface aggregations of krill (red colour patches in water) were observed during 20% of boat surveys, especially during summer and fall months.

Discussion

Although fin whales have been widely recorded in the ESP waters (Clarke, 1962; Gerrodette & Palacios, 1996; Aguayo et al., 1998b; Denkinger et al., 2011; Palacios et al., 2012), their overall distribution and population dynamics are not well

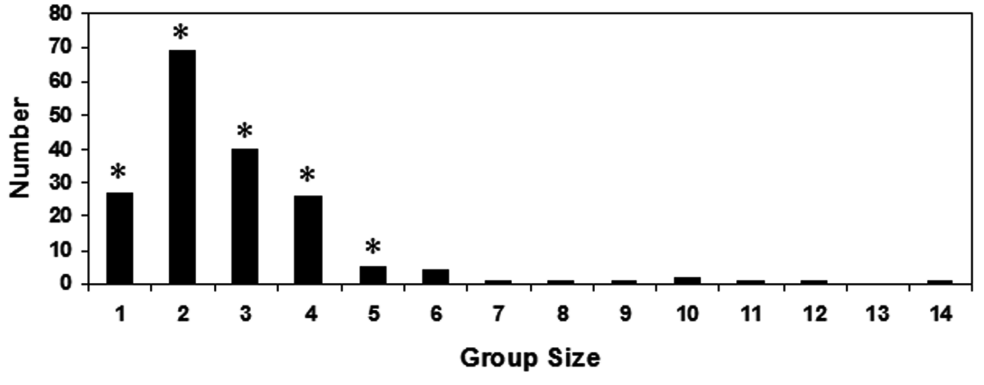

Figure 3. Fin whale group size distribution for the study area from 1993 to 2015 ($n = 179$). *Denotes group with feeding events.

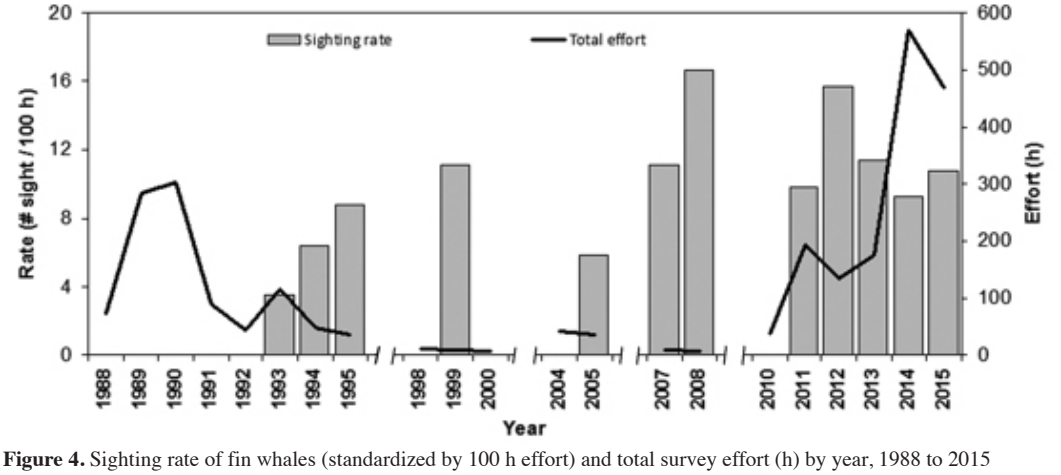

Figure 4. Sighting rate of fin whales (standardized by 100 h effort) and total survey effort (h) by year, 1988 to 2015

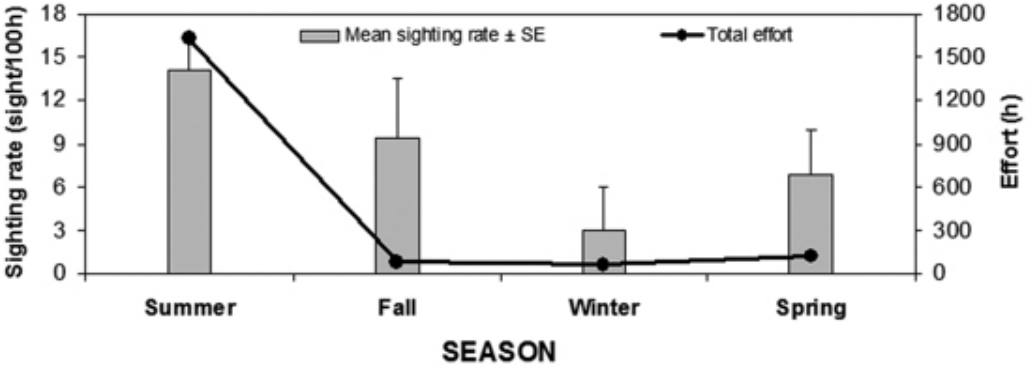

Figure 5. Sighting rate of fin whales (standardized by 100 h effort) and total survey effort (h) by season for the study area from 1993 to 2015

understood (Aguayo et al., 1998b; Capella et al., 1999; Palacios et al., 2012). Occurrence of fin whales was not reported within inshore waters from northern Chile until 1993 (Capella et al., 1999), despite previous marine surveys (Clarke, 1962; Clarke et al., 1978; Capella et al., 1999). Neither did nonsystematic surveys for cetaceans carried out in the mid-1980s along beaches north of our study area (21 to 26° S) record strandings or bone remains of fin whales (Guerra et al., 1987).

In the 22 y following the first coastal reports (Capella et al., 1999), fin whales have occurred commonly in the study area (Pérez et al., 2006; this study), but with higher rate and regularity in recent years. Fin whales also reached the highest number of sightings among baleen whales during inshore oceanographic cruises made between 27 to 30° S from 1999 to 2004 (Thiel et al., 2007). The species is now sighted throughout the year, but more frequently during summer, with a decrease from fall and spring to winter. Clarke et al. (1978) suggested fin whales encountered in Chilean waters during the austral spring and summer might be individuals migrating to Antarctic waters to feed; and that those sighted during fall, might be individuals returning from Antarctic waters after having fed. The higher rate of occurrence and long-term residence during the austral summer and the absence of calves in the study area are consistent with a feeding habitat only. The months of maximum occurrence do not match the mating period (winter) proposed for South Hemisphere fin whales (Mackintosh & Wheeler, 1929; Laws, 1959, 1961). In addition, the breeding habitat of this species is still unknown in the ESP, although an offshore breeding ground at mid-latitudes of Chile was recently suggested, but with limited and weak support and with no calves recorded (Acevedo et al., 2012). Bérubé et al. (2001) suggest that mothers may choose feeding areas where calf survival is assured. This would explain their spatial segregation as observed in the Gulf of Maine (Agler et al., 1993). If this notion holds true, the area of the present study should not be optimal for sheltering mothers with calves, although it would satisfy adult males, nonreproductive females, and juveniles' requirements.

The diet of fin whales off Chile is consistent with that reported elsewhere. Although direct observations of feeding behaviour were uncommon in the study area (5.6% of all sightings), the whales have targeted either Peruvian anchovy (fish) and *Euphausia* (krill) (i.e., *E. mucronata*) as was reported before for the same place by Pérez et al. (2006) and for Antarctic fin whales (Kawamura, 1994; Joiris & Dochy, 2013) or fish as reported for north Atlantic (Jonsgård, 1966; Overholtz & Nicolas, 1979) and north Pacific fin whales (Kawamura, 1982).

The high occurrence of the species within the study area, the apparent concentration of whales during summer and fall, and the observed feeding on abundant local food lends support to the hypothesis that this inshore area off Chile represents a hitherto unrecognized feeding destination or mid-latitude step feeding site or transit station for fin whales in the ESP as they do for humpback whales (*Megaptera novaeangliae*) at similar latitude in coastal west South African waters (Barendse et al., 2011) or for blue (*Balaenoptera musculus*) and humpback whales off central-south Chile between 38 and 41° S (Hucke-Gaete et al., 2003, 2013; Galletti-Vernazzani et al., 2012). A similar condition has been reported for fin and blue whales in the north Atlantic in which, during migration to their northern feeding grounds in Greenland, whales stop over during spring and summer at places like the Azores islands (38° 30' N) where they remain for a few days to feed on elevated phytoplankton and zooplankton biomass (Silva et al., 2013). If so,

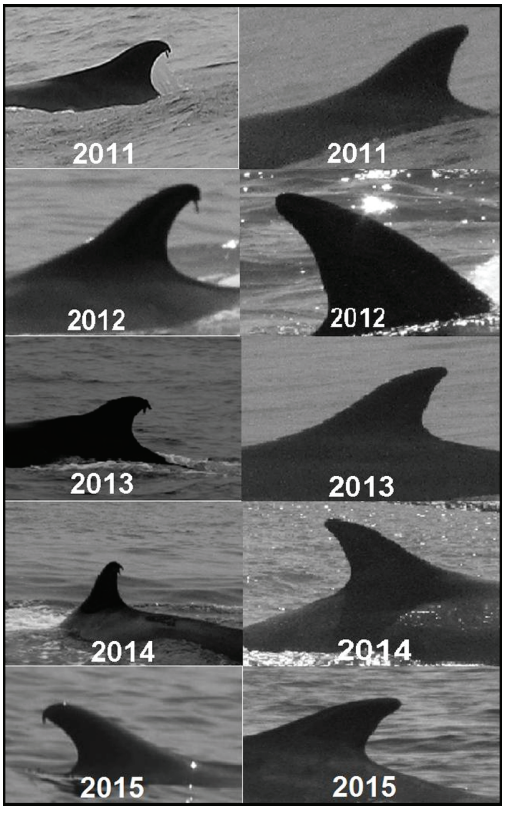

Figure 6. Two catalogued individual fin whales recorded yearly from 2011 to 2015 in the study area, coast of northern Chile

this also would be the first such coastal destination known for fin whales for the ESP.

Characteristic dorsal fin shape and nicks (*sensu* Agler et al., 1990) indicate two of the fin whales observed in surveyed waters of the archipelago returned to the study area in 4 y, five in 2 y, and ten individuals resided in the area during summer for periods of 1 wk to 3 mo between 2011 and 2014. Re-identification of individuals could be attributed to repeated passage through these waters on an established migratory route, but transit does not explain longer-term (up to 3 mo) periods of residence in these waters reported for some individuals unless they specifically migrated to or perhaps stopped over in this region given a local abundance of food. An equivalent final feeding destination along the Chilean coast has been reported for humpback whales at Strait of Magellan (Gibbons et al., 2003; Acevedo et al., 2007; Capella et al., 2008) and for blue whale at Corcovado Gulf (Hucke-Gaete et al., 2003). The hypothesis of a highly productive zone for whales and other cetaceans feeding in our study area is plausible as it is located in the northern limit of the Coquimbo Bay (30° S), a strong and predictable coastal upwelling (Montecino et al., 1996; Marín & Delgado, 2003; Thiel et al., 2007) where *E. mucronata* concentrations are common (Escribano et al., 2000; Antezana, 2002). Trophic links between euphausids, feeding whales (e.g., blue and fin whales), and coastal upwellings have been described off California (Croll et al., 2005) and Azores (Silva et al., 2013).

If migration accounts for the recurring observation of certain individuals in inshore waters, neither their direction nor destination is known. Most probably, fin whales that stay the entire summer off central-north Chile will not go to the Antarctic. Future research is needed, particularly on genetics, to establish the level of relatedness with Antarctic fin whales as a way to know if this whale population corresponds either as part of a larger Antarctic population or a separate stock such as the blue whales from southern Chile (Hucke-Gaete et al., 2003).

It is possible that our study area is also a marginal habitat, being on the fringe of or part of a much larger feeding area for this species and other baleen whales as well. For blue whales, individuals sighted in our study area were re-sighted in south Chile (41° S), a recognized feeding ground destination (Hucke-Gaete et al., 2003; Galletti-Vernazzani et al., 2012).

Given that few juvenile and no calf fin whales have been reported from Chilean waters in over 50 y (Clarke, 1962; Clarke et al., 1978; Aguayo et al., 1998a; Capella et al., 1999; Pérez et al., 2006; Acevedo et al., 2012; this paper) it is likely that females with calves neither visit nor migrate through them. Alternatively, new migratory routes and feeding locations in the area described in this study might be being explored by individuals within an aging adult population.

As fin whales only have been recorded from the last two decades in the study area, and now routinely occur within it and throughout the year, it is possible that the ESP population of this species is recovering as has been the case for certain Northern Hemisphere regions (Moore & Barlow, 2011). Should the population be recovering and should inshore Chilean waters prove suitable habitat for this species, then the possibility of calves being sighted in the future cannot be discounted. Should the opposite scenario be the case, then none is likely, and the fin whale population is truly in trouble.

The existence of fin whales and various species of other whales and dolphins in the coastal area certainly maximizes vulnerability to human activities like the nonregulated but constantly increasing whale-watching operations (Ramírez, 2005) and the risk of collisions with vessels transiting the close maritime route to Coquimbo harbor. Vessel strike on cetaceans is a real threat that has

been documented in Chile in the last few decades (Canto et al., 1991; Hucke-Gaete et al., 2005; Van Waerebeek et al., 2007), with estimates of evidence of collision on 4% of stranded cetaceans for Chilean waters by Galletti-Vernazzani & Cabrera (2007). Understanding the patterns of habitat use, residency, and local movements is critical for conservation of this fin whale population. Future satellite tracking data may improve our understanding of migratory routes and residency in feeding areas that will allow a comprehensive assessment of anthropogenic threats faced by fin whales, providing the basis for implementing effective and dynamic national management and conservation measures.

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