Polar Biol (2012) 35:801–806
DOI 10.1007/s00300-011-1133-8

SHORT NOTE

Habitat use of hourglass dolphins near the South Shetland Islands, Antarctica

Jarrod A. Santora

Received: 3 September 2011 / Revised: 14 November 2011 / Accepted: 15 November 2011 / Published online: 3 December 2011

Abstract The hourglass dolphin *Lagenorhynchus cruciger* is the only regularly occurring small delphinid found south of the Antarctic Polar Front, yet little is known about its ecology and habitat use. This study uses 8 years (14 cruises) of standardized shipboard surveys during January–March (2003–2011) in southern Drake Passage near the South Shetland Islands to summarize the spatial distribution of hourglass dolphin sightings and quantify habitat use. Sighting data are linked to bathymetry (depth, slope) and distance to the average location of oceanographic features. A generalized linear model is used to examine the relationships between sightings and habitat features. Hourglass dolphins were sighted on 50% of surveys ($n = 29$); sightings were concentrated in February. Group size tended to be 2–6 individuals; there were only 2 sightings of larger groups, of 15 and 25 individuals. Sightings were distributed entirely within the deep pelagic waters north of the South Shetland Islands in southern Drake Passage and were closely associated with the southern boundary of the Antarctic Circumpolar Current. Information on occurrence and distribution reported in this study may be useful for refining habitat associations for hourglass dolphins at regional scales in the Southern Ocean.

Keywords Antarctic Circumpolar Current · Habitat use · Hourglass dolphin · *Lagenorhynchus cruciger* · South Shetland Islands

Electronic supplementary material The online version of this article (doi:10.1007/s00300-011-1133-8) contains supplementary material, which is available to authorized users.

J. A. Santora (✉)
Fisheries Ecology Division, Southwest Fisheries Science Center, NOAA, 110 Shaffer Rd., Santa Cruz, CA 95060, USA
e-mail: jasantora@gmail.com

Introduction

The hourglass dolphin *Lagenorhynchus cruciger* has a circumpolar distribution in the Southern Ocean and is the only small delphinid regularly found south of the Antarctic Polar Front (Brownell and Donahue 1999; Electronic Supplementary Material Figure). Very little is known about its habitat, dietary preferences and interactions with other cetaceans (Ashford et al. 1996; Goodall et al. 1997; Fernandez et al. 2003; Goodall 2009). In the southwest Atlantic, localized concentrations have been documented around the southern tip of South America, Falkland Islands and South Georgia (Goodall 1997; Goodall et al. 1997; White et al. 1999). However, information regarding the occurrence and spatial distribution of these dolphins in waters around the South Shetland Islands and Antarctic Peninsula is lacking. Understanding habitat use patterns of hourglass dolphins should provide valuable information about their spatial ecology, role in food webs and potential interactions with commercial fishery operations in this region (Trites et al. 1997).

The Antarctic Circumpolar Current (ACC) in Drake Passage (Fig. 1) is characterized by a series of frontal zones that form boundaries between different water masses. The southernmost extent of the ACC, the southern boundary (sbACCf), is marked by shoaling and terminus of warm Upper Circumpolar Deep Water. The ACC frontal jets and boundary are important ecological features, the location of which vary spatially due to bathymetry and changes in atmospheric pressure and wind forcing (Orsi et al. 1995; Tynan 1998). This highly dynamic region provides important habitat for a variety of marine mammals and seabirds (Tynan 1998; Santora et al. 2009, 2010). Specifically, in southern Drake Passage, the ACC southern front (sACCf) and boundary (Fig. 1) are locations of complex ocean mixing (e.g., eddies) that contain elevated concentrations of Antarctic krill (*Euphausia superba*), myctophids and squid (Rodhouse and White 1995; Pakhomov et al. 1996). The sbACCf lies immediately along the northern shelf-break of South Shetland Islands, with bathymetrically related longitudinal variation (Fig. 1). This is the location of wind-driven divergence and upwelling that bring relatively warm, nutrient-rich water to the surface, thereby supporting elevated primary and secondary production. Because of the predictability of high densities of baleen whales at the sbACCf, this region was targeted during commercial whaling operations (Tynan 1998). Recent works document the spatial relationships between fin whales (*Balaenoptera physalus*) and krill as well as southern bottlenose whales (*Hyperoodon planifrons*) relative to the sbACCf (Santora et al. 2010; Santora and Brown 2010).

The objective of this study is to summarize sightings of hourglass dolphins recorded during 14 oceanographic surveys around the South Shetland Islands during austral summer (January–March) to determine their habitat use patterns. In particular, I examine the relationships between dolphin sightings, bathymetry and average position of oceanographic features. Such baseline information is required for inferring relative abundance and distribution patterns of hourglass dolphins, which is important for understanding their role in Antarctic marine ecosystems.

Methods

The US Antarctic Marine Living Resources (AMLR) program (NOAA NMFS) conducts annual standardized surveys in southern Drake Passage and Bransfield Strait waters surrounding the South Shetland Islands (Elephant, King George and Livingston Islands; Fig. 1). Ship-based surveys are on a fixed grid along inshore and offshore north–south transects with stations spaced at ca. 55-km intervals across a $\sim 120{,}000\ \mathrm{km}^2$ area. During January–March 2003–2011, a total of 14 surveys were conducted to map the distribution and relative abundance of seabirds and marine mammals. Each month-long survey covered

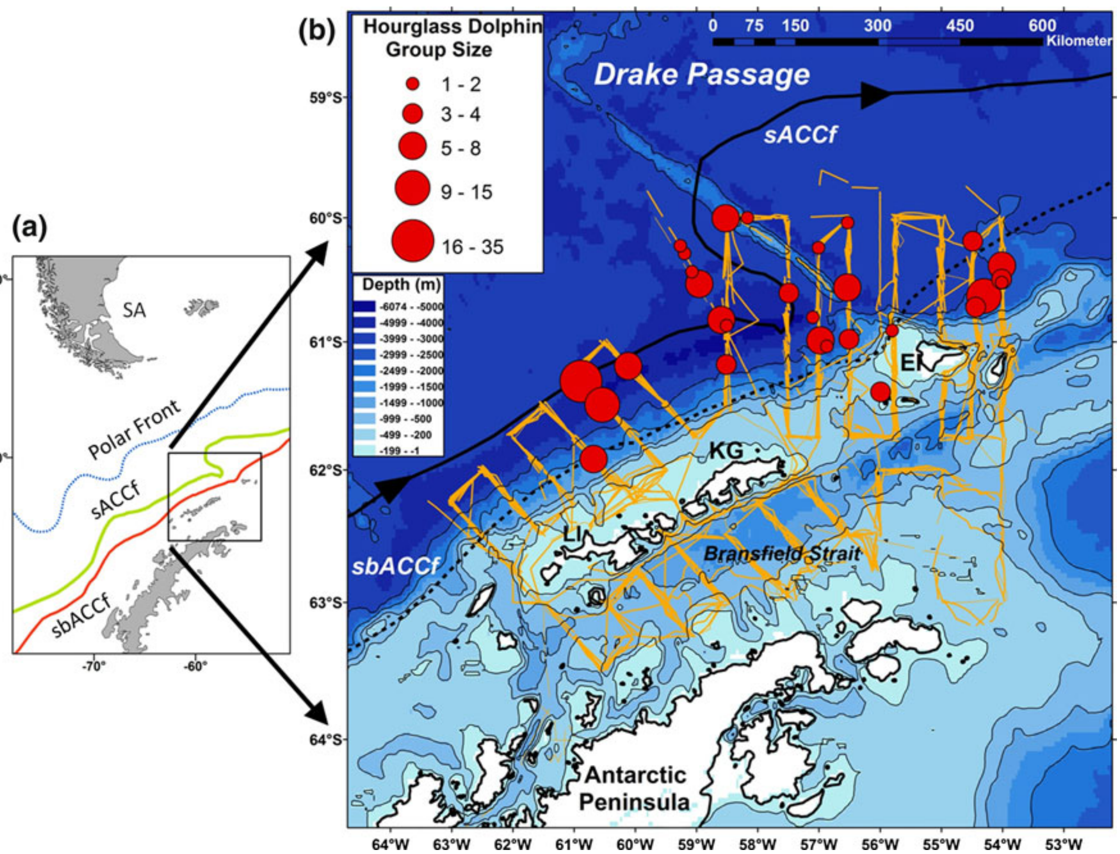

Fig. 1 **a** Southwest Atlantic region showing the location of the South Shetland Islands (SSI), oceanographic fronts within Drake Passage and the US AMLR survey area. Fronts are from Orsi et al. 1995 and 'sACCf' is southern Antarctic Circumpolar Current front, and sbACCf is southern boundary of the Antarctica Circumpolar Current front. 'SA' is South America. **b** Survey trackline (*yellow*) and spatial distribution of sightings and group size of hourglass dolphins collected during 14 AMLR surveys. 'LI' is Livingston Island, 'KG' is King George Island and 'EI' is Elephant Island (color figure online)

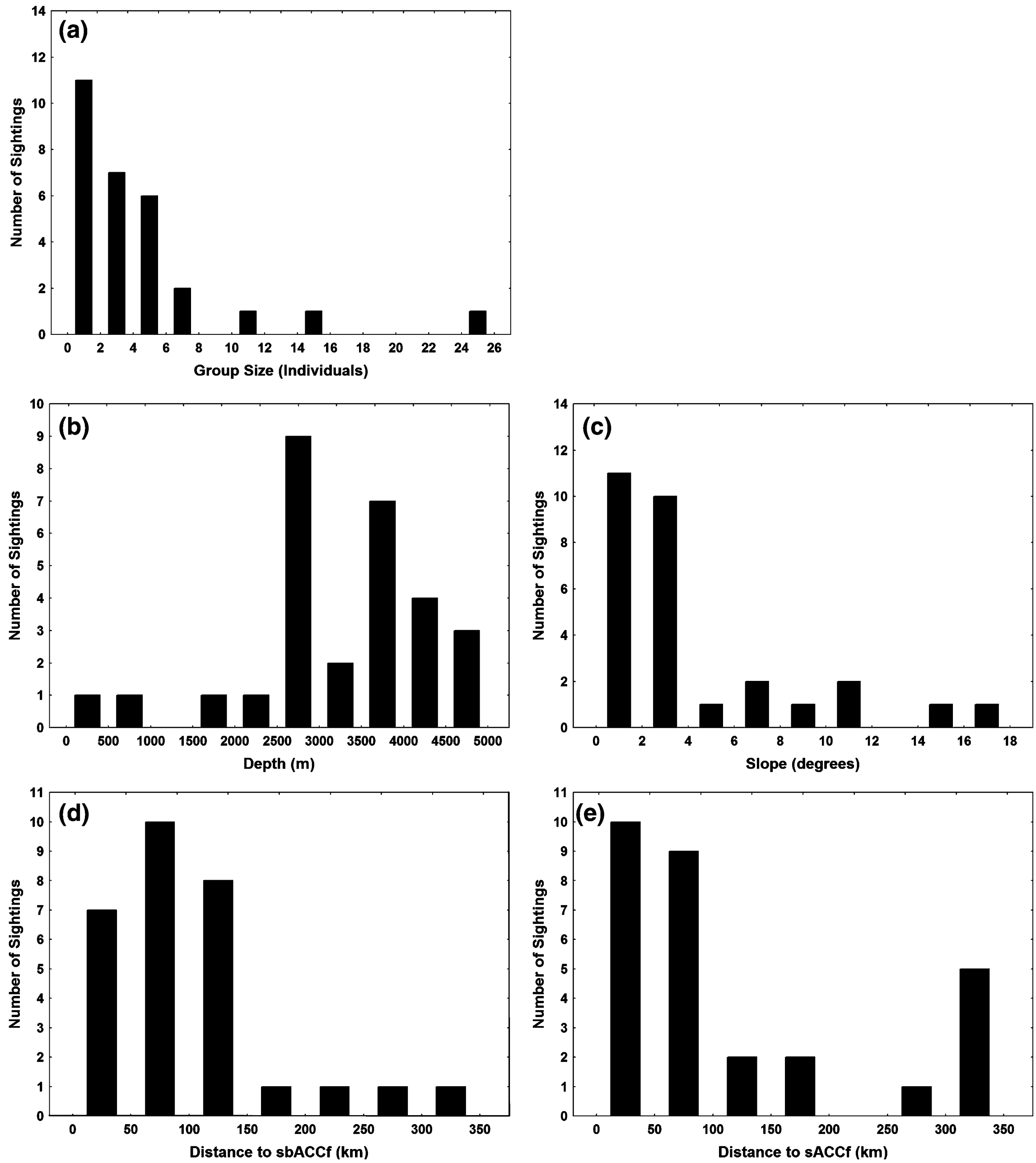

Fig. 2 Frequency distribution of hourglass dolphin sightings in relation to **a** group size (individuals), **b** depth (m), **c** slope (degrees), **d** distance to sbACCf (km) and **e** distance to sACCf (km)

~2,500 km of trackline. For additional review of survey effort, please see Santora and Brown (2010) and Santora et al. (2010).

Sighting data on top-predator species abundance and distribution were continuously collected using standard line transects during daylight hours on transits between the sampling stations (Fig. 1). Ship speed was usually 10 knots (~18.6 km/h). Experienced bird and cetacean observers used hand-held binoculars from a height of ~13 m above sea level. Data were entered into a computer using real-time mapping software, and positions were logged every 10 s while underway. Each sighting was assigned a time (to the nearest tenth of a second) and spatial position from the ships' global positioning system (GPS). Sea surface state (Beaufort scale) and visibility (e.g., fog, glare) were monitored, and effort during unfavorable conditions (e.g., Beaufort >6, heavy fog) was excluded from the data set (Santora et al. 2010; Santora and Brown 2010). Weather conditions permitting all sightings recorded were observed in a 180° arc forward of and up to 3 km away from the vessel. For each sighting, a best-estimate spatial position, bearing and distance estimate to the ship's trackline were logged (Buckland et al. 1993). However, due to their small size and attraction to ships (e.g., bow-riding) combined with often undesirable sea states, the sightings of hourglass dolphins reported in this study were detected within 10–500 m from the ship's trackline. Therefore, group sizes of dolphins are estimates that reflect animals, which were in close proximity to the ship and do not take into account detection probability at distances greater than 500 m.

Hourglass dolphin sightings were integrated in a GIS and linked to geo-referenced data on bathymetry (depth, slope) and distance (km) to the average position of oceanographic fronts (Orsi et al. 1995) including the sACCf and sbACCf. Given the general paucity of dolphin sightings, all data were combined for analysis to examine their habitat use patterns. A generalized linear model (GLM) is used to examine the relationships between sighting group size and spatial covariates for describing habitat use of dolphins (Ferguson et al. 2006). Sighting group size is specified as a Poisson distribution with a log-link function.

Results

A total of 29 hourglass dolphins sightings were made, yielding a mean group size of 4.79 ± 5.01 SD (Tables 1, 2). Three sightings were of group sizes greater than 10 individuals, with the largest group comprised of 25 individuals. Dolphins were only sighted on 7 of 14 surveys (50%) during 5 years, with sightings predominantly concentrated (23 of 29) during February (Tables 1, 2).

Table 1 Summary of sightings by year

Year	Sightings	Ind.	Mean Ind. per sighting	SD	Min	Max
2003	6	26	4.3	2.6	1	7
2005	6	41	6.8	9.2	1	25
2009	2	5	2.5	0.7	2	3
2010	7	27	3.8	3.5	1	11
2011	8	40	5.0	4.2	2	15
Total	29	139	4.8	5.0		

No sightings were made during 2004, 2006–2008 surveys

Table 2 Summary of sightings by month

Month	Sightings	Individuals	Mean Ind. per sighting	SD	Min	Max
January	2	5	2.5	0.7	2	3
February	23	111	4.8	5.4	1	25
March	4	23	5.7	4.1	1	11
Total	29	139	4.4	5.0		

All hourglass dolphins were observed in southern Drake Passage north of the South Shetland Islands (Fig. 1). They were highly clustered north of Elephant Island, particularly to the northwest around the topographic relief of the Shackleton Fracture Zone and northeast in proximity to the sbACCf (Fig. 2). They occurred in regions between the sbACCf and sACCf; 86% of sightings were located within ~125 km from the SACCB, while 65% of sightings were within 100 km from the sACCf. The majority of sightings (90%) were located in waters greater than 2,000 m in depth with low slope values, indicating affinity for deep pelagic waters away from the shelf-break (Figs. 1, 2).

The GLM indicates that distance to the ACC fronts is a significant predictor of dolphin distribution (Table 3). The model also shows that slope is negatively related to sighting spatial distribution, with most sightings occurring in waters of low bathymetric relief. Regarding spatial distribution, sightings and group size are negatively related to latitude, indicating that sightings increased further to the south, possibly involving an attraction to the ACC southern boundary. On the other hand, longitude is not a significant factor; this may indicate that within this region, dolphin sightings tend to be distributed uniformly along the longitudinal extent of the frontal system (Table 3).

Discussion

Due to its highly pelagic nature and broad distribution in the Southern Ocean, the hourglass dolphin remains one of the least understood delphinids (Brownell and Donahue 1999). This study examined habitat use during January–March in southern Drake Passage and coastal Antarctic waters around the South Shetland Islands. Dolphins were sighted on 50% of surveys, with greatest frequency in late summer (February–March). Sightings were located well offshore in deep waters (>2,000 m) and were associated with the southern boundary of the Antarctic Circumpolar Current. Previous studies in the southwest Atlantic Ocean described distribution and occurrence of hourglass dolphins at the northern part of their range around the southern tip of South America (Goodall 1997); Falkland Islands (White et al. 1999) and South Georgia (Ashford et al. 1996; Rossi-Santos et al. 2007). This study focused on their habitat use at their southern distribution range within an ecologically important area for cetaceans (Tynan 1998; Santora et al. 2010). Furthermore, the study area is used by the commercial fishery for krill (Constable et al. 2000), and the dolphin distribution patterns described here may be

Table 3 GLM results for hourglass dolphin distribution

Effect	Estimate	Lower 95% CL	Upper 95% CL	SE	Wald Stat.	P
Dist sACCf	0.0051	0.002	0.0081	0.0015	10.777	0.001
Dist sbACCf	0.0052	0.001	0.0099	0.0024	4.926	0.026
Slope	−0.0747	−0.135	−0.0144	0.0307	5.901	0.015
Depth	0.0003	0.000	0.0006	0.0001	8.827	0.003
Latitude	−1.0318	−1.732	−0.3314	0.3574	8.337	0.004
Longitude	−0.1417	−0.331	0.0479	0.0967	2.146	0.143

"Dist sACCf" and "Dist sbCCf" are distance in km from sighting to the southern Antarctic Circumpolar Current front and its southern boundary, respectively

relevant for assessing potential interactions between cetaceans and fishing vessels (Ashford et al. 1996; Koch et al. 2005).

It is unclear why dolphins were only sighted on 50% of surveys and concentrated during February–March surveys. One explanation is that it may be due in part to a seasonal phenological shift in environmental conditions within southern Drake Passage. Kasamatsu and Joyce (1995) indicated that sightings of hourglass dolphins increased in early February. They postulated that the seasonally increased sighting frequency may relate to thermoregulation of this small-bodied species and that it coincided with either an increase in sea surface temperature or prey availability. Within the AMLR study area, spatial variability and interannual changes in the distribution and abundance of seabirds are linked to krill (Santora et al. 2009). Therefore, prey availability (abundance and aggregation intensity) may be an important factor underlying seasonal shifts in hourglass dolphin abundance (e.g., migration to optimal forage areas).

This study shows that oceanographic features are an important determinant of habitat use in southern Drake Passage. Although dolphin sightings were clustered in proximity to the sACCf and sbACCf, it is unclear what biological properties (prey type and concentration) are important to their habitat selection, especially at relatively fine scales within these features. In this region, krill are the principal prey for many species of fish, squid, seabirds and marine mammals, and they tend to concentrate with fronts (Atkinson et al. 2008). However, while no dietary information exists for hourglass dolphins near the South Shetland Islands, stomach contents of specimens from southern South America indicated that myctophids, squids and crustaceans are common prey (Goodall et al. 1997; Fernandez et al. 2003; Goodall 2009). Habitat selection by hourglass dolphins near the South Shetland Islands potentially indicates key areas for myctophids and squids in this region (Santora and Brown 2010). Since myctophids and squid feed on krill (Rodhouse and White 1995; Pakhomov et al. 1996), hourglass dolphins may exert indirect effects on krill populations, information useful for refining food web and ecosystem models (Hill et al. 2007).

Further study is needed to examine the spatial relationships among baleen and toothed whales near the South Shetland Islands. The spatial distribution patterns of hourglass dolphins described here overlap with those for southern bottlenose whales and fin whales (Santora and Brown 2010; Santora et al. 2010), indicating that these species are concentrating within the proximity of the sACCf and sbACCf, likely due to elevated prey concentration. However, it is unclear how they interact, whether they associate with each other and what types of prey they are selecting. It is generally assumed that fin whales are targeting krill aggregations while southern bottlenose whales and hourglass dolphins are presumably foraging on myctophids and squid. Clearly, their spatial overlap indicates these species select similar pelagic habitat and that the southern boundary of the ACC is an important factor. Using a multispecies approach, further study is needed to compare the spatial relationships and habitat use among baleen and toothed whales, as well as for pinnipeds and seabirds (Santora and Reiss 2011).

This study shows that there likely are predictable seasonal and spatial distribution patterns of hourglass dolphins north of the South Shetland Islands. Owing to their small size, combined with often undesirable ambient sea states, estimation of their population size remains problematic. Based on surveys during 1976/77 and 1987/88, Kasamatsu and Joyce (1995) reported a population estimate of 144,300 individuals for the entire Southern Ocean. The present study indicates that repeated surveys are useful for revealing temporal and spatial distributions of dolphins in relation to their environment. The relationship between sightings and oceanographic features developed in this study may be useful for targeting studies of other locations within the ACC that may be attractive to hourglass dolphins and for potentially improving our understanding of their population at local scales in the Southern Ocean.

Acknowledgments Funding support was provided by contracts to J. A. Santora from the NOAA US Antarctic Marine Living Resources program and to Richard R. Veit from an NSF-OPP grant (OPP-9983751). A special thanks to Michael P. Force and Kimberly S. Dietrich (photo credit) for assisting in collecting observations and to Valerie J. Loeb for providing valuable discussion.

References

Ashford JR, Rubilar PS, Martin AR (1996) Interactions between cetaceans and longline fishery operations around South Georgia. Mar Mamm Sci 12:452–457

Atkinson A, Siegel V, Pakhomov EA, Rothery P, Loeb V, Ross RM, Quetin LB, Schmidt K, Fretwell P, Murphy EJ, Tarling GA, Fleming AH (2008) Oceanic circumpolar habitats of Antarctic krill. Mar Ecol Prog Ser 362:1–23

Brownell RL Jr, Donahue MA (1999) Hourglass dolphin *Lagenorhynchus cruciger* (Quoy and Gaimard, 1824). In: Ridgway SH, Harrison R (eds) Handbook of marine mammals, vol 6: the second book of dolphins and the porpoises. Academic Press, London, pp 121–135

Buckland ST, Anderson DR, Burnham KP, Laake JL (1993) Distance sampling: estimating abundance of biological populations. Chapman & Hall, London

Constable AJ, de la Mare WK, Agnew DJ, Everson I, Miller DGM (2000) Managing fisheries to conserve the Antarctic marine ecosystem: practical implementation of the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR). ICES J Mar Sci 57:778–791

Ferguson MC, Barlow J, Fiedler P, Reilly SB, Gerrodette T (2006) Spatial models of delphinid (family Delphinidae) encounter rate and group size in the eastern tropical Pacific Ocean. Ecol Model 193:645–662

Fernandez M, Beron-Vera B, Raga JA, Crespo EA (2003) Food and parasites from two hourglass dolphins *Lagenorhynhus cruciger* (Quoy and Gaimard, 1824), from Patagonian waters. Mar Mamm Sci 19:832–836

Goodall RNP (1997) Review of sightings of the hourglass dolphin, *Lagenorhynchus cruciger*, in the South American sector of the Antarctic and the sub-Antarctic. Rep Int Whal Comm 47:1001–1014

Goodall RNP (2009) Hourglass dolphin *Lagenorhychus cruciger*. In: Perrin WF, Würsig B, Theurissen YGM (eds) Encyclopedia of marine mammals. Academic Press, Amsterdam, pp 573–576

Goodall RNP, Baker AN, Best PB, Meyer M, Miyazaki N (1997) On the biology of the hourglass dolphin, *Lagenorhynchus cruciger* (Quoy and Gaimard, 1824). Rep Int Whal Comm 47:985–999

Hill SL, Reid K, Thorpe SE, Hinke J, Watters GM (2007) A compilation of parameters for ecosystem dynamics models of the Scotia Sea - Antarctic Peninsula region. CCAMLR Sci 14:1–25

Kasamatsu F, Joyce GG (1995) Current status of odontocetes in the Antarctic. Antarct Sci 7:365–379

Koch K-H, Purves MG, Duhamel G (2005) Interactions between cetaceans and fisheries in the Southern Ocean. Polar Biol 29:379–388

Orsi AH, Whitworth T, Nowlin WD (1995) On the meridional extent and fronts of the Antarctic Circumpolar Current. Deep-Sea Res Pt I 42:641–673

Pakhomov EA, Perissinotto R, McQuaid CD (1996) Prey consumption and daily rations of myctophid fishes in the Southern Ocean. Mar Ecol Prog Ser 134:1–4

Rodhouse PG, White MG (1995) Cephalopods occupy the ecological niche of epipelagic fish at the Antarctic Polar Frontal Zone. Biol Bull 189:77–80

Rossi-Santos MR, Baracho C, Cipolotti S, Marcovaldi E (2007) Cetacean sightings near South Georgia islands, South Atlantic Ocean. Polar Biol 31:63–68

Santora JA, Brown ET (2010) Spatial distribution patterns of southern bottlenose whales *Hyperoodon planifrons* near the South Shetland Islands. Mar Mamm Sci 26:960–968

Santora JA, Reiss CS (2011) Geospatial variability of krill and top-predators within an Antarctic submarine canyon system. Mar Biol 158:2527–2540

Santora JA, Reiss CS, Cossio AC, Veit RR (2009) Interannual spatial variability of Antarctic krill (*Euphausia superba*) influences seabird foraging behavior near Elephant Island, Antarctica. Fish Oceanogr 18:20–35

Santora JA, Reiss CS, Loeb VJ, Veit RR (2010) Spatial association between hotspots of baleen whales and demographic patterns of Antarctic krill *Euphausia superba* suggest size dependent predation. Mar Ecol Prog Ser 405:255–269

Trites AW, Chistensen V, Pauly D (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. J Northwest Atl Fish Sci 22:173–187

Tynan CT (1998) Ecological importance of the southern boundary of the Antarctic Circumpolar Current. Nature 392:708–710

White RW, Reid JB, Black AD, Gillon KW (1999) Seabird and marine mammal dispersion in the waters around the Falkland Islands 1998–1999. Joint Nature Conservation Committee, UK