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Short Note

First Observations of Cooperative Circle Feeding in Southern Right Whales (*Eubalaena australis*)

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Marine mammals have developed various feeding strategies, including cooperative foraging in groups. Cooperative feeding is more common in social marine mammals like odontocetes that include smaller oceanic dolphins (Neumann & Orams, 2003; Oliveira et al., 2013) and killer whales (*Orcinus orca*; Similä & Ugarte, 1993; Pitman & Durban, 2012). Cooperative feeding allows these species to hunt more efficiently by working together to gain access to food. For example, common bottlenose dolphins (*Tursiops truncatus*) can create waves and simultaneously rush towards the shore to catch fish (Gazda et al., 2005; Duffy-Echevarria et al., 2008; Jiménez & Alava, 2015). Dusky dolphin (*Lagenorhynchus obscurus*) behavior has been studied in Argentina and New Zealand where they exhibit considerable plasticity in feeding behaviors by using diverse feeding tactics that include herding prey (Würsig & Würsig, 1980), using the shore as a barrier, and feeding individually (Vaughn et al., 2007). Killer whales are found in several different ecotypes which feed on varying items, including fish, seals, dolphins, whales, and birds, and have been observed knocking seals into the water from ice floes or herding dolphins cooperatively (Pitman & Durban, 2012; Coscarella et al., 2015). Contrary to odontocetes, which often feed in large groups, most mysticetes forage singly and independently (Heithaus & Dill, 2008). Nevertheless, cooperative feeding, for example, by using bubble-net feeding (Hain et al., 1982, Wiley et al., 2011; Ware et al., 2014), is relatively well described for humpback whales (*Megaptera novaeangliae*).

Mysticetes exhibit one of the most energetically efficient foraging strategies by feeding on aggregations of zooplankton and small fish (Goldbogen et al., 2011), and many strategies and tactics are used to locate and capture prey (Heithaus & Dill, 2008). Humpback whales, like other baleen whales (Balaenopteridae), use intermittent ram feeding or lunge feeding, techniques in which an individual animal engulfs a large volume of prey-laden water (Goldbogen et al., 2010). Another strategy is trap-feeding, reported in Chile, where herding with pectorals increases concentrations of diffuse schools of small fish towards the whale's open mouth, used as a trap (García-Cegarra et al., 2021). Contrary to Balaenopteridae, gray whales (*Eschrichtius robustus*) use suction to consume benthonic prey by sucking the prey into their mouth while bottom feeding (Werth, 2000; Goldbogen et al., 2017), whereas bowhead (*Balaena mysticetus*) and right (*Eubalaena* spp.) whales use a continuous filter feeding approach at the water's surface called skim feeding (Goldbogen et al., 2017). This technique involves the continuous filtration of water to skim dense swarms of zooplankton (Werth, 2000).

In the present study, we report the observation of a large group of southern right whales (*Eubalaena australis*; SRWs) cooperatively foraging in Bahía Nueva (Puerto Madryn), Argentina (Figure 1). By "cooperating," we refer to SRWs being able to work together to concentrate their prey and obtain more food with less expenditure of time or energy than they could invest alone. This feeding behavior that we propose to be termed *cooperative circle feeding behavior* is, to our knowledge, the first record of this activity for this species.

The cooperative circle feeding observation was opportunistically conducted from a semi-rigid hull research boat (5.60 m long with a 60 HP outboard engine) at a distance < 100 m to the whales while studying interactions between whales and maritime

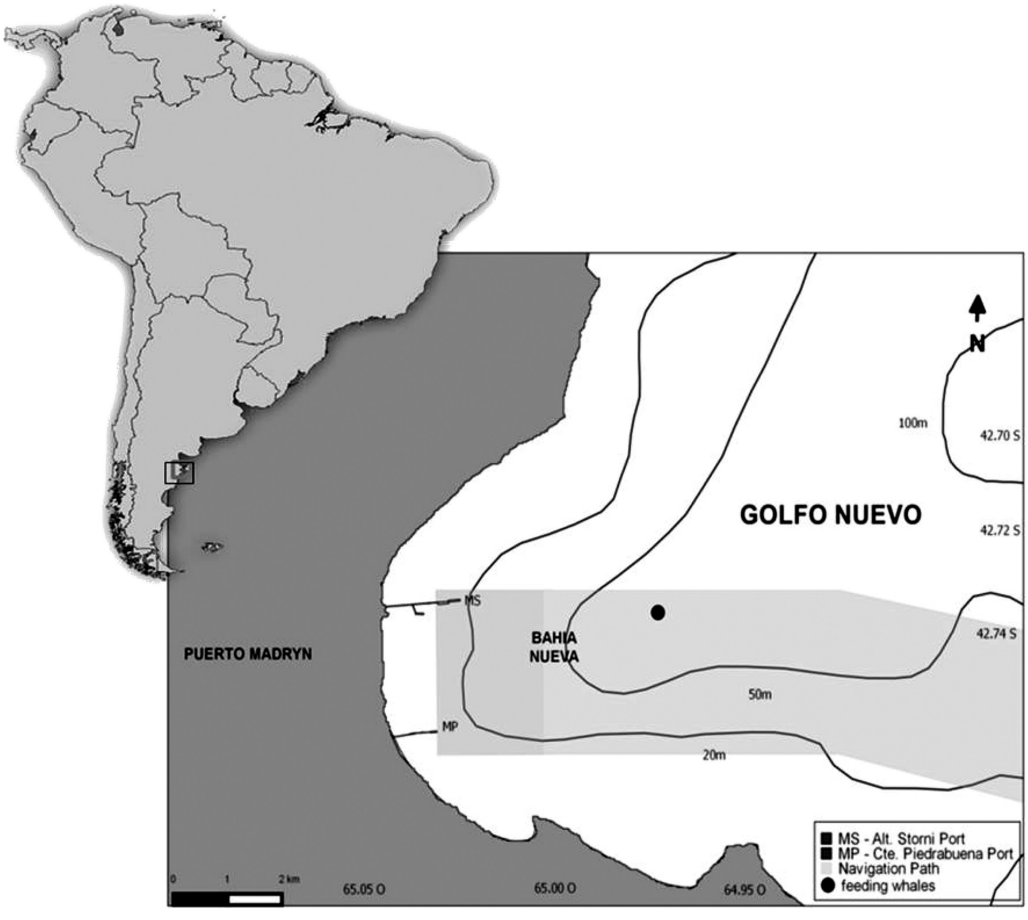

Figure 1. Study area in Golfo Nuevo, Patagonia, Argentina. Black dot represents the area where feeding southern right whales (*Eubalaena australis*; SRWs) have been observed. Puerto Madryn ports (black solid lines) and the route used by ships to enter the Puerto Madryn ports (light grey area) are also shown.

traffic (Argüelles et al., 2021). During this study, 971 whale observations were recorded in 34 trips that were undertaken in the survey area between 2013 and 2015. The area surveyed covered 42.76 km^2, using a line transect design (Argüelles, 2017), totaling 972.14 km of track-line effort. The most common behaviors observed were surface activity (including active behaviors such as breaching and tail/pectoral fin slapping), traveling, resting, and diving (Argüelles et al., 2021). Most whale groups (70.14%) consisted of one or two individuals.

On 28 August 2014, a feeding group of at least 40 adult SRWs were observed associating and swimming synchronously in a feeding patch for 90 min (Figure 1). Whales were in pairs, forming two concentric circles about 1,000 m in diameter around the prey (unidentified small reddish zooplankton) and were separated from other pairs by an approximate average distance of about six whale body lengths. All individuals were oriented towards the same direction (Figure 2). Although water depth in the area is more than 50 m, whales were feeding at the surface. All whale pairs—one whale at the inner side of the circle (whale 1) and the other at the outer side (whale 2)—were observed in side-by-side or echelon formation while swimming at the surface (Figure 3; see supplementary video).

Similar events, but at a smaller scale and involving fewer animals, were observed in 2015. A feeding group of five individuals was observed swimming with open mouths in a circular pattern (27 August 2015). These whales were neither in pairs nor swimming in echelon formation, and they were separated by a distance of half an adult body length (Figure 4). Also in 2015 (20 November), a group of 10 whales (5 pairs) was also observed

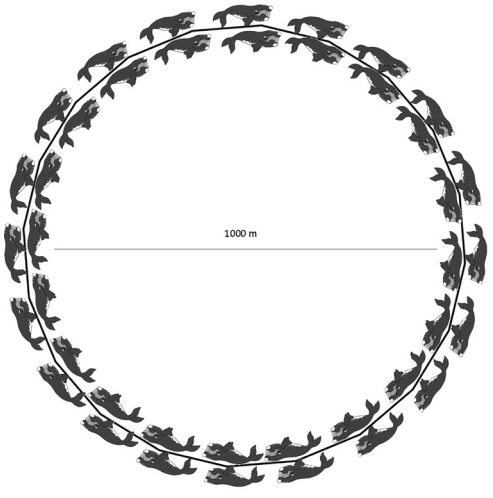

Figure 2. Schematic of cooperative feeding with pairs of SRWs in echelon formation around a circle. *Date of observation:* 28 August 2014. *Number of whales observed:* 40 adult whales. (Illustration created by Soledad Martínez)

swimming in echelon formation while surface feeding.

SRWs migrate annually between high-latitude feeding areas in the austral summer and low-latitude breeding grounds in the austral winter. Evidence based on genetic and stable isotope data demonstrate maternally directed fidelity to summer feeding grounds (Valenzuela et al., 2009). Feeding grounds are poorly known and mostly inferred from whaling records (Smith et al., 2012; Torres et al., 2013; González Carman et al., 2019), and more recently satellite track data (Zerbini et al., 2018). Even though the study area represents an important breeding ground for the species (Bastida et al., 2007), SRWs could be most often watched feeding when they have the opportunity to encounter some prey item. Hoffmeyer et al. (2010) demonstrated that patches of zooplankton in the Península Valdés breeding ground during spring are dense enough to make feeding worthwhile in this nursery. D'Agostino et al. (2018) confirmed that dense patches of mesozooplankton are exploited by SRWs in the Península Valdés breeding area with two annual peaks: during austral spring, following the annual phytoplankton maximum, and during late austral summer.

The cooperative circle feeding described herein involved a large group of adult whales working

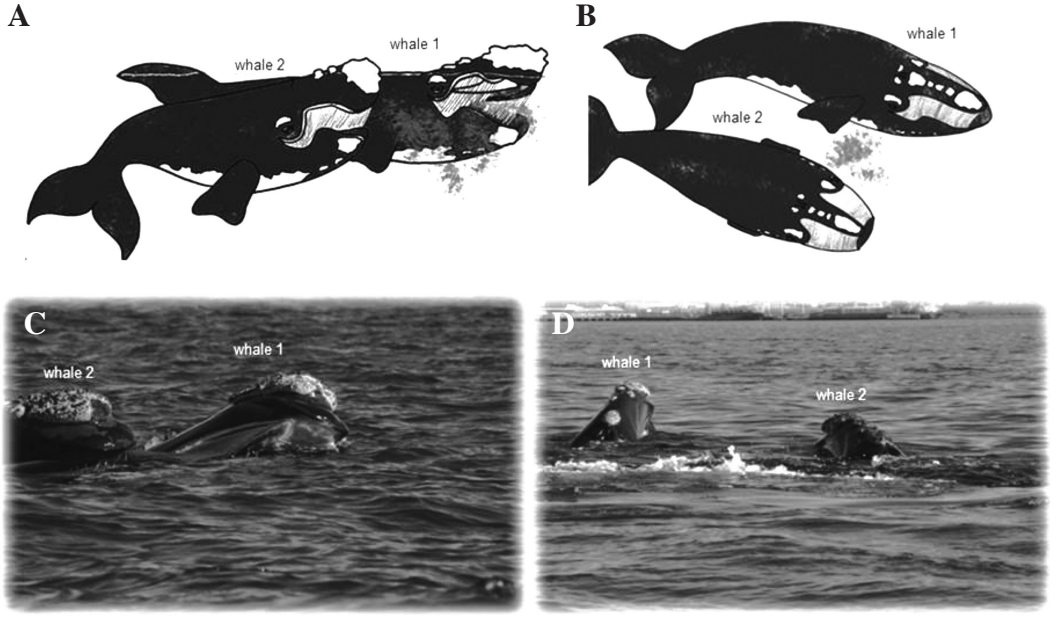

Figure 3. (A & B) Schematics of two SRWs swimming in echelon formation, with a side view (A) and a top view (B) (Illustrations created by Soledad Martínez). (C & D) Photographs of two SRWs swimming in echelon formation. Feeding is facilitated by the whale at the inner side of the circle (whale 1) pushing the swarm through to the whale at the outer side of the circle (whale 2) (*Photo credit:* Dr. Carla Fiorito).

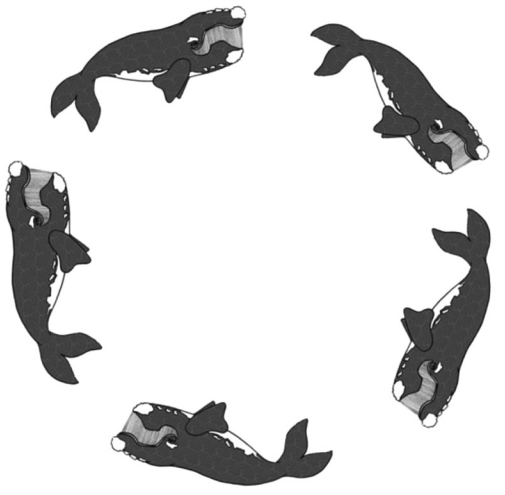

Figure 4. Schematic of SRWs feeding in a circle formation. Whales were neither in pairs nor swimming in echelon formation. *Date of observation:* 27 August 2015. *Number of whales observed:* 5 adult whales. (Illustration created by Soledad Martínez)

together to obtain the prey item. This was the first event in which a large group of SRWs were observed in a circular pattern, with individuals feeding synchronously and oriented in the same direction. Moreover, all pairs of whales observed in the circle were in echelon formation. Echelon swimming has been reported for bowhead whales (Landino et al., 1994; Fish et al., 2013; Goldbogen et al., 2017), but cooperative circle feeding as described herein has not been reported for that species (F. E. Fish, pers. comm., 24 January 2018). It has been demonstrated that echelon formations may increase feeding efficiency for bowhead whales (Würsig et al., 1985; Fish et al., 2013). This formation is thought to allow a trailing whale to capture the food spilled from the mouth of a lead whale or for a lead whale to channel prey towards a trailing individual (Würsig et al., 1985; Fish et al., 2013).

The purpose of circle swimming may be to congregate prey near the center of the circle to keep the prey packed together. Unfortunately, there was no aerial footage of the behavior, so it was difficult to establish the role of each whale in the circle or if there were whales diving beneath the prey. The 2014 event counted at least 40 adult whales, but there may have been more. Prey was observed via researchers' naked eyes inside the circle; and though it was not possible to collect a sample, it may well be some kind of *Euphasia* sp. or copepod species. Copepods are known to be preyed upon by the whales in the area (D'Agostino et al., 2016).

Nevertheless, the circle formation could suggest a prey item that is large and powerful enough to escape by swimming. Many swarms of lobster krill (*Munida gregaria*) have been observed in Golfo Nuevo, and some boaters have reported whales feeding on these swarms (Argüelles et al., 2016). Also, some boaters have reported whales feeding on aggregations of *Peisos petrunkevitchi* (Burkenroad, 1945). This species is distributed between 32° S (Río Grande, Brazil) and approximately 45° S (Golfo San Jorge, Argentina) (Vinuesa, 2005). SRWs could be feeding on these *P. petrunkevitchi* or *M. gregaria* aggregations. Valenzuela et al. (2018) have suggested that the Península Valdés SRW population uses at least three distinct food sources, and this area may represent a single feeding ground or a combination of feeding grounds with different prey species distributions. The authors suggest that the Patagonian Shelf, South Georgia, and the waters of the Polar Front are the grounds that appear to contribute most to the diets of Península Valdés SRWs. These areas were also identified by Zerbini et al. (2018).

Although it is not clear why whales were swimming around in a circle, their feeding may have been opportunistic as a result of encountering a large patch of prey. The lack of evidence for cooperative feeding in SRWs could be related to the low frequency in which this behavior occurs or the fact that new behaviors are starting to be observed due to the increase in density and number of SRWs in the southwestern Atlantic (Sueyro et al., 2018; Crespo et al., 2019). Another explanation could be that new behaviors are being developed by the population or that historically present behaviors are becoming more common in the population as the population recovers.

SRWs may be combining different strategies to feed, possibly to increase their feeding efficiency by rounding up prey. The observed behavior could not only be a feeding strategy but also an opportunity for socializing and fostering social relationships before and after feeding as whales remained together in the area for a long period of time during observations. The observation of cooperative feeding described herein highlights the presence of behaviors not yet recorded for this species. Future studies on specific questions concerning cooperation among SRWs and the prey species they target may provide a better understanding of this behavior.

Note: A supplemental video for this short note is available in the "Supplemental Material" section of the *Aquatic Mammals* website: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147.

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Literature Cited

Argüelles, M. B. (2017). *Efectos de la navegación comercial y turística sobre la distribución, abundancia y comportamiento de las ballenas francas (*Eubalaena australis*) en el Golfo Nuevo, Chubut* [Effects of commercial and tourist navigation on the distribution, abundance and behavior of southern right whales (*Eubalaena australis*) in Golfo Nuevo, Chubut] (Doctoral dissertation). Universidad Nacional del Comahue, Bariloche, Argentina. 185 pp.

Argüelles, M. B., Coscarella, M., Fiorito, C., & Bertellotti, M. (2021). Southern right whales generally appear not to react to transiting research vessels. *Marine Mammal Science*, *38*(1), 6-17. https://doi.org/10.1111/mms.12843

Argüelles, M. B., Fazio, A., Fiorito, C., Pérez-Martínez, D., Coscarella, M., & Bertellotti, M. (2016). Diving behavior of southern right whales (*Eubalaena australis*) in a maritime traffic area in Patagonia, Argentina. *Aquatic Mammals*, *42*(1), 104-108. https://doi.org/10.1578/AM.42.1.2016.104

Bastida, R., Rodriguez, D., Secchi, E., & da Silva, V. (2007). *Mamíferos acuáticos de Sudamérica y Antártida* [Aquatic mammals of South America and Antarctica] (1st ed.). Vazquez Mazzini Editores.

Burkenroad, M. D. (1945). A new sergestid shrimp (*Peisos petrunkevitchii*, n. gen., n. sp.), with remarks on its relationships. *Transactions of the Connecticut Academy of Arts and Sciences*, *36*, 553-591.

Coscarella, M. A., Bellazzi, G., Gaffet, M. L., Berzano, M., & Degrati, M. (2015). Technique used by killer whales (*Orcinus orca*) when hunting for dolphins in Patagonia, Argentina. *Aquatic Mammals*, *41*(2), 192-197. https://doi.org/10.1578/AM.41.2.2015.192

Crespo, E. A., Pedraza, S. N., Dans, S. L., Svendsen, G. M., Degrati, M., & Coscarella, M. A. (2019). The southwestern Atlantic southern right whale, *Eubalaena australis*, population is growing but at a decelerated rate. *Marine Mammal Science*, *35*(1), 93-107. https://doi.org/10.1111/mms.12526

D'Agostino, V., Hoffmeyer, M. S., & Degrati, M. (2016). Faecal analysis of southern right whales (*Eubalaena australis*) in Península Valdés calving ground, Argentina: *Calanus australis*, a key prey species. *Journal of the Marine Biological Association of the United Kingdom*, *96*, 859-868. https://doi.org/10.1017/S0025315415001897

D'Agostino, V., Degrati, M., Santinelli, N., Sastre, V., Dans, S. L., & Hoffmeyer, M. S. (2018). The seasonal dynamics of plankton communities relative to the foraging of the southern right whale (*Eubalaena australis*) in northern Patagonian gulfs, Península Valdés, Argentina. *Continental Shelf Research*, *164*, 45-57. https://doi.org/10.1016/j.csr.2018.06.003

Duffy-Echevarria, E., Connor, R., & St. Aubin, D. (2008). Observations of strand-feeding behavior by bottlenose dolphins (*Tursiops truncatus*) in Bull Creek, South Carolina. *Marine Mammal Science*, *24*(1), 202-206. https://doi.org/10.1111/j.1748-7692.2007.00151.x

Fish, F. E., Goetz, K. T., Rugh, D. J., & Vate Brattström, L. (2013). Hydrodynamic patterns associated with echelon formation swimming by feeding bowhead whales (*Balaena mysticetus*). *Marine Mammal Science*, *29*(4), 498-507. https://doi.org/10.1111/mms.12004

García-Cegarra, A. M., Castro, C., & Van Waerebeek, K. (2021). Feeding of humpback whales in low latitudes of the southeast Pacific Ocean. *Neotropical Biodiversity*, *7*(1), 421-430. https://doi.org/10.1080/23766808.2021.1971041

Gazda, S. K., Connor, R. C., Edgar, R. K., & Cox, F. (2005). A division of labour with role specialization in group-hunting bottlenose dolphins (*Tursiops truncatus*) off Cedar Key, Florida. *Proceedings of the Royal Society B: Biological Sciences*, *272*, 135-140. https://doi.org/10.1098/rspb.2004.2937

Goldbogen, J. A., Potvin, J., & Shadwick, R. E. (2010). Skull and buccal cavity allometry increase mass-specific engulfment capacity in fin whales. *Proceedings of the Royal Society B: Biological Sciences*, *277*, 861-868. https://doi.org/10.1098/rspb.2009.1680

Goldbogen, J. A., Cade, D., Calambokidis, J., Friedlaender, A. S., Potvin, J., Segre, P. S., & Werth, A. J. (2017). How baleen whales feed: The biomechanics of engulfment and filtration. *Annual Review of Marine Science*, *9*, 367-386. https://doi.org/10.1146/annurev-marine-122414-033905

Goldbogen, J. A., Calambokidis, J., Oleson, E., Potvin, J., Pyenson, N. D., Schorr, G., & Shadwick, R. E. (2011). Mechanics, hydrodynamics and energetics of blue whale lunge feeding: Efficiency dependence on krill density. *Journal of Experimental Biology*, *214*, 131-146. https://doi.org/10.1242/jeb.048157

González-Carman, V., Piola, A. R., O'Brien, T. D., Tormosov, E., & Acha, E. M. (2019). Circumpolar frontal systems as feeding grounds of southern right whales. *Progress in Oceanography*, *176*, 102-123. https://doi.org/10.1016/j.pocean.2019.102123

Hain, J. H. W., Carter, G. R., Krauss, S. D., Mayo, C. A., & Winn, H. E. (1982). Feeding behavior of the humpback whale, *Megaptera novaeangliae*, in the western North Atlantic. *Fishery Bulletin*, *80*(2), 259-268.

Heithaus, M., & Dill, L. (2008). Feeding tactics and strategies. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *The encyclopedia of marine mammals* (2nd ed., pp. 414-423). Academic Press. https://doi.org/10.1016/B978-0-12-373553-9.00099-7

Hoffmeyer, M. S., Lindner, M. S., Carribero, A., Fulco, V. K., Menéndez, M. C., Fernández Severini, M. D., Diodato, S. L., Berasategui, A. A., Biancalana, F., & Berrier, E. (2010). Planktonic food and foraging of *Eubalaena australis*, on Península Valdés (Argentina) nursery ground. *Revista de Biología Marina y Oceanografía*, *45*(1), 131-139. https://doi.org/10.4067/S0718-19572010000100013

Jiménez, P. J., & Alava, J. J. (2015). Strand-feeding by coastal bottlenose dolphins (*Tursiops truncatus*) in the Gulf of Guayaquil, Ecuador. *Latin American Journal of Aquatic Mammals*, *10*(1), 33-37. https://doi.org/10.5597/lajam00191

Landino, S. W., Treacy, S. D., Zerwick, S. A., & Dunlap, J. B. (1994). A large aggregation of bowhead whales (*Balaena mysticetus*) feeding near Point Barrow, Alaska, in late October 1992. *Arctic*, *47*(3), 232-235. https://doi.org/10.14430/arctic1293

Neumann, D. R., & Orams, M. B. (2003). Feeding behaviours of shortbeaked common dolphins, *Delphinus delphis*, in New Zealand. *Aquatic Mammals*, *29*(1), 137-149. https://doi.org/10.1578/016754203101023997

Oliveira, E. C., Tardin, R. H., Poletto, F. R., & Simão, S. M. (2013). Coordinated feeding behavior of the Guiana dolphin, *Sotalia guianensis* (Cetacea: Delphinidae), in southeastern Brazil: A comparison between populations. *Zoologia*, *30*(6), 585-591. https://doi.org/10.1590/S1984-46702013005000013

Pitman, R. L., & Durban, J. W. (2012). Cooperative hunting behavior, prey selectivity and prey handling by pack ice killer whales (*Orcinus orca*), type B, in Antarctic Peninsula waters. *Marine Mammal Science*, *28*(1), 16-36. https://doi.org/10.1111/j.1748-7692.2010.00453.x

Similä, T., & Ugarte, F. (1993). Surface and underwater observations of cooperatively feeding killer whales in northern Norway. *Canadian Journal of Zoology*, *71*(8), 1494-1499. https://doi.org/10.1139/z93-210

Smith, T. D., Reeves, R. R., Josephson, E. A., & Lund, J. N. (2012). Spatial and seasonal distribution of American whaling and whales in the age of sail. *PLOS ONE*, *7*, e34905. https://doi.org/10.1371/journal.pone.0034905

Sueyro, N., Crespo, E. A., Arias, M., & Coscarella, M. A. (2018). Density-dependent changes in the distribution of southern right whales (*Eubalaena australis*) in the breeding ground Peninsula Valdés. *PeerJ*. https://doi.org/10.7717/peerj.5957

Torres, L. G., Smith, T. D., Sutton, P., MacDiarmid, A., Bannister, J., & Miyashita, T. (2013). From exploitation to conservation: Habitat models using whaling data predict distribution patterns and threat exposure of an endangered whale. *Diversity Distributions*, *19*, 1138-1152. https://doi.org/10.1111/ddi.12069

Valenzuela, L. O., Rowntree, V. J., Sironi, M., & Seger, J. (2018). Stable isotopes (δ15N, δ13C, δ34S) in skin reveal diverse food sources used by southern right whales *Eubalaena australis*. *Marine Ecology Progress Series*, *603*, 243-255. https://doi.org/10.3354/meps12722

Valenzuela, L. O., Sironi, M., Rowntree, V. J., & Seger, J. (2009). Isotopic and genetic evidence for culturally inherited site fidelity to feeding grounds in southern right whales (*Eubalaena australis*). *Molecular Ecology*, *18*(5), 782-791. https://doi.org/10.1111/j.1365-294X.2008.04069.x

Vaughn, R. L., Shelton, D. E., Timm, L. L., Watson, L. A., & Würsig, B. (2007). Dusky dolphin (*Lagenorhynchus obscurus*) feeding tactics and multi-species associations. *New Zealand Journal of Marine and Freshwater Research*, *41*(4), 391-400. https://doi.org/10.1080/00288330709509929

Vinuesa, J. H. (2005). *Distribución de crustáceos decápodos y estomatópodos del Golfo San Jorge, Argentina* [Distribution of decapod and stomatopod crustaceans from San Jorge Gulf, Argentina]. *Revista de Biología Marina y Oceanografía*, *40*(1), 7-21. https://doi.org/10.4067/S0718-19572005000100002

Ware, C., Wiley, D. N., Friedlaender, A. S., Weinrich, M., Hazen, E. L., Bocconcelli, A., Parks, S. E., Stimpert, A. K., Thompson, M. A., & Abernathy, K. (2014). Bottom side-roll feeding by humpback whales (*Megaptera novaeangliae*) in the southern Gulf of Maine, U.S.A. *Marine Mammal Science*, *30*(2), 494-511. https://doi.org/10.1111/mms.12053

Werth, A. J. (2000). Feeding in marine mammals. In K. Schwenk (Ed.), *Feeding form, function and evolution in tetrapod vertebrates* (pp. 475-514). Academic Press. https://doi.org/10.1016/B978-012632590-4/50017-4

Wiley, D. N., Ware, C., Bocconcelli, A., Cholewiak, D., Friedlaender, A. S., Thompson, M. A., & Weinrich, M. T. (2011). Underwater components of humpback whale bubble-net feeding. *Behaviour*, *148*, 575-602. https://doi.org/10.1163/000579511X570893

Würsig, B., & Würsig, M. (1980). Behavior and ecology of the dusky dolphin, *Lagenorhynchus obscurus*, in the South Atlantic. *Fishery Bulletin*, *77*, 871-890.

Würsig, B., Dorsey, E. M., Fraker, M. A., Payne, R. S., & Richardson, W. J. (1985). Behavior of bowhead whales, *Balaena mysticetus*, summering in the Beaufort Sea: A description. *Fishery Bulletin*, *83*, 357-377.

Zerbini, A. N., Rosenbaum, H., Mendez, M., Sucunza, F., Andriolo, A., Harris, G., Clapham, P. J., Sironi, M., Uhart, M., & Fernández-Ajó, A. (2018). *Tracking southern right whales through the southwest Atlantic: An update on movements, migratory routes and feeding grounds*. International Whaling Commission.