Short Communication: Humpback whales demonstrate group protection response to killer whale harassment in Brazil

Israel Maciel[1,2], Gabriel Melo-Santos[1,2,3], Guilherme Maricato[2], Gustavo Vancellote[2], Maria Alice S. Alves[4], Mariana M. Vale[5] and Rodrigo Tardin[2,5]

Contact email: oceanmaciel@gmail.com

ABSTRACT

Mixed species groups are usually associated with group protection to avoid predation. Reports of killer whale occurrence and attacks are scarce in Brazilian waters. Here we report the first case of an attack by killer whales on a mixed group of humpbacks (*Megaptera novaeangliae*) and a southern right whale (*Eubalaena australis*). This is also the first report of humpback whales possibly interfering with killer whales harassing right whales. The recent increase in humpback and southern right whale populations in Brazil may be influencing the presence of killer whales, which are known to attack humpback whales.

KEYWORDS: PREDATION; ORCINUS ORCA; EUBALAENA AUSTRALIS; MEGAPTERA NOVAEANGLIAE; CABO FRIO

The killer whale (*Orcinus orca*) is a cosmopolitan predator distributed throughout all ocean basins (Forney *et al*., 2006; Ford *et al*., 2009). Killer whales perform complex hunting behaviours, with distinct ecological specialisations. For example, 'resident-type' killer whales feed primarily on fish, while 'transient-type' killer whales prey on over 20 species of marine mammals around the world, including humpback whales (*Megaptera novaeangliae*) and right whales (*Eubalaena australis* and *Eubalaena glacialis*) (Jefferson *et al*., 1991; Sironi *et al*., 2008). In the north Pacific, 'resident' killer whales are better studied (e.g., Bigg *et al*., 1990; Krahn *et al*., 2002; Durban & Volker, 2011; Ford *et al*., 2011; Hanson *et al*., 2021), whereas 'transient' killer whales are still little understood because they travel long distances with no apparent site fidelity. In the southwest Atlantic, records of killer whales are rare in both coastal and offshore waters (Lodi & Hetzel, 1998; Secchi & Vaske Jr., 1998; Siciliano *et al*., 1999; Iñíguez, 2001; Dalla Rosa *et al*., 2002; Di Tullio *et al*., 2016; Ott *et al*., 2017; Sucunza *et al*., 2022), especially in southeastern and southern Brazil where research efforts are concentrated. Despite the lack of obvious seasonal patterns in Brazilian waters (Dalla-Rosa *et al*., 2002), sightings have been more common in austral spring and summer from opportunistic observations (Lodi & Hetzel, 1998; Siciliano *et al*., 1999; Santos & Netto, 2005; Santos & Silva, 2009; Lodi & Farias, 2011; Ott *et al*., 2017; Sucunza *et al*., 2022; Athayde *et al*., 2023) and systematic cetacean surveys (Di Tullio *et al*., 2016; Martins *et al*., 2023).

Killer whale occurrence in Brazilian waters is still little understood. Reports of attacks are globally scarce (Hucke-Gaete *et al*., 2004; Reeves *et al*., 2006; Alava *et al*., 2013) and even more so in Brazil, with significant

[1] Graduate Programme in Ecology and Evolution (PPGEE), Biology Institute Roberto Alcantara Gomes (IBRAG), State University of Rio de Janeiro (UERJ), Rio de Janeiro, Brazil.
[2] Marine Ecology and Conservation Lab (ECoMAR), Department of Ecology, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil.
[3] Biology and Conservation of Amazonian Aquatic Mammals (BioMA), Federal Rural University of Amazon (UFRA), Belém, Pará, Brazil.
[4] Department of Ecology, IBRAG, State University of Rio de Janeiro (UERJ), Rio de Janeiro, Brazil.
[5] Department of Ecology, IB, Federal University of Rio de Janeiro (UFRJ), Rio de Janeiro, Brazil.

knowledge gaps on predator-prey strategies, attacked species and temporal patterns (Sucunza *et al*., 2022). As a transient-like ecotype, the killer whales in Brazilian waters are expected to prey primarily on mammals. For example, there are reports of attacks on franciscana dolphins (*Pontoporia blainvillei*) (Santos & Netto, 2005), minke whales (*Balaenoptera spp.*) (Troina *et al*., 2020) and harassment of sperm whales (*Physeter macrocephalus*) (Sucunza *et al*., 2022). Here we report the first case of a killer whale attack on a mixed group of humpback whales and a southern right whale.

Both humpback and southern right whales use the coast of Brazil during their winter migrations. The humpback whale is a migratory species of baleen whale found in oceans around the world (Fleming & Jackson, 2011; Jackson *et al*., 2014). The 'A' stock breeds in Brazil from late austral fall to late austral spring and has been recovering rapidly in recent years, reaching more than 90% of its pre-exploitation population size (Bortolotto *et al*., 2016; Zerbini *et al*., 2019). In Brazil, its breeding area reaches from Rio de Janeiro State in southeastern Brazil to northeastern Brazil (Zerbini *et al*., 2019). Southern right whales ('right whales' hereafter) also perform seasonal migration, breeding in southern Brazil from winter to spring. Historically, this breeding occurred from southern to northeastern Brazil, but due to intense whaling efforts, its breeding range is now concentrated in southern Brazil (Groch, 2017). Rapid population recovery (Groch *et al*., 2005; Romero *et al*., 2022) has recently resulted in sporadic right whale records in southeastern Brazil (Figueiredo *et al*., 2017). For example, Siciliano *et al*. (2006) report right whales accompanying groups of humpback whales during migration in the Campos Basin.

Our record was made during a long-term cetacean monitoring study off the coast of Rio de Janeiro State, southeastern Brazil. Between 1 and 5 August 2023, we conducted systematic surveys in the waters of Arraial do Cabo, Cabo Frio and Armação dos Búzios municipalities to investigate cetaceans' ecological, acoustic and behavioural features. From spring to summer, an upwelling phenomenon in the region, driven by north-northeastern wind and the formation of meanders and cyclones offshore, enhances local productivity (Carbonel, 1998; Coelho-Souza *et al*., 2012). We conducted boat surveys under Beaufort condition ≤3, with boat speeds between 15–20 km/h (8–10 knots), following haphazard routes to cover the study area. Every time we spotted a cetacean group, we slowed down, photographed their individual marks and features using a CANON EOS 70D with 75–300 mm lens, georeferenced the individuals with a GARMIN MAP 78 and collected behavioural data in a standardised spreadsheet (Tardin *et al*., 2017). We also recorded acoustic data using a Sound Trap ST300HF with a sampling rate of 576 kHz/16 bit.

On 3 August 2023, we sighted a pair of mother-calf right whales but no humpback whales. On 4 August, a group of citizen scientists informed us that a mixed group of humpback and right whales was sighted in the area (Figure 1). When we sighted the group at ca. 500 m distance, we observed intense surface activity, including humpback whales breaching, with fluke and flipper slaps. During our approach, we sighted a mixed group of five humpback whales (four adults and a calf) and one adult right whale swimming in a diamond formation, keeping the right whale in the centre of this group. All whales kept a close distance from each other – no more than one body length apart. No killer whales were observed at this point. Our photo-ID data revealed that it was a different adult right whale from the day before. After this initial observation, we moved away (~200 m) to collect acoustic data. In these recordings, we identified right whale calls, and even though we had not yet seen killer whales, we also detected killer whale whistles. In the last two minutes of this recording, we observed the mixed group swimming fast with erratic movements, intense surface activity, including fluke slaps, flipper slaps and strong loud blows. At the end of this five-minute recording, humpback whales swam away from the right whale. Humpback whale calls were only detected when we observed the mixed group separating, just before we ended the recording. As we approached the right whale, we observed three killer whales, two females and a calf, chasing the former, who increased its speed towards the coast. A sequence of attack attempts by the adult killer whales then began, lasting seven minutes. The two adult killer whales swam parallel to the right whale, one at each side, and attempted to bite its abdomen multiple times while approaching the right whale by the flanks, forcing it to swim faster in a sideways position during these bite attempts (Figure 1). The killer whale calf, despite being present in the group, did not attempt any attack but remained next to its potential mother. As a probable anti-predatory behaviour, the right whale increased its speed when the killer whales were close and tail-slapped

to avoid the killer whales' attacks. After seven minutes of harassment, the killer whales abandoned the chase and swam towards offshore waters. Meanwhile, the right whale was observed again close to shore where it approached the research vessel. No bite or blood was observed. On the next day (5 August), citizen scientists observed a pair of mother-calf right whales about 4 km from the position of the attack and we observed multiple humpback whales at ~7 km from the shore. After we left the right whale mother-calf pair, we observed a pod of nine killer whales closer to the coast in the same area where the first attack occurred. This pod comprised a male, seven females and a calf, exhibiting foraging behaviour close to an island while emitting several echolocations clicks. We observed the pod for approximately five hours, during which time they conducted long dives (~5 minutes) and kept foraging along the region where the attack had occurred the previous day. Afterwards, the pod travelled north and was observed by tourists in Armação dos Búzios, an adjacent town ~40 km in linear distance.

'Transient'-type killer whales are poorly understood, especially in the southwest Atlantic Ocean. Reports of harassment or attacks in Brazilian waters are scarce and indicate that franciscana dolphins (Santos & Netto, 2005), minke (Troina *et al*., 2020) and sperm whales (Sucunza *et al*., 2022) were already targeted. Worldwide, humpback whales are more frequently reported to be preyed upon or harassed by killer whales, especially in the Northern Hemisphere (Jefferson *et al*., 1991). However, little is known about killer whale attacks on southern right whales and their anti-predatory behaviour(s). In Argentina's Patagonia, Sironi *et al*. (2008) suggest that right whales have

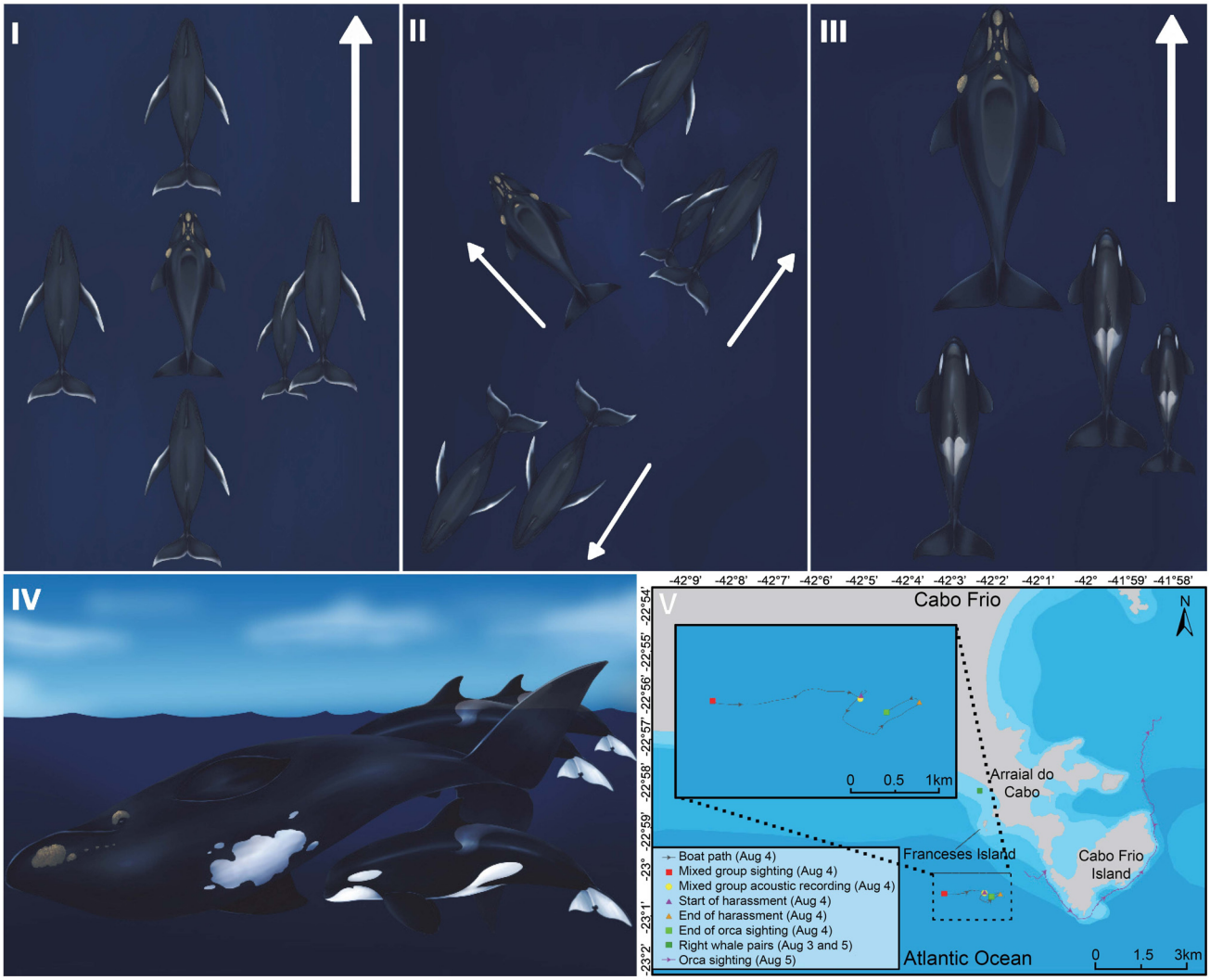

Figure 1. Schematic drawing representing the event of killer whale harassment of a mixed group of humpback whales and a southern right whale in Brazil: (I) mixed group in diamond formation; (II) separation of the mixed group; (III) group of orcas chasing the southern right whale; (IV) adult orcas attempt to bite the right whale's abdomen; (V) georeferenced sightings between 3–5 August 2023.

shifted their core habitat use over three decades, possibly due to predator pressure. They also report similar anti-predatory behaviours to the tail slap and diving in shallow waters which we observed. Zhe *et al*. (2022) propose that mother and calf pairs of southern right whales prefer shallow waters as nursery sites, where sound propagation is lower, to reduce the chance of being detected by predators, especially killer whales. A similar situation was also observed in Cabo Frio, where mother-calf pairs were seen in shallow and sheltered waters (Figure 1).

Humpback whales are known to interfere with killer whales' harassment of other marine mammals. Pitman *et al*. (2017) reviewed 115 accounts of interactions between killer whales and humpback whales. In 89% of these cases, humpback whales helped 10 other species rather than co-specifics. On numerous occasions, humpback whales approached other species in an attempt to separate them from killer whales. They exhibited vigorous surface behaviours, such as the tail and pectoral fin slaps, as observed in the present case. It is also worth noting that, to the best of our knowledge, our study is the first to report humpback whales possibly interfering with killer whales harassing right whales.

Humpback whales appear to have displayed group protection behaviour to protect the right whale from orcas. This was evidenced by the formation of the mixed group swimming at less than one body length apart and the intense surface activity of humpback whales at the beginning of the harassment, similar to the events compiled by Pitman *et al*. (2017).

The significant increase in humpback whale stock 'A' in recent years is noteworthy (Zerbini *et al*., 2019). In Rio de Janeiro (~110 km south of Arraial do Cabo), humpback whales have been increasingly observed in large numbers travelling through a migratory corridor about 10 km from the coast (Lodi *et al*., 2020). In Arraial do Cabo, where the harassment occurred, newborn humpback whale calves and male competing groups have been observed more often in the last three years by citizen scientists and our research group (R. Tardin, pers. comm.). These observations were not common 10 years ago in the same area (Tardin *et al*., 2020). The intense and recurring presence of humpback whales in the region may be influencing the presence of killer whales as they are known to attack humpback whales (Naessig & Lanyon, 2004; Mehta *et al*., 2007, Steiger *et al*., 2008). More data are needed to corroborate this hypothesis and future studies should be directed towards answering these questions.

ACKNOWLEDGEMENTS

The authors thank Marco Aurelio Crespo and Pierre Blancpain for their valuable expertise and support in the field. We thank the Funtec Ambiental, Prefeitura de Arraial do Cabo e Projeto Mar de Baleias for their valuable support with logistics and to detect whales from the land station (Arraial do Cabo, Brazil). We thank all the citizen scientists who provided photos and information. This study was funded by the Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro – FAPERJ, process number: SEI 260003/014944/2023. FAPERJ also supports a post-doctoral fellowship of G.M.S. (PDR-10 process number: E-26/204.304/2021), the research of M.A.S.A. (CNE process number: E-26/201.126/2022), R.T. (JCNE process number: E-26/200.238/2023) and M.M.V. (CNE process number: E-26/202.647/2019). The National Council for Scientific and Technological Development (CNPq) supports a post-doctoral fellowship (PDJ) of I.M. (process number: 151239/2023-1). M.A.S.A. and M.M.V. are supported by CNPq productivity grant (PQ processes number: 306.579/2018-9, 308615/2022-0 and 304309/2018-4; 304908/2021-5, respectively). M.A.S.A is also supported by a productivity fellowship from Rio de Janeiro State University (Prociência, UERJ/FAPERJ).

REFERENCES

Alava, J.J., Smith, K.J., O'Hern, J., Alarcón, D., Merlen, G., & Denkinger, J. (2013). Observations of killer whale (*Orcinus orca*) attacks on Bryde's whales (*Balaenoptera edeni*) in the Galapagos Islands. *Aquat. Mamm.* 39(2): 196–201. [Available at: *https://doi.org/10.1578/AM.39.2.2013.196*]

Athayde, A., Cantor, M., Cardoso, J., Francisco, A., Pereira dos Santos, F., Crespo, H., de Morais, M.V., Albaladejo, M.C., Gallo Neto, H., & Siciliano, S. (2023). Movements and social behavior of killer whales (*Orcinus orca*) off the Brazilian coast. *Front. Mar. Sci.* 10: 1206796. [Available at: *https://doi.org/10.3389/fmars.2023.1206796*]

Bigg, M.A., Olesiuk, P.F., Ellis G.M., Ford, J.K.B., & Balcomb, K.C. (1990). Social organization and genealogy of resident killer whales (Orcinus orca) in the coastal waters of British Columbia and Washington State. *Rep. Int. Whal. Comm.* 12: 383–405.

Bortolotto, G.A., Danilewicz, D., Andriolo, A., Secchi, E.R., & Zerbini, A.N. (2016). Whale, whale, everywhere: Increasing abundance of western South Atlantic humpback whales (*Megaptera novaeangliae*) in their wintering grounds. *PLoS One* 11(10): e0164596. [Available at: *https://doi.org/10.1371/journal.pone.0164596*]

Carbonel, C. (1998). Modelling of upwelling in the coastal area of Cabo Frio (Rio de Janeiro-Brazil). *Revista Brasileira de Oceanografia* 46: 1–17. [Available at: *https://doi.org/10.1590/S1413-77391998000100001*]

Coelho-Souza, S.A., López, M.S., Guimarães, J.R.D., Coutinho, R., & Candella, R.N. (2012). Biophysical interactions in the Cabo Frio upwelling system, Southeastern Brazil. *Braz. J. Oceanogr.* 60: 353–365.

Dalla Rosa, L., Secchi, E.R., Lailson-Brito, J., & Azevedo, A.F. (2002). A review of killer whales (*Orcinus orca*) in Brazilian waters. *Proceedings of the Fourth International Orca Symposium and Workshop* (pp.46–49).

Di Tullio, J.C., Gandra, T.B.R., Zerbini, A.N., & Secchi, E.R. (2016). Diversity and distribution patterns of cetaceans in the subtropical southwestern Atlantic outer continental shelf and slope. *PLoS One* 11(5): e0155841. [Available at: *https://doi.org/10.1371/journal.pone.0155841*]

Durban, J., & Deecke, V. (2011). How do we study killer whales. *J. Am. Cet. Soc.* 40: 6–14.

Figueiredo, G.C., Santos, M.C.O., Siciliano, S., & Moura, J.F. (2017). Southern right whales (*Eubalaena australis*) in an urbanized area off the Southwestern Atlantic Ocean: Updated records and conservation issues. *Aquat. Mamm.* 43(1). [Available at: *https://doi.org/10.1578/AM.43.1.2017.52*]

Fleming, A., & Jackson, J.A. (2011). Global review of humpback whales (*Megaptera novaeangliae*). US Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-474.

Ford, J.K.B. (2009). Killer whale: Orcinus orca. In: *Encyclopedia of Marine Mammals* (pp.650–657). Academic Press. [Available at: *https://doi.org/10.1016/B978-0-12-373553-9.00150-4*]

Ford, J.K.B., Ellis, G.M., & Balcomb, K.C. (2011). *Killer Whales: The Natural History and Genealogy of Orcinus Orca in British Columbia and Washington*. UBC Press.

Forney, K.A., Wade, P.R., & Estes, J.A. (2006). Worldwide distribution and abundance of killer whales. In: *Whales, Whaling and Ocean Ecosystems* (pp.145–162). [Available at: *https://doi.org/10.1525/california/9780520248847.003.0012*]

Groch, K.R., Palazzo Jr., J.T., Flores, P.A.C., Adler, F.R., & Fabian, M.E. (2005). Recent rapid increases in the right whale (*Eubalaena australis*) population off southern Brazil. *Lat. Am. J. Aquat. Mamm*. 4(1): 41–47. [Available at: *https://doi.org/10.5597/lajam00068*]

Groch, K. (2017). Conservation advances for southern right whales in Brazil. In: *Advances in Marine Vertebrate Research in Latin America: Technological Innovation and Conservation* (pp.441–475). Cham, Springer International Publishing. [Available at: *https://doi.org/10.1007/978-3-319-56985-7_16*]

Hanson, M.B., Emmons, C.K., Ford, M.J., Everett, M., Parsons, K., Park, L.K., & Hempelmann, J. (2021). Endangered predators and endangered prey: Seasonal diet of Southern Resident killer whales. *PLoS One* 16(3): e0247031. [Available at: *https://doi.org/10.1371/journal.pone.0247031*]

Hucke-Gaete, R., Moreno, C.A., & Arata, J. (2004). Operational interactions of sperm whales and killer whales with the Patagonian toothfish industrial fishery off southern Chile. *CCAMLR Science* 11: 127–140.

Iñíguez, M.A. (2001). Seasonal distribution of killer whales (*Orcinus orca*) in Northern Patagonia, Argentina. *Aquat. Mamm.* 27(2): 154–161.

Jackson, J.A., Steel, D.J., Beerli, P., Congdon, B.C., Olavarría, C., Leslie, M.S., Pomilla, C., Rosenbaum, H., & Baker, C.S. (2014). Global diversity and oceanic divergence of humpback whales (*Megaptera novaeangliae*). *Proc. R. Soc. B*. 281(1786): 20133222. [Available at: *https://doi.org/10.1098/rspb.2013.3222*]

Jefferson, T.A., Stacey, P.J., & Baird, R.W. (1991). A review of killer whale interactions with other marine mammals: Predation to co-existence. *Mamm. Rev.* 21(4): 151–180. [Available at: *https://doi.org/10.1111/j.1365-2907.1991.tb00291.x*]

Krahn, M.M., Wade, P.R., Kalinowski, S.T., Dahlheim, M.E., Taylor, B.L., Hanson, M.B., Ylitalo, G.M., Angliss, R.P., Stein, J.E., & Waples, R.S. (2002). Status review of southern resident killer whales (Orcinus orca) under the Endangered Species Act. US Department of Commerce, NOAA Technical Memorandum NMFS-NWFSC–54.

Lodi, L., & Hetzel, B. (1988). Orcinus orca (Cetacea, Delphinidae) em águas costeiras do Estado do Rio de Janeiro. *Bioikos* 12(1): 46–54.

Lodi, L., & Farias-Júnior, S. (2011). Scientific Note: Movements of a solitary adult male killer whale, Orcinus orca (Cetacea, Delphinidae), along the coast of south-eastern Brazil. *Pan-Am. J. Aquat. Sci.* 6(4): 325–328.

Lodi, L., Tardin, R., & Maricato, G. (2020). Modeling cetacean habitat use in an urban coastal area in southeastern Brazil. *Mar. Ecol. Prog. Ser.* 642: 227–240. [Available at: *https://doi.org/10.3354/meps13313*]

Martins, A.C., Kinas, P.G., Wedekin, L.L., & Dalla Rosa, L. (2023). Spatial and seasonal patterns of cetacean species richness: A Bayesian approach. *Deep Sea Res. I.* 196: 104046. [Available at: *https://doi.org/10.1016/j.dsr.2023.104046*]

Mehta, A.V., Allen, J.M., & Constantine, R., (2007). Baleen whales are not important as prey for killer whales in high-latitude regions. *Mar. Ecol. Prog. Ser.* 348: 297–307. [Available at: *https://doi.org/10.3354/meps07015*]

Naessig, P.J., & Lanyon, J.M. (2004). Levels and probable origin of predatory scarring on humpback whales (*Megaptera novaeangliae*) in east Australian waters. *Wildl. Res.* 31: 163–170. [Available at: *https://doi.org/10.1071/WR03086*]

Ott, P.H., Sucunza, F., Wickert, J., Danilewicz, D., & Tavares, M. (2017). Evidence of attack of a killer whale on a calf southern right whale in southern Brazil. *Mastozoología Neotropical* 24(1): 235–240.

Pitman, R.L., Deecke, V.B., Gabriele, C.M., Srinivasan, M., Black, N., Denkinger, J., & Ternullo, R. (2017). Humpback whales interfering when mammal-eating killer whales attack other species: Mobbing behavior and interspecific altruism? *Mar. Mammal Sci.* 33(1): 7–58. [Available at: *https://doi.org/10.1111/mms.12343*]

Reeves, R.R., Berger, J., & Clapham, P.J. (2006). Killer whales as predators of large baleen whales and sperm whales. In: *Whales, Whaling and Ocean Ecosystems* (pp.174–187). [Available at: *https://doi.org/10.1525/california/9780520248847.003.0014*]

Romero, M.A., Coscarella, M.A., Adams, G.D., Pedraza, J.C., González, R.A., & Crespo, E.A. (2022). Historical reconstruction of the population dynamics of southern right whales in the southwestern Atlantic Ocean. *Sci. Rep.* 12(1): 3324. [Available at: *https://doi.org/10.1038/s41598-022-07370-6*]

Santos, M. C. de O., & Ferreira Netto, D. (2005). Killer whale predation on a franciscana dolphin in Brazilian waters. *Lat. Am. J. Aquat. Mamm.* 4(1); 69–72. [Available at: *https://doi.org/10.5597/lajam00072*]

Santos, M.C. de O., & Silva, E. (2009). Records of a male killer whale (*Orcinus orca*) off southeastern Brazil. *Braz. J. Oceanogr.* 57: 65–68. [Available at: *https://doi.org/10.1590/S1679-87592009000100007*]

Secchi, E.R., & Vaske Jr., T. (1998). Killer whale (*Orcinus orca*) sightings and depredation on tuna and swordfish longline catches in southern Brazil. *Aquat. Mamm.* 24(2): 117–122.

Siciliano, S., Brito, J.L., & Azevedo, A.F. (1999). Seasonal occurrence of killer whales (*Orcinus orca*) in waters of Rio de Janeiro, Brazil. *Mamm. Biol.* 64(4): 251–255.

Siciliano, S., Moreno, I., Silva, E.D., & Alves, V.C. (2006). Baleias, botos e golfinhos na Bacia de Campos. Série Guias de Campo fauna marinha da Bacia de Campos. *ENSP/FIOCRUZ*.

Sironi, M., Lopez, J.C., & Bubas, R. (2008). Predation by killer whales (Orcinus orca) on southern right whales (Eubalaena australis) off Patagonia, Argentina: Effects on behavior and habitat choice. SC/60/BRG/29 presented to the IWC Scientific Committee, Santiago, Chile, 2008. [Available from the IWC Publications Team]

Steiger, G.H., Calambokidis, J., & Straley, J.M. (2008). Geographic variation in killer whale attacks on humpback whales in the North Pacific: Implications for predation pressure. *Endanger. Species Res.* 4: 247–256. [Available at: *https://doi.org/10.3354/esr00078*]

Sucunza, F., Andriolo, A., Dalla Rosa, L., Rezende de Castro, F., Danilewicz, D., & Zerbini, A.N. (2022). Sperm whale, Physeter macrocephalus, harassment by killer whales in the western South Atlantic Ocean. *Lat. Am. J. Aquat. Mamm.* 17(2): 129–132. [Available at: *https://doi.org/10.5597/lajam00286*]

Zerbini, A.N., Adams, G., Best, J., Clapham, P.J., Jackson, J.A., & Punt, A.E. (2019). Assessing the recovery of an Antarctic predator from historical exploitation. *R. Soc. Open Sci.* 6(10): 190368. [Available at: *https://doi.org/10.1098/rsos.190368*]