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REPORT

Epizoic barnacle (*Xenobalanus globicipitis*) infestations in several cetacean species in south-eastern Brazil

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ABSTRACT
The sessile barnacle *Xenobalanus globicipitis* was observed on multiple cetacean species during field surveys off the northern coast of São Paulo state, Brazil. However, the occurrence of *X. globicipitis* in cetaceans in Brazilian waters has been, up to now, scarce. In the present study, this epibiont is reported for the first time in orcas (*Orcinus orca*), rough-toothed dolphins (*Steno bredanensis*) and Atlantic spotted dolphins (*Stenella frontalis*) from south-eastern Brazil. Guiana dolphins (*Sotalia guianensis*) and common bottlenose dolphins (*Tursiops truncatus*) have also been infested. This is the first world record of *X. globicipitis* in *Balaenoptera brydei* and *Stenella frontalis*. All records were photographed and may reveal changes in this barnacle's settlement in 2018 and 2019. The possible causes for these infestations are discussed, including anthropogenic activities and recent oceanic events.

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Introduction

Observations concerning epizoic barnacles on living cetaceans have led to concerns regarding dolphin and whale health, as it has been reported that unhealthy cetaceans are usually more susceptible to attachment by barnacles, due to immune system impairments and/or the presence of skin diseases (Aznar et al. 1994, 2005), as well as the presence of barnacles in stranded cetaceans (Dailey and Walker 1978; Karuppiah et al. 2004; Aznar et al. 2005). Hence, the high presence of the pseudostalked barnacle *Xenobalanus globicipitis* Steenstrup, 1852 in wild cetacean populations has been postulated as likely to be an indication of the overall health of the host population (Aznar et al. 2005).

Several sessile barnacles have been linked to marine vertebrates, such as *Amphibalanus* Pitombo, 2004, *Balanus* Costa, 1778, *Cetopirus* Ranzani, 1817, *Chelonibia* Leach, 1817, *Coronula* Lamarck, 1802, *Cryptolepas* Dall, 1872, *Platylepas* Gray, 1825, *Tubicinella* Lamarck, 1802 and *Xenobalanus* (Fertl & Newman 2008). In particular, *X. globicipitis*, a cosmopolitan species, has been reported for 34 cetacean species, including dolphins and both toothed and baleen whales (Spivey 1981; Rajaguru and Shantha 1992; Kane et al. 2008; Bearzi and Patonai 2010). Individuals of this species attach themselves to the dorsal fins, pectoral flippers and tail flukes (Seilacher 2005; Toth-Brown and Hohn 2007), probably passively selected by the creation of vortices that increase cyprid larvae contact with the host skin, leading to increased early survival (Carrillo et al. 2015). According to Moreno-Colom et al. (2020), new recruits actively seek placement near to previously settled barnacles, forming aggregations possibly to facilitate copulation.

Other factors such as age and swimming speed of host individuals, as well as oceanographic conditions (including water temperature, primary productivity) have been suggested to affect barnacle settlement in dolphins (Van Waerebeek et al. 1993; Aznar et al. 1994; Orams and Schuetze 1998; Toth-Brown and Hohn 2007; Kane et al. 2008). In addition, the presence of these epizootic organisms may also serve as useful biological markers regarding cetacean movement patterns and area use (Di Beneditto and Ramos 2000) and has been recently applied as a biological tag to discriminate common bottlenose dolphins stocks (Urian et al. 2019).

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In this context, recent observations of the pseudostalked barnacle *X. globicipitis* in six cetacean species in south-eastern Brazilian waters are reported herein and the possible causes for these infestations are discussed.

Methods

The Archipelago of Ilhabela, situated along south-eastern Brazil, is a coastal, large and important touristic region, located ~37 km from Ubatuba and 2.7 km from São Sebastião, situated on the mainland, on the northern coast of the state of São Paulo, and 130 km from the largest Brazilian port, the Port of Santos. These waters offer habitats for several cetacean species, with regular sightings of Bryde's whale *Balaenoptera brydei* Olsen, 1913, humpback whale *Megaptera novaeangliae* (Borowski, 1781), orca *Orcinus orca* (Linnaeus, 1758), Atlantic spotted dolphin *Stenella frontalis* (Cuvier, 1829), bottlenose dolphin *Tursiops truncatus* (Montagu, 1821), rough-toothed dolphin *Steno bredanensis* (G. Cuvier in Lesson, 1828), short-beaked common dolphin *Delphinus delphis* Linnaeus, 1758, Guiana dolphin *Sotalia guianensis* (Van Beneden, 1864), and franciscana dolphin *Pontoporia blainvillei* (Gervais & d'Orbigny, 1844) (Santos et al. 2010). The sea surface temperature in the waters off the northern coast of São Paulo range between 19–29°C. This region is influenced by the warm, oligotrophic waters of the Brazil Current and by the cold, nutrient-rich waters of the South Atlantic Central Water (SACW) (Rossi-Wongtschowski and Madureira 2006). Due to their enhanced biological relevance, these waters were declared an Environment Protection Area (EPA) in 2008, named the Marinha do Litoral Norte de São Paulo EPA, comprising 1451 km^2, exclude hectares of protected marine waters (Brasil 2008).

Regular cetacean sighting cruises have been carried out by the Project 'Baleia à Vista' (PROBAV) on the coast of the Archipelago of Ilhabela and São Sebastião (northern São Paulo state, southern Brazilian coast) since 2004. From June 2004 until December 2019, an average of 321.68 h of navigation/year were conducted. PROBAV is a citizen science project focused on creating cetacean conservation awareness in this hotspot for marine fauna and flora.

Expeditions were carried out aboard two boats (a 53 ft Ferretti and a 27 ft BostonWhaler Vantage). For each sighting, navigation heading, dolphin position and current speed and direction were reported (Raymarine Chartplotter/GPS), as well as depth, and sea surface temperature (Raymarine sonar). Pictures were taken using Nikon D4S, D850 and Canon 5D Mark IV cameras, and Nikon 300mm f/4, 70/200mm f/2.8, 24/70mm f/2.8 and Canon 100/400 f/4.5–5.6 lens respectively, with minimum velocity of 1/1250 and openings varying from 2.8–11 depending on light and depth of field required. Photo-identification was carried out herein only for humpback whales and all cruises were conducted regarding the same sighting methodology.

Barnacles were visually identified by the photographs due to their general morphology. The genus *Xenobalanus* is monotypic, and the most similar barnacle genus is *Conchoderma* von Olfers, 1814, with four recognized species, of which two (*C. auritum* (Linnaeus, 1767) and *C. virgatum* Spengler, 1789) were registered on cetaceans, settling in hard substrata such as teeth and sessile barnacles (Aznar et al. 1994; Carrillo et al. 2015). Thus, *X. globicipitis* was identified by its narrower peduncle and darker colouration and its settlement in soft substrate (Kane et al. 2008; Pugliese et al. 2012). Quantification of barnacle infestations was classified according to Toth-Brown and Hohn (2007): light (1–5 barnacles/fin), medium (6–10 barnacles/fin) and heavy (>10 barnacles/fin).

Results

Sightings of rough-toothed dolphins, orcas, Atlantic spotted dolphins, common bottlenose dolphins, Guiana dolphins and Bryde's whale infested by pseudostalked barnacles recorded during PROBAV sighting cruises conducted between winter and late spring 2018 and winter 2019 are reported herein (Figure 1, Table I).

Xenobalanus globicipitis was first noticed in a group of 15–20 rough-toothed dolphins sighted on 15 July 2018. A second record was made on 11 November 2018 when a group of ~6–8 rough-toothed dolphins were observed actively chasing needlefish, possibly *Strongylura marina* (Walbaum, 1792), in which at least two dolphins were reported hosting *X. globicipitis* (Figure 2). One dolphin leaped upside down several times, violently shaking the barnacles, seemingly in an attempt to displace them. The abundance classes of *X. globicipitis* in this rough-toothed dolphin specimen was recorded as medium (7 barnacles/right pectoral fin), and heavy (>20 barnacles/fluke), following Toth-Brown and Hohn (2007). Rough-toothed dolphins were observed as still infested on 9 June 2019, where a group of 25 rough-toothed dolphins interacted with a humpback whale individual during the early humpback migratory season.

One photo-identified Bryde's whale, known as 'Escondidinha', was also observed with a *X. globicipitis* attached to the tip of the dorsal fin on 11 November 2018 (Figure 3A and B). This Bryde's whale had been previously reported in the study waters, although this

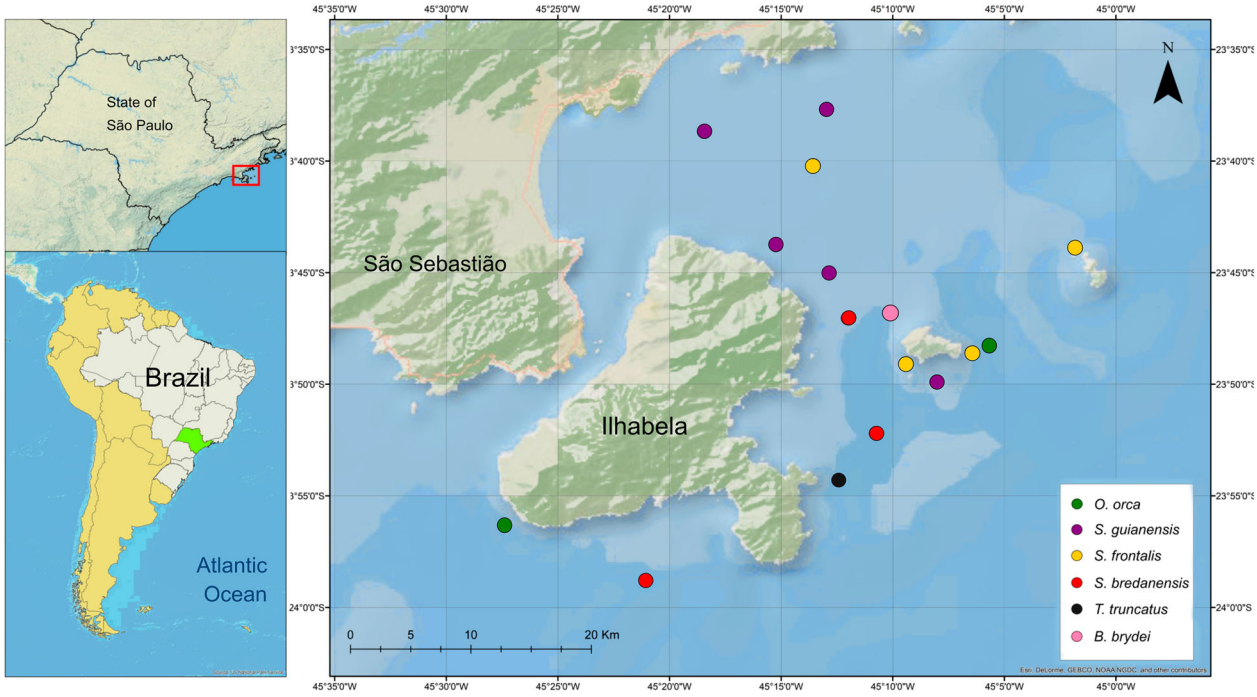

Figure 1. Sites of observed cetacean hosts epibiotized by *Xenobalanus globicipitis* Steenstrup, 1852 in 2018 and 2019.

Table I. Data concerning cetaceans epibiotized by *Xenobalanus globicipitis* off the northern coast of São Paulo, Brazil.

Sighting #	Date	Species	Latitude / Longitude	Minimum number of infested specimens
1	07Jul2018	*Sotalia guianensis*	23° 50.429'S / 45° 07.203'W	2
2	15Jul2018	*Steno bredanensis*	23° 52.235'S / 45° 10.744'W	2
3	11Nov2018	*Steno bredanensis*	23° 47.096'S / 45° 12.008'W	2
4	11Nov2018	*Balaenoptera brydei*	23° 46.815'S / 45° 10.165'W	1
5	30Nov2018	*Orcinus orca*	23° 48.250'S / 45° 04.459'W	2
6	19Jan2019	*Tursiops truncatus*	23° 57.331'S / 45° 12.994'W	7
7	20Jan2019	*Stenella frontalis*	23° 40.226'S / 45° 13.613'W	5
8	20Jan2019	*Sotalia guianensis*	23° 37.689'S / 45° 12.964'W	2
9	26Jan2019	*Stenella frontalis*	23° 49.433'S / 45° 09.471'W	5
10	08Feb2019	*Stenella frontalis*	23° 48.526'S / 45° 06.586'W	1
11	05Mar2019	*Sotalia guianensis*	23° 44.303'S / 45° 15.447'W	1
12	08Mar2019	*Sotalia guianensis*	23° 38.750'S / 45° 18.403'W	1
13	23May2019	*Stenella frontalis*	23° 44.784'S / 45° 02.926'W	10+
14	08Jun2019	*Sotalia guianensis*	23° 45.247'S / 45° 13.842'W	1
15	09Jun2019	*Steno bredanensis*	23° 58.172'S / 45° 21.067'W	1
16	20Jul2019	*Orcinus orca*	23° 56.250'S / 45° 27.402'W	2

is the first record of the presence of *X. globicipitis* in this individual. 'Escondidinha' was then sighted again in March 2019, with the previously observed barnacle absent (Figure 3C and D). This is the first record of *X. globicipitis* on a Bryde's whale.

Xenobalanus globicipitis was also observed on orcas on 30 November 2018 (Figure 4). This observation is of particular importance, as several natural orca behaviour aspects in coastal waters of south-eastern Brazil are still poorly understood. This group of orcas was sighted in close presence of two Bryde's whales apparently searching for prey or actively preying on the same organisms as the orcas, although it was not possible to identify whether the prey were small fish, squid or other invertebrates, such as salps (Tunicates). The Bryde's whales were observed swimming upside down and particularly interested in chasing prey but not in avoiding the orcas. The latter were very active, and the presence of numerous *X. globicipitis* individuals attached to their dorsal fins was noted, not only on the trailing edge of the flukes or flippers, but also on the right flank, near the base of the dorsal fin, of two observed specimens. One orca filmed in an underwater video presented *X. globicipitis* individuals attached to the dorsal surface of the fluke and old barnacle attachment scars along the body. This orca specimen also displayed round scars on the body typically attributed to cookie-cutter sharks (*Isistius* sp. Gill, 1865). Another

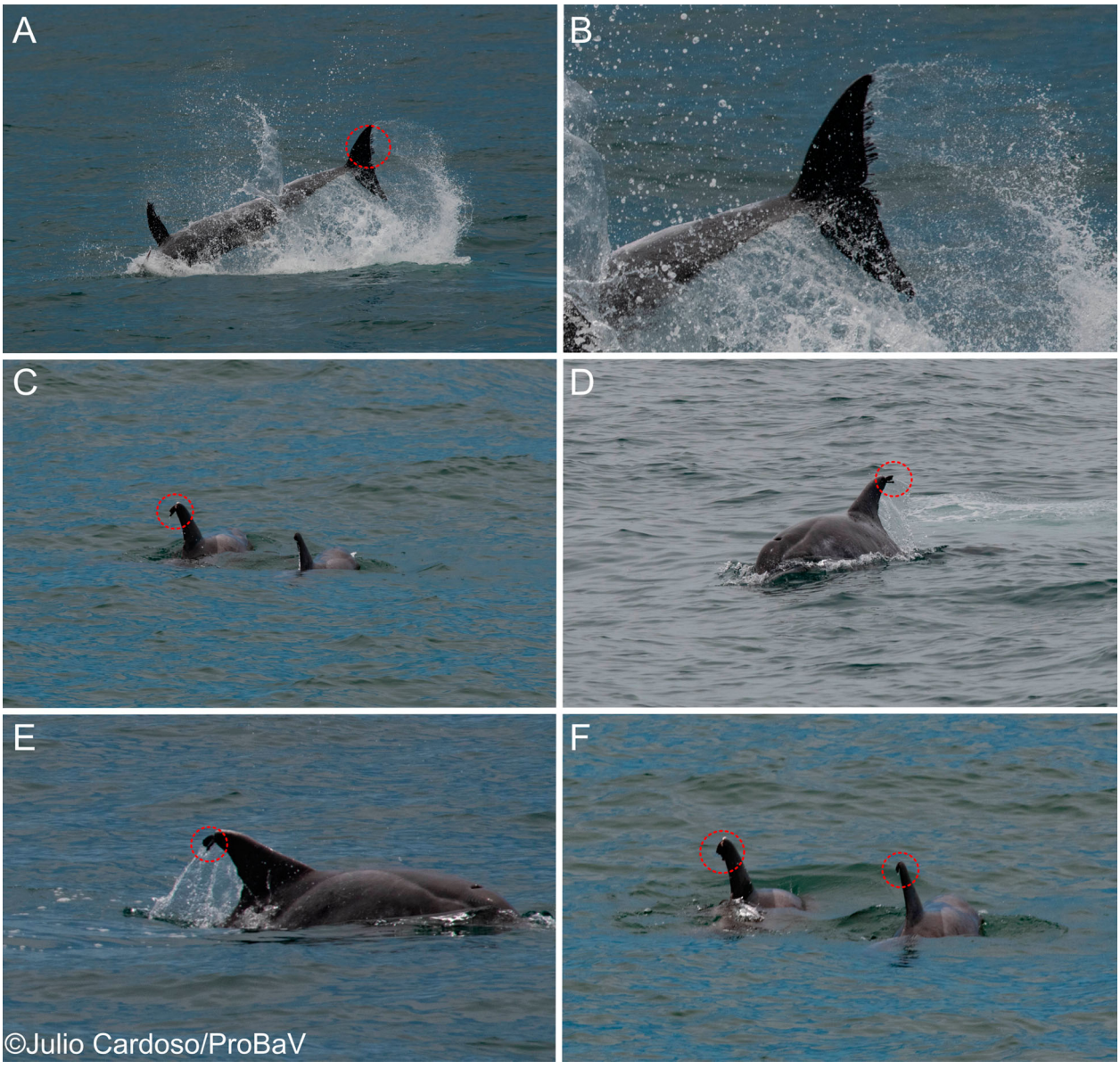

Figure 2. Rough-toothed dolphins *Steno bredanensis* (G. Cuvier in Lesson, 1828) infested with *Xenobalanus globicipitis* Steenstrup, 1852. Red circles show the attachment to the host.

group of six orcas was observed on 20 July 2019 revealing the persistence of *X. globicipitis* for over a year in south-eastern Brazilian waters.

Common bottlenose dolphins, Atlantic spotted dolphins and Guiana dolphins infested with *X. globicipitis* were observed during three consecutive days during January 2019 (Table I). A group of 40–50 adult and juvenile common bottlenose dolphins was observed chasing a school of triggerfishes (Balistidae) on 19 January 2019. At least seven common bottlenose dolphins presented *X. globicipitis* attached to their flukes, dorsal or pectoral fins (Figure 5).

A very active group of 10–12 Atlantic spotted dolphin individuals, mostly juveniles, was reported on both 20 and 26 January with at least five infested by *X. globicipitis* on their dorsal fins. The group was chasing schools of unidentified fish and displaying 'belly-up' behaviour and lateral swimming, strongly interacting with each other (Figure 6). A sighting on 23 May of a group of over 100 individuals, revealed the persistence of *X. globicipitis* in Brazilian coastal populations, with several infested specimens.

Xenobalanus globicipitis individuals were observed attached to the tip of the dorsal fins of at least two Guiana dolphins in a small group sighted on 7 July 2018. Later on 20 January 2019 a large aggregation of almost 100 Guiana dolphins was also observed, with at least two infested by *X. globicipitis*, on the tip of their dorsal fins (Figure 7). Interestingly, several groups comprising up to five franciscana dolphins

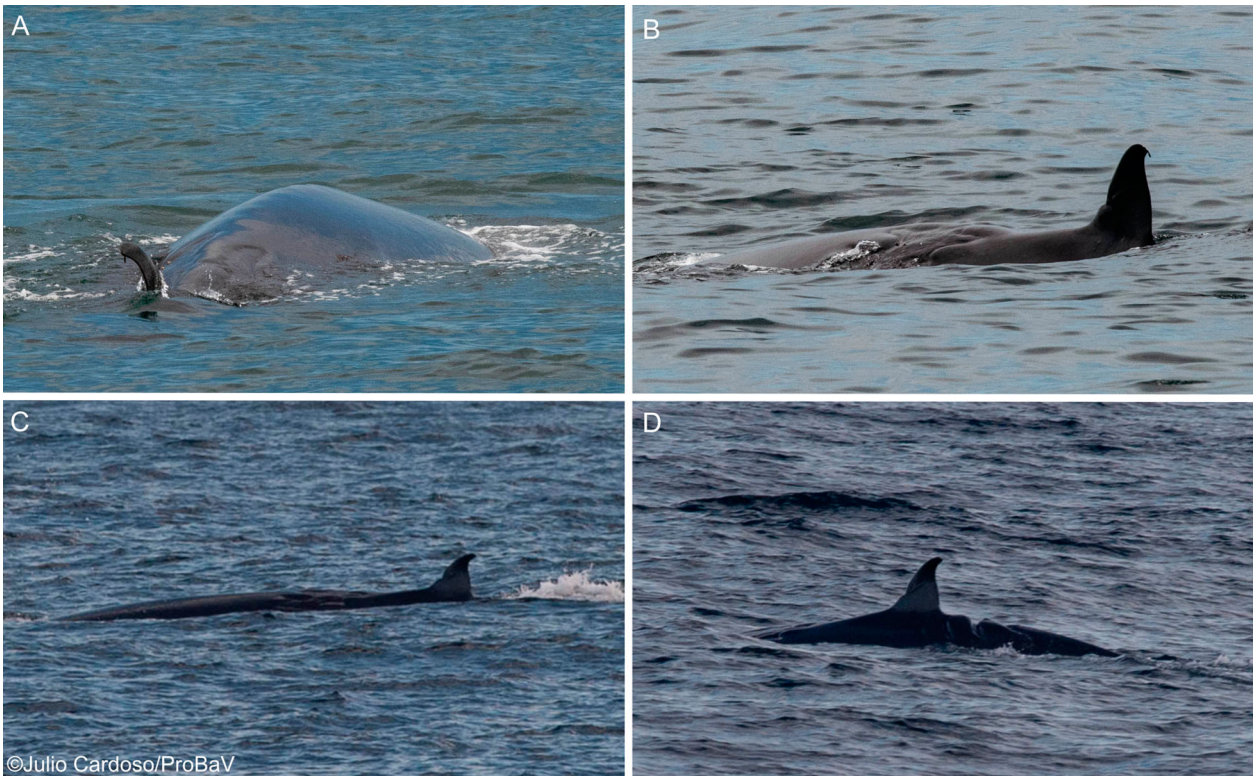

Figure 3. Bryde's whale *Balaenoptera brydei* Olsen, 1913 infested with *Xenobalanus globicipitis* Steenstrup, 1852. 3A and B. Sightings of 'Escondidinha' with *X. globicipitis*. 3C and D. Sightings of 'Escondidinha' without *X. globicipitis*.

specimens were sighted on the next day after the consecutive observations of common bottlenose dolphins, Atlantic spotted dolphins and Guiana dolphins, with no indication of the presence of *X. globicipitis*. In addition, a recent observation was made of barnacles in a group of about 50 Guiana dolphins, on 8 June 2019.

The prevalence of *X. globicipitis* on Atlantic spotted dolphins, common bottlenose dolphins and Guiana dolphins was considered medium in all observed specimens, usually of less than 10 specimens/fluke. In most cases, the stalked barnacles were attached to the tips of the dorsal fins, the trailing edges or alongside the flukes and fins of adult/subadult dolphins.

Discussion

Xenobalanus globicipitis was observed in Atlantic spotted dolphins, rough-toothed dolphins, killer whales, a Bryde's whale, Guiana dolphins and common bottlenose dolphins. In Brazilian waters, this barnacle species has been previously recorded in eight Guiana dolphin (79 examined specimens), a common bottlenose dolphin (five examined specimens), and a franciscana (96 examined specimens) stranded on the coast of Rio de Janeiro (Di Beneditto and Ramos 2000). More recently, Carvalho et al. (2010) and Ribeiro et al. (2011) reported the occurrence of *X. globicipitis* on a striped dolphin *Stenella coeruleoalba* (Meyen, 1833) from two individuals stranded in Ceará, north-eastern Brazil (Table II). Carvalho et al. (2010) reported on parasitic and epizootic metazoans of cetaceans along the north-east coast of Brazil from 1994–2009 and found only one *X. globicipitis* (parasitizing striped dolphin) among 82 analysed carcasses belonging to 14 cetacean species, and noted only one record of *X. globicipitis* for one striped dolphin. To the authors' knowledge, this is the first record of *Xenobalanus globicipitis* in Atlantic spotted dolphins and Bryde's whale (under classification *B. brydei*).

According to the PROBAV dataset, the Atlantic spotted dolphin is one of the most frequently observed small cetaceans in the shallow waters off northern São Paulo in the last few years, alongside franciscana dolphins and rough-toothed dolphins. However, only two groups of Atlantic spotted dolphins were observed infested by *X. globicipitis*. The Atlantic spotted dolphin can be categorized into age classes by their degree of spotting and colour phases, where juveniles lack spots (Herzing 1997), and the observations reported herein include both juveniles and adults infested with *X. globicipitis*. Previous assessment of Atlantic spotted dolphins stranded along the north-east coast of Brazil

Figure 4. Orcas *Orcinus orca* (Linnaeus, 1758) infested with *Xenobalanus globicipitis* Steenstrup, 1852. Red circles indicate host attachment.

reported one Atlantic spotted dolphin without *X. globicipitis* (Carvalho et al. 2010).

Balaenoptera edeni Anderson, 1878 and *B. brydei* were synonymised based on skeletal comparisons by Junge (1950), which led to the use of *B. edeni*. However, recent findings based on behavioural, morphological, osteological and genetic differences suggest that this synonymization was premature (Best 1977; Omura et al. 1981; Kanda et al. 2007; Penry et al. 2018). The Bryde's whale is considered data deficient in Brazil (Rocha-Campos and Câmara 2011), and the taxonomic identity of Bryde's whale in South America is still poorly understood, however, recent genetic studies suggested that the whales distributed in Brazilian waters belong to *B. brydei* (Pastene et al. 2015). Kane et al. (2008) reported *X. globicipitis* for the first time from three *B. edeni* of 43 studied individuals. In the present study, we report the first association of *X. globicipitis* with *B. brydei*.

Furthermore, this study also provides the first record of *X. globicipitis* for rough-toothed dolphins and orcas in the South-west Atlantic Ocean, according to the GEMM-Lagos database (see Supporting Information). Previous sightings of rough-toothed dolphins in the area (Cardoso et al. 2019) did not provide evidence of the presence of barnacles. In 15 opportunistic sightings conducted by PROBAV since October 2012 to the present (2019), the only occasions when *X. globicipitis* effectively infested this species were on 15 July 2018 and 11 November 2018. The presence of *X. globicipitis* in

Figure 5. Common bottlenose dolphins *Tursiops truncatus* (Montagu, 1821) infested with *Xenobalanus globicipitis* Steenstrup, 1852. Red circles indicate host attachment.

rough-toothed dolphins has been previously reported off Mauritania (North-east Atlantic Ocean) (Addink and Smeenk 2001), and not detected in the Eastern tropical Pacific Ocean (Kane et al. 2008). In addition, no *X. globicipitis* specimens were observed on 11 rough-toothed dolphin carcasses carefully examined along the central-north coast of Rio de Janeiro state from 2003 to 2010 (S. Siciliano, pers. observ.), nor any other evidence presented in the literature covering rough-toothed dolphin strandings and field observations in Brazil.

Although orcas are regularly seen along the south-eastern Brazilian coast, this is the first record of an orca specimen hosting *X. globicipitis* in the South-west Atlantic Ocean. Records of *X. globicipitis* attached to this species in South African waters indicated a prevalence of 50% of infested specimens from the 16 observed individuals (Whitehead et al. 2014), while previous records for this barnacle were scarce for the region, using as a basis the few orca sightings recorded for South African waters (Best et al. 2010) or the misobservation of *X. globicipitis*. *Xenobalanus globicipitis* is common in the eastern North Pacific, with 68% of sighted orcas infested as reported from 1977–2003 (Kane et al. 2008). Recently observations of Arctic orcas indicate that individuals might acquire *X. globicipitis* in warmer waters and may have ranged as far south as Florida or the Gulf of Mexico or that populations from large geographic areas with barnacle exposure may undergo range expansions with diminishing Arctic sea ice (Matthews et al. 2020).

Figure 6. Atlantic spotted dolphins *Stenella frontalis* (Cuvier, 1829) infested with *Xenobalanus globicipitis* Steenstrup, 1852. Red circles indicate host attachment.

Studies on the biology and ecology of Guiana dolphins in south-eastern Brazil are plentiful (Flach et al. 2008; Santos and Rosso 2008; Van Bressem et al. 2009; Moura et al. 2012; Andrade et al. 2015), and, following the study carried out by Di Beneditto and Ramos (2000) in Rio de Janeiro, no *X. globicipitis* were observed in this dolphin species since then. Thus, this is the first evidence of this pseudostalked barnacle in Guiana dolphins after over 25 years of regular sightings in Brazilian coastal waters.

Little is known about the biology of *Xenobalanus*, and the mechanisms driving its occurrence remain uncertain (Toth et al. 2012), with larvae and early life history strategies still undescribed (Whitehead et al. 2014). Larval settlement appears to occur in temperate and/or tropical waters (Rajaguru and Shantha 1992; Kane et al. 2008), although the presence of adult *Xenobalanus* in Arctic to Antarctic waters (Bushuev 1990; Kane et al. 2008; Olafsdottir and Shinn 2013; Matthews et al. 2020) indicates a wide thermal tolerance in later life stages. While the diving depth of the host may limit barnacle settlement (Kane et al. 2008), *X. globicipitis* seems to present a wide salinity tolerance, as it has also been reported for estuarine species, such as Guiana dolphins and franciscanas (Di Beneditto and Ramos 2000).

Several authors have associated *Xenobalanus* infestations to sick or injured animals, with limited or reduced ability to swim. Indeed, their presence in cetaceans in the Mediterranean has been linked to die-offs,

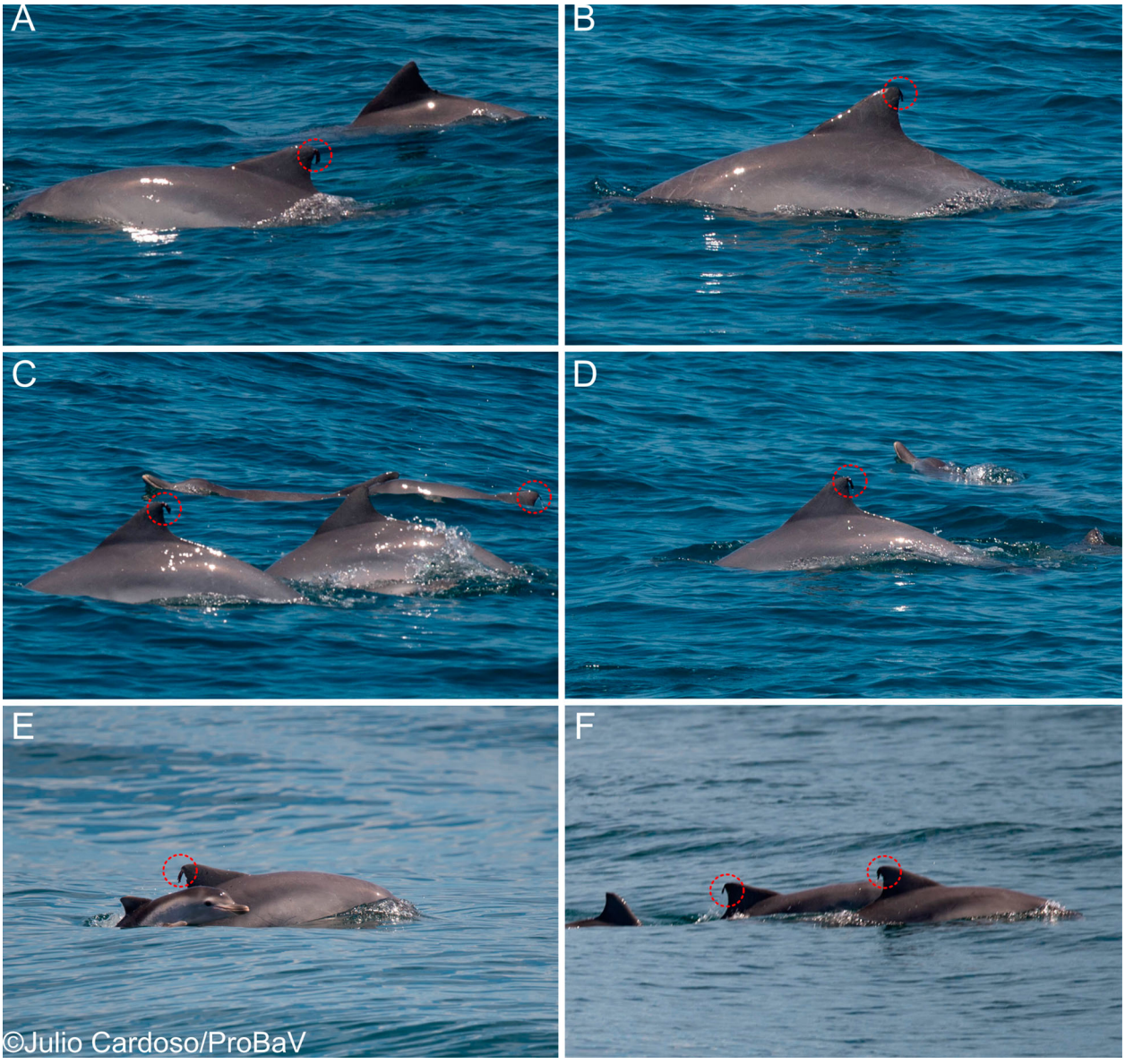

Figure 7. Guiana dolphins *Sotalia guianensis* (Van Beneden, 1864) infested with *Xenobalanus globicipitis* Steenstrup, 1852. Red circles indicate host attachment.

Table II. Previous records of *Xenobalanus globicipitis* in Brazil. *The record of X. *globicipitis* from *Physeter macrocephalus* is dubious and it might correspond to the barnacle *Conchoderma* sp. von Olfers, 1814, according to the attachment description.

Species	Date	Location	Reference
*Physeter macrocephalus**	Jun-93	Caravelas, BA	Engel (1994)
Pontoporia blainvillei	Dec-92	Flecheiras, RJ	Di Beneditto and Ramos (2000)
Sotalia guianensis	Mar-87	Guanabara Bay, RJ	Siciliano et al. (1988)
	May-88	São Sebastião, SP	Geise and Gomes (1992)
	Feb-91	Quissamã, RJ	Di Beneditto and Ramos (2000)
	May-91	Farol de São Tomé, RJ	Di Beneditto and Ramos (2000)
	Oct-91	Quissamã, RJ	Di Beneditto and Ramos (2000)
	Nov-91	Flecheiras, RJ	Di Beneditto and Ramos (2000)
	Jul-92	Guanabara Bay, RJ	Azevedo et al. (1996)
	Sep-92	Itabapoana, RJ	Di Beneditto and Ramos (2000)
	Oct-92	Quissamã, RJ	Di Beneditto and Ramos (2000)
	Jan-93	Itabapoana, RJ	Di Beneditto and Ramos (2000)
Stenella coeruleoalba		Icapuí, CE	Ribeiro et al. (2011); Carvalho et al. (2010)
Tursiops truncatus	Sep-91	Farol de São Tomé, RJ	Di Beneditto and Ramos (2000)
	May-95	Cabo Frio, RJ	Azevedo et al. (1996)

where hundreds of infested specimens were found dead ashore (Aznar et al. 1994). Given that the cetaceans observed by PROBAV were interacting with other species, actively feeding or milling, and no injuries or any abnormalities were noted, these reports may be related to abiotic traits.

Coastal cetaceans have been reported as particularly vulnerable to several anthropogenic impacts, such as pollution (Harvell et al. 1999), nutrient enrichment and habitat degradation (Geraci and Lounsbury 2009), novel pathogens (Lafferty et al. 2004), and changing diets which may, in turn, affect parasite loads (Lane et al. 2014). Moreover, several changes in different cetacean communities worldwide have been noted and linked to increases in local water temperatures due to global climate change (MacLeod et al. 2005), including alterations in gastrointestinal parasitic fauna and fungal infections (Bermudez et al. 2009; Kleinertz et al. 2014). Thus, climate change could play a role in the sudden infestation observed and reported in the present study, as also speculated by the recent report of *X. globicipitis* in orcas from Arctic waters in 2019, after over 10 years of field studies in the east Canadian Arctic (Matthews et al. 2020).

Another potential source of pseudostalked barnacles in Brazilian waters, and of significant concern, is the ballast water brought from overseas, that may also serve as a transportation route for several epibionts, including *Xenobalanus*, making this a distinct possibility for this barnacle species, as the Port of Santos, the largest Brazilian port, located a mere 130 km from the study area receives vessels from all over the world, and barnacle larvae are known to survive ballast water transport (Williams et al. 1988). Farrapeira et al. (2011) reported 343 non-indigenous and cryptogenic invertebrate species on the Brazilian coast, among which the dispersal of 115 could only be explained by ship transportation. This transportation route has been reported previously for several other invasive *Amphibalanus* barnacle species, such as *Amphibalanus reticulatus* (Utinomi, 1967), introduced to southern Brazil (Neves and Rocha 2008); *Amphibalanus improvisus*, introduced to the Caspian Sea (2006) and *Amphibalanus amphitrite*, introduced to the Salton Sea (Newman and Abbott 1980).

Although the life cycle of *X. globicipitis* is still unknown, its sister group, *Coronula* spp., which comprehends sessile barnacles associated to large baleen whales, such as right and humpback whales (Hayashi et al. 2013), displays the larval development and settlement described by Nogata and Matsumura (2006), where the metamorphosis process of *Coronula diadema* (Linnaeus, 1767) is similar to other barnacle species, hatching as nauplii larvae with six nauplii stages, followed by cyprid larvae metamorphosis after seven days and finally settling as juveniles. Furthermore, the authors observed the induction of larval settlement by a cue from the whale host, although the larvae can settle in other substrata (other than a whale's skin) after receiving a chemical cue (Nogata and Matsumura 2006). Considering the absence of *X. globicipitis* in previous assessments carried out on São Paulo's marine mammal fauna, including the pelagic orca, the similarities in the life cycle of epizoic barnacles to free living barnacles, and the constant increase of alien species brought by biofouling and ballast water, we believe the infestations of pseudostalked barnacles in cetaceans off south-east Brazil may indeed be due to the transportation of *X. globicipitis* larvae by ballast water, as reported for other barnacle species.

Interestingly, our observations cover apparently healthy groups of rough-toothed dolphins, Atlantic spotted dolphins, common bottlenose dolphins and Guiana dolphins, which are considered resident coastal species, where they are important marine biota components. The coastal upwelling system off south-eastern Brazil may also provide suitable conditions for orca occurrence during the austral spring and summer (Siciliano et al. 1999), although more than one stock of this species possibly inhabit the waters off southern Brazil (Passadore et al. 2015).

Our study increases the number of identified *X. globicipitis* hosts in Brazilian waters from four to nine cetacean species, revealing infestations of well-known coastal species. This may represent a subtle change in the environment and emphasizes the importance of long-term studies, indicating the importance of further population monitoring.

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Disclosure statement

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Ethical approval

No animal testing was performed during this study.

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References

Addink MJ, Smeenk C. 2001. Opportunistic feeding behaviour of rough-toothed dolphins *Steno bredanensis* off Mauritania. Zoologische Verhandelingen. 334:37–48.

Andrade LG, Lima IMS, Macedo HS, Carvalho RR, Lailson-Brito J, Flach L, de Freitas Azevedo A. 2015. Variation in Guiana dolphin (*Sotalia guianensis*) whistles: using a broadband recording system to analyze acoustic parameters in three areas of southeastern Brazil. Acta Ethologica. 18:47–57. doi:10.1007/s10211-014-0183-7.

Azevedo A, Soares MP, de Castro MCT, Lailson-Brito Jr, J, Gurgel MI. 1996. Ocorrência de epizoítos em cetáceos na costa do estado do Rio de Janeiro, Brasil. Resumos do XXI Congresso Brasileiro de Zoologia, Porto Alegre, Brasil, p. 254.

Aznar FJ, Balbuena JA, Raga JA. 1994. Are epizoites biological indicators of a western Mediterranean striped dolphin die-off? Diseases of Aquatic Organisms. 18:159–163. doi:10.3354/dao018159.

Aznar FJ, Perdiguero D, Perez del Olmo A, Repulles A, Agusti C, Raga JA. 2005. Changes in epizoic crustacean infestations during cetacean die-offs: the mass mortality of Mediterranean striped dolphins *Stenella coeruleoalba* revisited. Diseases of Aquatic Organisms. 67:239–247. doi:10.3354/dao067239.

Bearzi M, Patonai K. 2010. Occurrence of the barnacle (*Xenobalanus globicipitis*) on coastal and offshore common bottlenose dolphins (*Tursiops truncatus*) in Santa Monica Bay and adjacent areas, California. Bulletin of the Southern California Academy of Sciences. 109 (2):37–44. doi:10.3160/0038-3872-109.2.37.

Bermudez L, Van Bressem MF, Reyes-Jaimes O, Sayegh AJ, Paniz-Mondolfi AE. 2009. Lobomycosis in man and lobomycosis-like disease in bottlenose dolphin, Venezuela. Emerging Infectious Diseases. 15(8):1301–1303. doi:10.3201/eid1508.090347.

Best PB. 1977. Two allopatric forms of Bryde's whale off South Africa. Reports of the International Whaling Committee. 1:10–38.

Best PB, Meÿer MA, Lockyer C. 2010. Killer whales in South African waters— a review of their biology. African Journal of Marine Science. 32:171–186. doi:10.2989/1814232X.2010.501544.

Brasil. 2008. Decreto no. 53525/2008. APA Marinha do Litoral Norte de São Paulo, Brasil. Available from www.al.sp.gov.br.

Bushuev S. 1990. A study of the population structure of the southern minke whale (*Balaenoptera acutorostrata* Lacépède) based on morphological and ecological variability. Reports of the International Whaling Commission. 40:317–324.

Cardoso J, Francisco A, de Souza SP, Siciliano S. 2019. Rough-Toothed dolphins (*Steno bredanensis*) along Southeastern Brazil: report of an anomalous pigmented juvenile and description of social and feeding behaviors. Aquatic Mammals. 45(1):30–36. doi:10.1578/AM.45.1.2019.30.

Carrillo JM, Overstreet RM, Raga JA, Aznar FJ. 2015. Living on the edge: settlement patterns by the symbiotic barnacle *Xenobalanus globicipitis* on small cetaceans. PLoS One. 10 (6):e0127367. doi:10.1371/journal.pone.0127367.

Carvalho VL, Bevilaqua CML, Iniguez AM, Mathews-Cascon H, Ribeiro FB, Pessoa LMB, de Meirelles ACO, Borges JCG, Marigo J, Soares L, de Lima Silva FJ. 2010. Metazoan parasites of cetaceans off the northeastern coast of Brazil. Veterinary Parasitology. 173:116–122. doi:10.1016/j.vetpar.2010.06.023.

Dailey MD, Walker WA. 1978. Parasitism as a factor (?) in single strandings of southern California cetaceans. Journal of Parasitology. 64:593–596. doi:10.2307/3279939.

Di Beneditto APM, Ramos RMA. 2000. Records of the barnacle *Xenobalanus globicipitis* (Steenstrup, 1851) on small cetaceans of Brazil. Biotemas. 13:159–165. doi:10.5007/%25x.

Engel M. 1994. Encalhe de um cachalote, *Physeter macrocephalus*, provocado por um emalhamento em rede de pesca no litoral da Bahia, Brasil. In: Anales da VI Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur. p. 99.

Farrapeira CMR, Tenório DO, Amaral FD. 2011. Vessel biofouling as an inadvertent vector of benthic invertebrates occurring in Brazil. Marine Pollution Bulletin. 62:832–839. doi:10.1016/j.marpolbul.2010.12.014.

Fertl D, Newman WA. 2008. Barnacles. In: Perrin WF, Würsig B, Thewissen JGM, editors. Encyclopedia of marine mammals. Amsterdam: Academic Press; p. 89–91.

Flach L, Flach PA, Chiarello AG. 2008. Aspects of behavioral ecology of *Sotalia guianensis* in Sepetiba Bay, southeast Brazil. Marine Mammal Science. 24(3):503–515. doi:10.1111/j.1748-7692.2008.00198.x.

Geise L, Gomes N. 1992. Ocorrência de Plástico no estômago de um golfinho, Sotalia guianensis (Cetacea, Delphinidae). Resumenes de la III Reunión Trabajo de Especialistas en Mamíferos Acuaticos de América del Sur, 25–30 July 1988, Montevideo. pp. 26–28.

Geraci JR, Lounsbury VJ. 2009. Health. In: Perrin WF, Würsig B, Thewissen JGM, editors. Encyclopedia of marine mammals. 2nd ed. London: Academic Press; p. 546–553.

Harvell CD, Kim K, Burkholder JM, Colwell RR, Epstein PR, Grimes DJ, Hofmann EE, Lipp EK, Osterhaus ADME, Overstreet RM, et al. 1999. Emerging marine diseases - climate links and anthropogenic factors. Science. 285:1505–1510. doi:10.1126/science.285.5433.1505.

Hayashi R, Chan BKK, Simon-Blecher N, Watanabe H, Guy-Haim T, Yonezawa T, Levy Y, Shuto T, Achituv Y. 2013. Phylogenetic position and evolutionary history of the turtle and whale barnacles (Cirripedia: Balanomorpha: Coronuloidea). Molecular Phylogenetics and Evolution. 67:9–14. doi:10.1016/j.ympev.2012.12.018.

Herzing DL. 1997. The life history of free-ranging Atlantic spotted dolphins (*Stenella frontalis*): age classes, color phases, and female reproduction. Marine Mammal

Science. 13(4):576–595. doi:10.1111/j.1748-7692.1997.tb00085.x.

Junge GCA. 1950. On a specimen of the rare Fin whale, *Balaenoptera edeni* Anderson, stranded on Pulu Sugi near Singapore. Zoologische Verhandelingen. 9:1–33.

Kanda N, Goto M, Kato H, McPhee M, Pastene LA. 2007. Population genetic structure of Bryde's whales (Balaenoptera brydei) at the inter-oceanic and trans-equatorial levels. Conservation Genetics. 8:853–864. doi:10.1007/s10592-006-9232-8.

Kane EA, Olson PA, Gerrodette TG, Fiedler PC. 2008. Prevalence of the commensal barnacles *Xenobalanus globicipitis* on cetacean species in the eastern tropical Pacific Ocean, and a review of global occurrence. Fisheries Bulletin. 106:395–404.

Karuppiah S, Subramanian A, Obbard P. 2004. The barnacle *Xenobalanus globicipitis* (Cirripedia, Coronulidae) attached to the bottlenose dolphin *Tursiops truncatus* (Mammalia, Cetacea) on the southeastern coast of India. Crustaceana. 77:879–894. doi:10.1163/156854004774248753.

Kleinertz S, Hermosilla C, Ziltener A, Kreicker S, Hirzmann J, Abdel-Ghaffar F, Taubert A. 2014. Gastrointestinal parasites of free-living Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in the Northern Red Sea, Egypt. Parasitology Research. 113:1405–1415. doi:10.1007/s00436-014-3781-4.

Lafferty KD, Porter JW, Ford SE. 2004. Are diseases increasing in the ocean? Annual Review of Ecology, Evolution, and Systematics. 35:31–54. doi:10.1146/annurev.ecolsys.35.021103.105704.

Lane EP, De Wet M, Thompson P, Siebert U, Wohlsein P, Plön S, Vaughan L. 2014. A systematic health assessment of Indian ocean bottlenose (*Tursiops aduncus*) and Indo-Pacific humpback (*Sousa plumbea*) dolphins incidentally caught in shark nets off the KwaZulu-Natal coast, South Africa. PLoS One. 9(9):e107038. doi:10.1371/journal.pone.0107038.

MacLeod CD, Bannon SM, Pierce GJ, Schweder C, Learmonth JA, Reid RJ, Herman JS. 2005. Climate change and the cetacean community of northwest Scotland. Biological Conservation. 124:477–483. doi:10.1016/j.biocon.2005.02.004.

Matthews CJD, Ghazal M, Lefort KJ, Inuarak E. 2020. Epizoic barnacles on Arctic killer whales indicate residency in warm waters. Marine Mammal Science. 1–5. doi:10.1111/mms.12674.

Moreno-Colom P, Ten S, Raga JA, Aznar FJ. 2020. Spatial distribution and aggregation of *Xenobalanus globicipitis* on the flukes of striped dolphins, *Stenella coeruleoalba*: An indicator of host hydrodynamics? Marine Mammal Science. 1–18. doi:10.1111/mms.12691.

Moura JF, Hacon SS, Veja CM, Hauser-Davis RA, Campos RC, Siciliano S. 2012. Guiana dolphins (*Sotalia guianensis*, Van Benédén 1864) as indicators of the bioaccumulation of total mercury along the coast of Rio de Janeiro State, southeastern Brazil. Bulletin of Environmental Contamination and Toxicology. 88:54–59. doi:10.1007/s00128-011-0448-z.

Neves CS, Rocha RM. 2008. Introduced and cryptogenic species and their management in Paranaguá Bay, Brazil. Brazilian Archives on Biology and Technology. 51(3):623–633. doi:10.1590/S1516-89132008000300025.

Newman WA, Abbott DP. 1980. Cirripedia: the barnacles. In: Morris RJ, Abbott DP, Haderlie EC, editors. Intertidal invertebrates of California. Stanford: Stanford University Press; p. 504–535.

Nogata Y, Matsumura K. 2006. Larval development and settlement of a whale barnacle. Biology Letters. 2:92–93. doi:10.1098/rsbl.2005.0409.

Olafsdottir D, Shinn AP. 2013. Epibiotic macrofauna on common minke whales, *Balaenoptera acutorostrata* Lacépède, 1804, in Icelandic waters. Parasitic Vectors. 6:105–114. doi:10.1186/1756-3305-6-105.

Omura H, Kasuya T, Kato H, Wada S. 1981. Osteological study of the Bryde's whale from the central south Pacific and Eastern Indian Ocean. Scientific Reports of the Whales Research Institute. 33:1–26.

Orams MB, Schuetze C. 1998. Seasonal and age/size-related occurrence of a barnacle (*Xenobalanus globicipitis*) on common bottlenose dolphins (*Tursiops truncatus*). Marine Mammal Science. 14:186–189. doi:10.1111/j.1748-7692.1998.tb00706.x.

Passadore C, Domingo A, Secchi ER. 2015. Depredation by killer whale (*Orcinus orca*) and false killer whale (*Pseudorca crassidens*) on the catch of the Uruguayan pelagic longline fishery in Southwestern Atlantic Ocean. ICES Journal of Marine Sciences. 72(5):653–1666. doi:10.1093/icesjms/fsu251.

Pastene LA, Acevedo J, Siciliano S, Sholl TGC, de Moura JF, Ott PH, Aguayo-Lobo A. 2015. Population genetic structure of the South American Bryde's whale. Revista de Biología Marina y Oceanografía. 50:453–464. doi:10.4067/S0718-19572015000400005.

Penry GS, Hammond PS, Cockcroft VG, Best PB, Thornton M, Graves JA. 2018. Phylogenetic relationships in southern African Bryde's whales inferred from mitochondrial DNA: further support for subspecies delineation between the two allopatric populations. Conservation Genetics. 19:1349–1365. doi:10.1007/s10592-018-1105-4.

Pugliese MC, Böttger SA, Fish FE. 2012. Barnacle bonding: morphology of attachment of *Xenobalanus globicipitis* to its host *Tursiops truncatus*. Journal of Morphology. 273:453–459. doi:10.1002/jmor.20006.

Rajaguru A, Shantha G. 1992. Association between the sessile barnacle *Xenobalanus globicipitis* (Coronulidae) and the common bottlenose dolphin *Tursiops truncatus* (Delphinidae) from the Bay of Bengal, India, with a summary of previous records from cetaceans. Fisheries Bulletin. 90:197–202.

Ribeiro FB, Carvalho VL, Bevilaqua CML, Bezerra LEA. 2011. First record of *Xenobalanus globicipitis* (Cirripedia: Coronulidae) on *Stenella coeruleoalba* (Cetacea: Delphinidae) in the oligotrophic waters of north-eastern Brazil. Marine Biodiversity Records. 3:e8. doi:10.1017/S1755267209991151.

Rocha-Campos CC, Câmara IG. 2011. Plano de ação nacional para conservação dos mamíferos aquáticos: grandes cetáceos e pinípedes. Instituto Chico Mendes de Conservação da Biodiversidade, Brasília.

Rossi-Wongtschowski CLDB, Madureira LSP. 2006. O ambiente oceanográfico da plataforma continental e do talude na região SE-S do Brasil. São Paulo: EDUSP.

Santos MCO, Rosso S. 2008. Social organization of marine tucuxi dolphins, *Sotalia guianensis*, in the Cananéia

estuary of southeastern Brazil. Journal of Mammalogy. 89 (2):347–355. doi:10.1644/07-MAMM-A-090R2.1.

Santos MCO, Siciliano S, Vicente AFC, Alvarenga FS, Zampirolli E, Souza SP, Maranho A. 2010. Cetacean records along São Paulo State coast, Southeastern Brazil. Brazilian Journal of Oceanography. 58(2):123–142. doi:10.1590/S1679-87592010000200004.

Seilacher A. 2005. Whale barnacles: exaptational access to a forbidden paradise. Paleobiology. 31:27–35. doi:10.1666/0094-8373(2005)031[0027:WBEATA]2.0.CO;2.

Sicliliano S, Capistrano L, Lodi L. 1988. Xenobalanus globicipitis registrado em Sotalia sp. na Baía de Guanabara, Rio de Janeiro, Brasil. Resumenes de la III Reunión de Trabajo de Especialistas en Mamíferos Acuaticos de América del Sur, Montevideo, Uruguay, p. 18.

Siciliano S, Lailson-Brito Jr J, Azevedo A. 1999. Seasonal occurrence of killer whales (*Orcinus orca*) in waters of Rio de Janeiro, Brazil. Zeitschrift für Säugetierkunde (Mammalian Biology). 64(4):251–255.

Spivey HR. 1981. Origins, distribution, and zoogeographic affinities of the Cirripedia (Crustacea) of the Gulf of Mexico. Journal of Biogeography. 8:153–176. doi:10.2307/2844558.

Toth JL, Hohn A, Able KW, Gorgone AM. 2012. Defining bottlenose dolphin (*Tursiops truncatus*) stocks based on environmental, physical, and behavioral characteristics. Marine Mammal Science. 28:461–478. doi:10.1111/j.1748-7692.2011.00497.x.

Toth-Brown J, Hohn A. 2007. Occurrence of the barnacle, *Xenobalanus globicipitis*, on coastal common bottlenose dolphins (*Tursiops truncatus*) in New Jersey. Crustaceana. 80:1271–1279. doi:10.1163/156854007782321137.

Urian KW, Kaufmann R, Waples DM, Read AJ. 2019. The prevalence of ectoparasitic barnacles discriminates stocks of Atlantic common bottlenose dolphins (*Tursiops truncatus*) at risk of entanglement in coastal gill net fisheries. Marine Mammal Science. 35(1):290–299. doi:10.1111/mms.12522.

Van Bressem M-F, Santos COM, Oshima JEF. 2009. Skin diseases in Guiana dolphins (*Sotalia guianensis*) from the Paranaguá estuary, Brazil: A possible indicator of a compromised marine environment. Marine Environmental Research. 67 (2):63–68. doi:10.1016/j.marenvres.2008.11.002.

Van Waerebeek K, Reyes JC, Alfaro J. 1993. Helminth parasites and phoronts of dusky dolphins *Lagenorhynchus obscurus* (Gray, 1828) from Peru. Aquatic Mammals. 19:159–169.

Whitehead TO, Rollinson DP, Reisinger RR. 2014. Pseudostalked barnacles *Xenobalanus globicipitis* attached to killer whales *Orcinus orca* in South African waters. Marine Biodiversity. 45(4):873–876. doi:10.1007/s12526-014-0296-2.

Williams RJ, Griffiths FB, Van Der Wal EJ, Kelly J. 1988. Cargo vessel ballast water as a vector for the transport of non indigenous marine species. Estuarine, Coastal and Shelf Science. 26:409–420. doi:10.1016/0272-7714(88)90021-2.