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Is the reproductive area of the humpback whale (*Megaptera novaeangliae*) in Brazilian waters increasing? Evidence of breeding and calving activities around Ilhabela, São Paulo, Brazil

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Humpback whales (*Megaptera novaeangliae*) from breeding stock A ("BSA") are present along the Brazilian coast where reproduction occurs between April and December. The main breeding area in Brazil is the Abrolhos Bank, however the distribution range has been considered from Natal, Rio Grande do Norte (5° S) to Cabo Frio, Rio de Janeiro (23° S). In recent years, sightings of humpback whales along the coast of São Paulo have increased. Since 2019, a land-based study aiming to characterize cetaceans' occurrence, distribution and behavior was established at Ilhabela Island, SP. Every day, up to nine 30-minute surveys were performed. The range of humpback whale sightings occurred from 30 April to 02 October in 2019 and 2020. For both years, in 1,104.5 hours of surveys, 254 humpback whale groups were observed. In total seven groups containing calves and four competitive groups were sighted in the region. The presence of mother-and-calf pairs, and competitive groups, indicate that the humpback whales are using the region as a calving and mating area. Ilhabela presents intense anthropogenic activities; long-term surveys shall improve our understanding of the humpback whales' habitat use, and occurrence patterns of other cetacean species in the area to guide proper management of coastal activities allowing whales, dolphins and humans to share the region.

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Migration involves persistent movement between two destinations. The migrations of baleen whales include the longest known annual movements of any mammal (Stone *et al.*, 1990). Migration takes whales from warm tropical waters to cold productive waters in high latitudes (Dawbin, 1966). It is still not understood all the evolutionary compromises that migration causes in the biology and breeding behavior of humpback whales - it shall affect a wide range of characteristics and functions, from energetics to growth rate, from breeding strategy to social behavior, however its function remains unclear (Clapham, 2000).

The presence of humpback whales in low latitude areas fluctuates during autumn, winter and spring when breeding and calving activities occur; then they migrate to high latitudes feeding grounds where they spend the summer (Dawbin, 1966). Breeding and calving grounds of the humpback whales are typically found around insular coasts, or offshore reef systems, in tropical or subtropical waters (*e.g.* Dawbin, 1966). Their social behavior during the breeding season is characterized by small groups and brief associations, with occurrences of lone individuals, dyads and trios being common (*e.g.* Mobley and Herman, 1985). Larger groups, performing aggressive and agonistic behavior with physical contact, characterize the competitive groups (Clapham and Mattila, 1990). The presence of competitive groups may indicate a humpback whale breeding area (Clapham *et al.*, 1992; Weinrich, 1995). Humpback whale calves are born after a gestation period of 11-12 months (Chittleborough, 1958), and mothers with newborn calves require sheltered waters explaining, in part, aggregations in breeding grounds (Clapham, 2000). In the breeding areas, a shift in social groups is observed as the seasons progress, mother with newborn calves, and groups containing calves becoming more frequent (*e.g.* Martins *et al.*, 2001; Morete *et al.*, 2008).

Humpback whale populations were heavily exploited in the western South Atlantic, both in their feeding and breeding grounds (*e.g.* de Morais *et al.*, 2016). Humpback whales from the breeding stock A ("BSA") (IWC, 2005) are present along the Brazilian coast, and the population is increasing (Andriolo *et al.,* 2010; Zerbini *et al.*, 2011; 2019; Bortolotto *et al.*, 2016; Pavanatto *et al.*, 2017) and other areas used before the whaling period along the northeast and northern coasts of Brazil are being reoccupied (*e.g.* Zerbini *et*

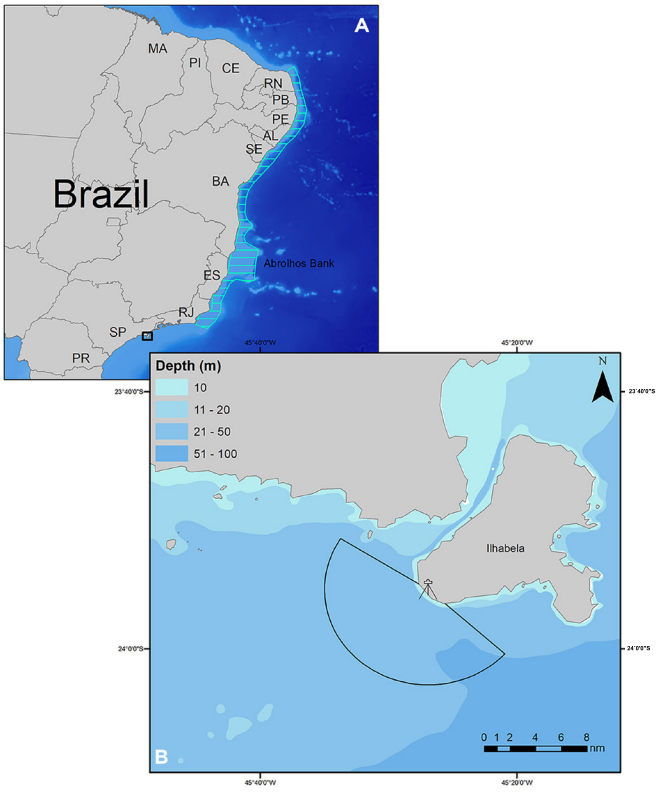

Figure 1. (A) Brazilian coast, showing the known distribution range of breeding stock A ("BSA") humpback whales (blue hatched lines). (B) Study area (encompassing a 14-km radius from the land base station corresponding to 278 km^2), located at the south portion of Ilhabela Island, São Paulo State, Brazil.

al. 2004; Rossi-Santos *et al.*, 2008; Gonçalves *et al.*, 2018; Ristau *et al.*, 2020). However, the main breeding area of humpback whales in Brazil is the Abrolhos Bank (Andriolo *et al.*, 2010).

Humpback whale calving and breeding in Brazil occur between April (Danilewicz *et al.*, 2009) and December, with peaks in August and September (Martins *et al.*, 2001; Zerbini *et al.*, 2004; Rossi-Santos *et al.*, 2008; Andriolo *et al.*, 2010). Then humpbacks migrate to feed off South Georgia and South Sandwich Islands (Engel and Martin, 2009; Zerbini *et al.*, 2006).

The island of Ilhabela (originally called Ilha de São Sebastião) is located on the northern coast of São Paulo, and is the largest in the state. Historical data show that whaling activity took place at Ilhabela, during periods of the 17th and 18th centuries (Ellis, 1958). In fact, there are two beaches at the island that report to the whaling period: "Praia da Armação" and "Praia Ponta Azeda". There are also locations named in past centuries that indicate the presence of whales, like "Borrifos" (blow) and Ponta do Gibalte (Gibalte: common name used to refer to humpback whales) also included in the official charts.

Motivated by recent sightings of humpback whales reported on the coast of São Paulo State, including of a competitive group and mother-and-calf pair in 2018 by opportunistic observers, a pilot research study was initiated in 2019. The main goal was to verifiy what humpback whales were doing in the region: were they just passing, still migrating north, or were they using the area as a breeding and calving ground. Also the study aimed to characterize humpback whale and other cetaceans' occurrence, distribution and behavior. Observations were conducted from a land-based station at the southern portion of Ilhabela Island (23°55'23.2" S, 45°26 53.7" W), 110 meters above sea level. The study area comprises 278 km², depth ranges between 21 and 50 m (Fig. 1), and temperature varies between 17°C and 27,8°C. A survey sampling protocol (Mann, 1999) was established. Each survey was defined as a 30-minute observation block, during which all marine mammal sightings were recorded. Surveys were conducted by one or two observers using 7x50 binoculars and naked eyed. Each sighting was located using a DT 10 Sokkia theodolite, species were identified whenever possible, and groups were observed for a period, in order to estimate the number of individuals and to characterize behavioral activity. Every day, weather and visibility permitting, along the daylight period, a maximum of nine surveys were performed. Consecutive surveys were spaced by one-hour intervals. In order to sample all periods within the daylight hours, the first survey of the day had different starting times: 05:30h, or 06:00h, or 06:30h. As individual identification is often impossible from the land-based station, these numbers represent sightings; although within the same survey, no groups were reccounted. However some groups might have been observed, registered and reccounted more than once in subsequent surveys, or even different days without the knowledge of the observer.

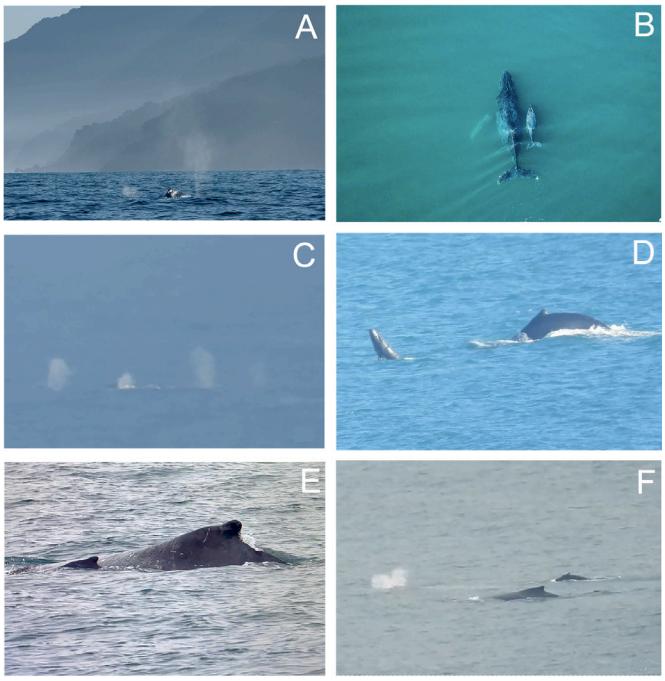

Figure 2. Sightings of humpback whale reproductive behavior observed around Ilhabela Island, Southeast Brazil. (A) Opportunistic sighting of a mother-and-calf pair on 28 July 2018 (photo by Luciano Candisani). (B) A mother-and-calf sighted on 14 July 2019 from land-based station (Photo by VIVA). (C) Competitive group sighted on 11 July 2020 from land-based station (Photo by VIVA). (D) Mother, calf and escort group sighted on 03 August 2020 from land-based station (Photo by VIVA). (E) Mother and calf group sighted on 31 August 2020 at north coast of Ilhabela (photo by Projeto Baleia à Vista). (F) Mother, calf and escort group seen on 02 October 2020 from land-based station (Photo by VIVA).

Table 1. Observations of typical humpback whale reproductive behavior around Ilhabela Island, São Paulo, Brazil, 2018-2020, recorded during land-based surveys, Projeto Baleia à Vista "PBAV" vessel survey and opportunistic sightings.

Date	Hour	Group	Location	Research platform	Behavioral description
24 July 2018	15:15h	Competitive group (5 whales)	South of Ilhabela	Vessel PBAV	Active swimming, underwater blows, head lunging, fluke up dives
28 July 2018	15:00h	Mother and calf	East of ilhabela	Opportunistic observation	Swimming, calf close to the mother all the time
14 July 2019	08:19h	Mother and calf	South of Ilhabela	Land base	The mother exhibited pectoral fin slap, and in one instance the calf showed the ventral part of its fluke while performing tail slap
22 June 2020	13:00h	Competitive group (3 whales)	East of Ilhabela	Opportunistic observation	Active swimming, tail and pectoral slashes
11 July 2020	14:53h	Competitive group (5 whales)	South of Ilhabela	Land base	Active swimming with frequent blows, fluke-up dives, splashes, caudal slashes and head lunging
02 August 2020	11:43h	Competitive group (5 whales)	South of Ilhabela	Land base	Moving north performing active swimming with frequent blows, fluke-up dives, changing swimming direction frequently; after a few minutes the group disaffiliated, part continued moving north and part moved south
03 August 2020	14:18h	Mother, calf and escort	South of Ilhabela	Land base	Active swimming heading south, the calf would show the head and chin out of the water when surfaced to breath
09 August 2020	10:30h	Mother and calf	South of Ilhabela	Land base	The calf performed clumsy tail slashes several times a nd also a breach attempt
26 August 2020	15:35h	Mother and calf	South of Ilhabela	Land base	Swimming heading north
31 August 2020	16:30h	Mother and calf	North of Ilhabela	Vessel PBAV	The calf would stay close to the mother and also on top of her rostrum
02 October 2020	13:30h	Mother, calf and escort	South of Ilhabela	Land base	Mother and escort swimming side by side, the calf sometimes would swim away from them

The pilot study was first designed to last two months: June and July 2019. However, because of the amount of humpback whales and other cetaceans sighted, observations continued for 10-day periods in the subsequent months: August, September and October. From June to October 2019, during the pilot study, which started on 04 June and ended on 31 October, seventy-seven days were sampled summing 306.5 hours of surveys. The first humpback whale was observed on 04 June and the last was seen on 22 October. In total, 184 humpback whale groups, containing 265 adults and one mother-and-calf pair, were recorded. In 2020, in order to verify the humpback whales' arrival, observations started in March, and surveys were performed on a daily basis until the last day of December. Two-hundred and forty (240) days were sampled summing 798 hours of survey effort. The first humpback whale was sighted on 30 April and the last was seen on 02 October. In total, 70 humpback whale groups, containing 107 adults and four calves were registered. Reproductive behavior was observed at least 11 times around Ilhabela (Table 1 and Fig. 2). Among groups with calves, three were composed of mother and calf, and two were composed of mother, calf and escort. Two competitive groups were also registered (Table 1). Besides the observations from the land base, two competitive groups and two mother and calf pairs were observed by a citizen science project (Projeto Baleia à Vista) and opportunistically registered from vessels (Table 1).

As mentioned earlier, with the increase of the BSA population, whales are spreading along the coast of Brazil (Rossi-Santos *et al.*, 2008; Gonçalves *et al.*, 2018; Ristau *et al.*, 2020), beyond the main reproductive area of the Abrolhos Bank, reoccupying pre-whaling habitats, as it seems to be the case of the region of Ilhabela and São Sebastião, a former whaling ground (Ellis, 1958). Here, we report not only the occurrence of humpback whales in this area, but also the presence of competitive groups and calves (Fig. 2), which characterize a breeding and calving area (Clapham *et al.*, 1992), indicating that the humpback whales are using the waters surrounding Ilhabela as a calving and mating area. Another recent study also suggested that this portion of the Brazilian coast is probably an important "snack" area for humpback whales, as there are evidences of feeding behavior during the months of June and July (Siciliano *et al.*, 2019).

Most humpback whale populations are increasing around the world (Clapham, 2018), and the species is now listed as Least Concern (LC) by the International Union for Conservation of Nature (Cooke, 2018). Whales play an important ecosystem role, fertilizing the oceans (Roman *et al.*, 2014) through the food chain. On one hand, the reoccupation of this area by humpback whales might improve the ecosystem's productivity and bring economic benefits for the local community also through the development of whale watching activities (O'Connor *et al.*, 2009). On the other hand, a rapidly increasing whale population also leads to intensification of interactions with human activities (Siciliano *et al.*, 2019). The study area presents intense anthropogenic activities, including an important shipping lane that gives access to the São Sebastião port, extensive traffic of recreational boats and a variety of fishing activities, and chemical pollution from untreated domestic sewage, representing threats to the marine mammals inhabiting this ecosystem.

At the Abrolhos Archipelago breeding area, a medium-term study showed that the relative abundance of humpback whales and presence of calves fluctuate inter and intra seasonally (Morete *et al.*, 2008). In order to better understand how the humpback whales will be using Ilhabela surroundings, if they are in fact reoccupying the area, if there is a distribution shift going on, and if the area is becoming a breeding site for humpback whales, land-based surveys should be continued. It is important to highlight that, besides the humpback whale, during this ongoing study, ten other cetacean species were observed, including the endangered species franciscana (*Pontoporia blainvillei*), Guiana dolphin (*Sotalia guianensis*), Southern right whales (*Eubalaena australis*), Bryde's whale (*Balaenoptera brydei*), minke whale (*Balaenoptera acutorostrata*), orca (*Orcinus orca*), bottlenose dolphin (*Tursiops truncatus*), Atlantic-spotted-dolphin (*Stenella frontalis*) and rough-toothed dolphin (*Steno bredanensis*), all sighted within 14 kilometers of the coastline of the southern portion of Ilhabela Island. The long-term monitoring of this area may provide further information to guide proper management of coastal activities allowing whales, dolphins and humans to share this ecosystem.

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