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Perspectives and limitations regarding participatory monitoring of cetaceans: Use of a Platform of Opportunities approach by the tourism industry at the Anhatomirim Environmental Protection Area

Perspectivas e limitações do monitoramento participativo de cetáceos: utilização de plataforma de oportunidades pelo setor turístico na APA do Anhatomirim

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ABSTRACT: The increasing advance of human populations over coastal areas puts the biodiversity associated with local ecosystems at risk. Among the anthropic activities developed in these regions, ecotourism, especially the one associated with the observation of cetaceans (dolphin watching), has presented significant growth over the last decades. Aiming to mitigate the impacts arising from this practice, a series of measures have been adopted, including the creation of protected areas. In 1992, the Anhatomirim Environmental Protection Area (AEPA) was set in Santa Catarina, southern Brazil, with the main objective of protecting the resident population of Guiana dolphins (*Sotalia guianensis*). After the publication of its management plan (2013), a participatory monitoring program for boat-based tourism associated with cetacean watching was launched. The monitoring is carried out by the tourist vessels registered to operate within the AEPA, adopting a platform of opportunities approach. Those in charge must record the sighted species, the geographic coordinates, the size of the groups and the time of the sightings carried out within the AEPA and adjacent areas. This article aimed at systematizing and critically analyzing the data collected in the first five years (from 2014 to 2018) since deployment of the participatory monitoring program. During this period, the vessels made 11,136 departures and recorded 2,022 sightings of cetaceans, with predominance of Guiana dolphins (*Sotalia guianensis*, n=1,459) and bottlenose dolphins (*Tursiops truncatus*, n=546). 39% of the total Guiana dolphin sightings and 8% of the bottlenose dolphin sightings were made within the protected area limits. The results obtained corroborate previous “traditional science” research carried out in the region, but weaknesses in the implementation of participatory monitoring were evident, affecting data reliability when seen individually. Errors in coordinates were verified, as well as strong indications of errors in identifying species. There is also notable seasonality, with 61% concentration of departures and 71% of sightings in the summer months. On the other hand, participatory monitoring has brought tourism operators closer to the protected area management and has enabled a large number of records, contributing to improving knowledge about the species living in the region.

Keywords: conservation units; tourism; participatory monitoring; cetaceans; citizen science.

RESUMO: O crescente avanço das populações humanas sobre as áreas costeiras coloca em risco a biodiversidade associada aos ecossistemas locais. Dentre as atividades antrópicas exercidas nessas regiões, o ecoturismo, com destaque aquele associado à observação de cetáceos (*dolphin watching*), tem apresentado crescimento expressivo ao longo das últimas décadas. Visando mitigar os impactos oriundos dessa prática, uma série de medidas tem sido adotadas, entre elas a criação de áreas protegidas. Em 1992 foi criada a Área de Proteção Ambiental do Anhatomirim (APAA), em Santa Catarina, sul do Brasil, com o objetivo central de proteger a população residente de boto-cinza (*Sotalia guianensis*). Após a publicação de seu plano de manejo (2013), deu-se início um programa de monitoramento participativo do turismo embarcado associado à observação de cetáceos. O monitoramento é realizado por plataforma de oportunidades, pelas embarcações turísticas cadastradas para atuar no interior da APAA. Os responsáveis devem registrar a espécie avistada, as coordenadas geográficas, o tamanho do grupo e o horário das avistagens realizadas dentro da unidade e áreas adjacentes. Este artigo teve como objetivo sistematizar e analisar criticamente os dados coletados em cinco anos (de 2014 a 2018) pelo programa de monitoramento participativo. As embarcações realizaram nesse período 11.136 saídas e registraram 2022 avistagens de cetáceos, com predominância de boto-cinza (*Sotalia guianensis*, n=1459) e golfinho-nariz-de-garrafa (*Tursiops truncatus*, n=546). 39% do total das avistagens de boto-cinza e 8% das avistagens de golfinho-nariz-de-garrafa foram dentro dos limites da unidade. Os resultados obtidos corroboram pesquisas da “ciência tradicional” anteriores realizados na região, mas ficaram evidentes fragilidades na execução do monitoramento participativo, afetando a confiabilidade dos dados, quando observados individualmente. Foram verificados erros nas coordenadas, bem como fortes indícios de erros na identificação das espécies. Há também marcante sazonalidade, com concentração de 61% das saídas e 71% das avistagens nos meses de verão. Em contrapartida, o monitoramento participativo aproximou os operadores de turismo à gestão da unidade e vem possibilitando elevado número de registros, contribuindo para o melhor conhecimento das espécies na região.

Palavras-chave: unidades de conservação; turismo; monitoramento participativo; cetáceos; ciência cidadã.

1. Introduction

Dolphins from the *Sotalia guianensis* species (P. J. Van Benéden, 1864), popularly known as “Guiana dolphins”, correspond to small cetaceans (Order: *Cetacea*) living in the coastal waters of the western side of the Atlantic Ocean. They have an average size of approximately 150 cm (Lodi & Capistrano, 1990; ICMBio, 2013) and a grayish color, with stronger shades in the dorsal region. Commonly inhabiting protected waters such as estuaries and bays (Silva & Best, 1996; Simões-Lopes & Paula, 1997; ICMBio, 2013), they are distributed from Honduras (Edwards & Schnell, 2001) to the waters of southern Brazil, in the state of Santa Catarina, with its population living in the Bay of Santa Catarina Island (North Bay), the southern distribution limit for the species (Simões-Lopes, 1988).

This population of the North Bay has been studied over the last decades. Estimated at 80 individuals (Flores, 2003) and commonly found in the area in waters with depths of up to 5 meters, they exhibit a high degree of site fidelity (Wedekin *et al*., 2002; Flores & Bazzalo, 2004; 2010). They use local waters throughout their life cycle, including reproduction, raising offspring, feeding and resting (Wedekin *et al*., 2004; Daura-Jorge *et al*., 2005). Sightings are possible throughout the year (Flores & Fontoura, 2006). The species is classified as "vulnerable" according to the Red List of Brazilian Threatened Fauna (ICMBio, 2018) and as "endangered" according to the list for the state of Santa Catarina (CONSEMA, 2011).

Contact of these animals with human activities has been increasing, especially as a result of the growing urbanization of coastal areas (Bejder & Samuels, 2003; ICMBio, 2013). There is also a phenomenon of increased interest in interactions with cetaceans (Hoyt, 2001), mainly due to the adoption of policies for the conservation of these animals (O'Connor *et al*., 2009). In the North Bay area, the primary pressures are related to pollution, fishing activities, the high flow of recreational vessels, and boat-based tourism (Macedo *et al*., 2020).

The first records of boat-based cetacean-watching tourism in the world date back to 1955 (observation of gray whales, *Eschrichtius robustus*, in the United States). Currently, this activity is distributed across 119 countries on all continents, with at least 29 locations in Brazil alone (Gomes, 2021). In the North Bay region, boat-based cetacean-watching tourism emerged in the 1980s and plays a significant role in the economic dynamics of Santa Catarina. Combined with visits to historical 18th-century fortresses, this activity attracts more than 200,000 tourists a year (ICMBio, 2013), making it the location with the highest number of cetacean-watching visitors in South America (Hoyt, 2001).

The main counterpoint to the economic benefits of cetacean-watching tourism is its impact on local cetacean populations (Lusseau, 2005). The implications of these interactions are not yet fully understood, particularly due to the challenges in conducting long-term impact studies (Buultjens *et al*., 2016; Higham *et al*., 2016) and to the absence of data from before onset of the activity (Bejder & Samuels, 2003). Despite this, there are several studies suggesting negative effects on the animals (Hoyt, 2001; O'Connor *et al*., 2009). In response to the interactions with vessels, impacts that extend beyond the more evident effects of direct mechanical contact (collisions) between vessels and cetaceans (Barcenas-De La Cruz *et al*., 2017; Schoeman *et al*., 2020) are reported, such as alterations in movement patterns (Lusseau, 2005; Arcangeli & Crosti, 2009), changes in group structure (Bejder *et al*., 2006a), modifications in acoustic behavior (Guerra *et al*., 2014), variations in dive times (Lusseau, 2003), and a reduction in feeding activities (Carreta, 2004), including a decrease in nursing activities for calves (Glockner-Ferrari & Ferrari, 1990; Simões *et al*., 2005). There are also studies indicating a long-term decline in abundance as a consequence of exposure to tourist activity, such as the research by Bejder & Samuels (2003), which investigated the impacts of vessels on *Tursiops sp.* in Australia. Some studies also report a reduction in negative reactions and an increase in neutral responses among cetaceans in constant contact with vessels (Pereira *et al*., 2007), as well as an increase in tolerance to this disturbance (Bejder *et al*., 2006b).

The activity is increasingly important for the economy of the North Bay region (Macedo *et al*., 2020), and measures aiming to reconcile it with the conservation of the southernmost population of Guiana dolphins have been implemented. Among the measures is the creation of the Anhatomirim Environmental Protection Area (AEPA). Despite its creation being directly linked to the conservation of the Guiana dolphin, the AEPA and adjacent areas also have records of other cetacean species, such as bottlenose dolphin (*Tursiops truncatus*), *franciscana* dolphin (*Pontoporia blainvillei*), southern right whale (*Eubalaena australis*) and humpback whale (*Megaptera novaeangliae*), which directly or indirectly benefit from the establishment of the conservation unit.

Created in 1992, the unit has had few management actions beyond protection for more than twenty years, making it difficult to meet its initial objectives (Macedo & Medeiros, 2021). Only in 2013 was its Management Plan published, a document that establishes the rules and zoning of the territory to ease the fulfillment of its creation purposes.

As part of the management plan, a detailed set of regulations regarding boat-based cetacean-watching tourism came into effect. Among a series of standards, annual registration of the vessels was required, subjected to compliance with a series of procedures. Among these, they must have educational materials about the AEPA and dolphins, employ registered environmental guides trained by the unit, and participate in the Boat-based Tourism Monitoring Program.

In this program, whose premises and methodology were developed collaboratively with vessel operators (Macedo *et al*., 2020), each vessel has a designated person (the environmental guide registered by ICMBio) responsible for completing a "logbook" for every trip to the conservation unit. In this logbook, diverse information is recorded about the route, number of passengers and, in the case of cetacean sightings, the species, estimated group size, time and geographical coordinates of the location (ICMBio, 2013).

The practice of collecting cetacean observation data using means alternative to those established by "traditional science", oftentimes carried out by individuals without formal training in the field and whose central objective is not monitoring itself, as in the present case, is a data collection modality referred to as "Platforms of Opportunity Programs" (PoPs) (Davidson *et al*., 2014). PoPs can be classified as a citizen science initiative, meaning that they are science based on the partnership between scientists and citizens in the different phases of the scientific process, including data collection (Irwin, 2018). Despite being a relatively recent practice, it has proved to be highly valuable in a range of studies, including those focused on cetaceans, easing the collection of critical information for conservation of the taxon (Kiszka *et al*., 2007; Moura *et al*., 2012; Davidson *et al*., 2014; Hupman *et al*., 2014; Kaufman *et al*., 2021).

Data related to the cetaceans from the AEPA have been systematically collected by vessels since the publication of its management plan and tabulated by ICMBio. In the first five years since its implementation (from 2014 to 2018), there are "logbook sheets" for over 11,000 sea trips, with more than two thousand records of cetacean sightings. However, despite a previous study that aimed at illustrating the purposes of monitoring and the perception of those involved (Macedo *et al*., 2020), a more detailed and critical analysis of the results achieved so far has never been conducted. This analysis aims at understanding how this participatory monitoring strategy has (or has not) contributed to better understanding cetaceans and to improving territory management.

The current aims at bridging this gap. It was sought to understand how platform of opportunities monitoring is being executed in the conservation unit and what results have been achieved since the beginning of its implementation. Based on the systematization and analysis of the data collected by the vessels in the first five years of its existence (from 2014 to 2018), especially focusing on those related to the spatial and time distribution of cetaceans and comparing them with distribution patterns identified in existing "traditional science" research in the region, two guiding questions shaped the research: What information do the data from the Boat-based Tourism Monitoring Program provide for better understanding the distribution patterns of cetaceans living in the region? Which are the positive aspects and which are the main difficulties found in this monitoring program?

2. Methodology

2.1. Study area

The Anhatomirim Environmental Protection Area (AEPA) was created through Federal Decree No. 528 of May 20th, 1992, covering a total area of 4,750.39 hectares across coastal, marine and terrestrial environments. Its terrestrial portion is entirely located in the municipality of Governador Celso Ramos, in the central coastal region of Santa Catarina. The marine area consists of beaches, rocky cliffs, coastal islands, bays and coves, totaling approximately 60% of the AEPA area and situated within the North Bay (Figure 1).

In relation to its physical characteristics, the North Bay presents itself as a semi-confined water body with broad connections to the open sea, a factor that greatly influences local hydrodynamics (ICMBio, 2013). In general, the North Bay system is characterized as relatively shallow, rarely exceeding 5 meters in depth, with an average of around 3.5 meters (Cerutti, 1996).

The economy of the region is closely tied to the fishing activity, with approximately 75% of the total population of the municipality of Governador Celso Ramos living directly or indirectly from this activity (ICMBio, 2013). They are artisanal fishermen whose primary targets include shrimp (*Xiphopenaeus kroyeri*, *Farfantepenaeus paulensis* and *Litopenaeus schmitti*), croaker (*Micropogonias furnieri*), mullet (*Mugil liza*) and anchovy (*Cetengraulis edentulus*). These last two are important components in the diet of Guiana dolphins (Macedo & Medeiros, 2021).

In addition to the fishing activity, tourism has a growing influence on the local economy, with a significant contribution from nautical tourism, whether through recreational vessels or commercial boats, locally known as "*escunas*", which are the focus of this research (ICMBio, 2013; Macedo *et al*., 2020). These "*escunas*" transport approximately 180,000 passengers annually, making up to two trips per day to the conservation unit, predominantly during the summer season. During the tour, they enter the conservation unit, visit an 18th-century fortress (Santa Cruz de Anhatomirim Fortress), and

FIGURE 1 – Location of the Anhatomirim Environmental Protection Area in the municipality of Governador Celso Ramos, Santa Catarina.
SOURCE: prepared by the authors.

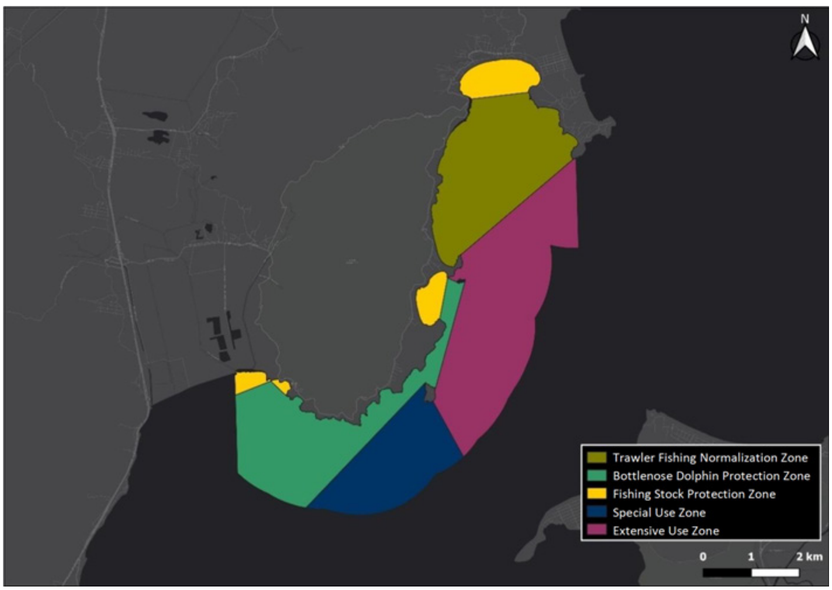

FIGURE 2 – Marine zoning of the Anhatomirim Environmental Protection Area.
SOURCE: prepared by the authors.

engage in cetacean-watching activities when the animals are sighted.

The management plan of the conservation unit, published in 2013 after a series of studies and discussions aimed at reconciling different human activities with biodiversity conservation (especially of *Sotalia guianensis*), divides the conservation unit into ten different zones. In the marine part, there are five zones (Figure 2), the most restrictive being the Dolphin Protection Zone. In this zone, which has the highest density of cetaceans according to previous studies, there are several restrictions and only artisanal fishing boats and registered "*escunas*" are allowed (ICMBio, 2013).

2.2. Data collection and analysis

2.2.1. Data sources

The data used in this study originated from the Boat-based Tourism Monitoring Program of the Anhatomirim Environmental Protection Area, collected through "logbook sheets". These sheets must be completed by the 22 registered boat tour operators associated with the conservation unit management for each trip to the CU. The logbook sheets are filled out by the environmental guides on the boats, who are trained by ICMBio in courses that take place biannually. The sampling period covers the five years after the implementation of the unit's management plan, issued in 2013 (thus, from 2014 to 2018). The material was provided by ICMBio in the form of Excel spreadsheets, containing data related to the following: vessel, date of departure, species sighted, time of sighting, location of sighting (latitude, longitude), and estimated group size (1-5 individuals, 5-20, or more than 20).

2.2.2. Data quantification and projection in the GIS platform

The records were quantified concerning the time distribution of sightings and the number of trips and sightings per vessel. To verify the frequency of these sightings, only the *Sotalia guianensis* and *Tursiops truncatus* records were considered due to the low number of records of other species (such as whales and *franciscana* dolphins).

The cartographic projections were produced using the *Quantum Gis* Desktop version 3.4.3 with GRASS 7.4.2 free software. The spreadsheets were converted to *shapefile* files for use in GIS as a vector layer, with each point corresponding to a sighting record. The raster layer used for projection was obtained through the *Quick Map Service* add-on, on the ESRI platform, *ESRI Gray* (*dark*) option. A *shapefile* in vector layer format, containing the zoning of the AEPA, was also used in overlay with the raster. The source coordinate reference system used for the projections was EPSG: 4326 – WGS 84.

2.2.3. Kernel density

Kernel density is a non-parametric statistical technique that, based on a given function, analyzes the existing patterns of a given data set, thus estimating its density in the study area (Jones *et al*., 1996). In order to list areas with a higher concentration of records, Kernel 95 (taking into account 95% of the sightings) and Kernel 50 (50% of the sightings) density analysis were performed.

The Kernel density projections were plotted via *Quantum Gis* Desktop version 3.4.3 with GRASS 7.4.2, using a *shapefile* produced in the R platform (R Studio, version 1.2.1335). The *adehabitatHR* package (Calenge, 2015) was used to produce the Kernel density *shapefile*.

3. Results

3.1. Sampling effort and time quantification of the departures

The analysis of the boat records revealed that 11,136 trips were made by the 22 registered tourism boats in the AEPA during the five years covered by the study (from 2014 to 2018), resulting in an average of 101.23 trips per year per vessel, with significant variation among them. Considering a tour duration of 6 hours, with 4 hours at sea and 2 hours on land, we can estimate that the total sampling effort in the marine environment was approximately 44,544 hours. There are no data regarding the distance adopted between vessels and cetaceans, but the current regulations in the conservation unit (ICMBio, 2013) stipulate that, within 100 meters, the engine must be turned off or kept in neutral.

Regarding the annual distribution, 2015 had the lowest numbers, totaling 2,053 departures, whereas 2017 is at the other end of the scale with 2,426 trips conducted. There was a notable seasonality, with only 611 trips made during the winter period and 6,754 in the summer months. 26.91% of all trips are concentrated in January, followed by February and December with 20.42% and 13.30% of the total, respectively. On the other hand, June was the month with the lowest flow of tourist vessels, with only 1.83% of the total. The maximum value recorded for a single month was 662 trips (January 2017), and the minimum was 15 trips in August 2016 (Figure 3).

3.2. Quantitative and time relationship of the sightings

In the five years analyzed, a total of 2,029 cetacean sightings were recorded, with five sightings promptly discarded due to lack of species identification, one sighting of a hammerhead shark, and one of a sea lion. Among the cetaceans, six species were recorded: Guiana dolphin (*Sotalia guianensis*, N=1459), bottlenose dolphin (*Tursiops truncatus*, N=546), *franciscana* dolphin (*Pontoporia blainvillei*, N=8), southern right whale (*Eubalaena australis*, N=7), humpback whale (*Megaptera novaeangliae*, N=1) and sperm whale (*Physeter macrocephalus*, N=1).

In relation to the monthly distribution of sightings, their number is strongly dependent on the sampling effort (vessel departures), as expected. January, the month with the most departures, was also the one with the most sightings (676, or 33.43% of the total), followed by February (24.48%) and December (13.45%), resulting in 71.36% of the total records during the summer. In contrast, the three winter months combined – June, July and August – had respectively 9, 19 and 8 records, which corresponds to only 1.78% of the total (Figure 4).

In terms of annual period, 2015 has the highest number of records (542) and 2017 the lowest, with 268 cataloged sightings. Proportionally, 2015 also has the highest rate of sightings by trips, with 26.4%, and 2017 the lowest rate with 11.04%,

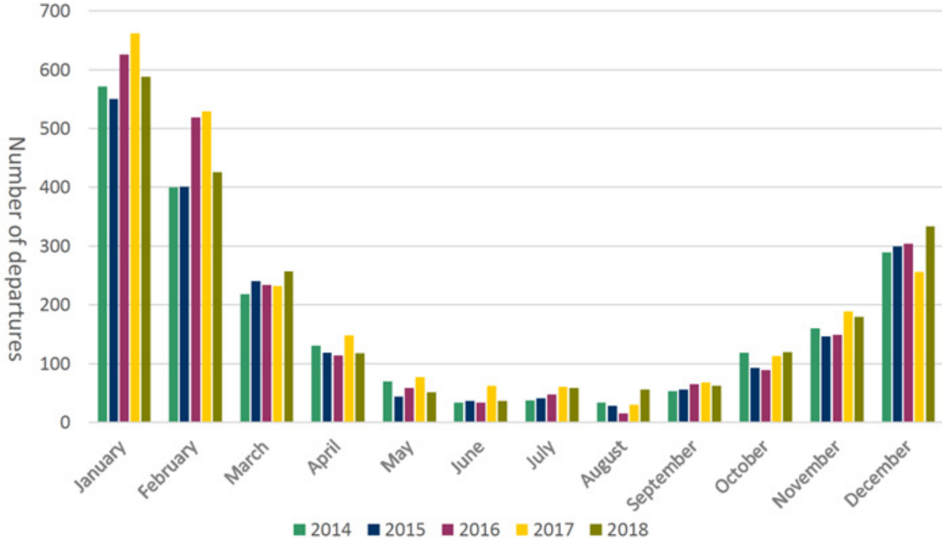

FIGURE 3 – Monthly quantification of the trips made by registered tourism boats in the Anhatomirim Environmental Protection Area.
SOURCE: prepared by the authors.

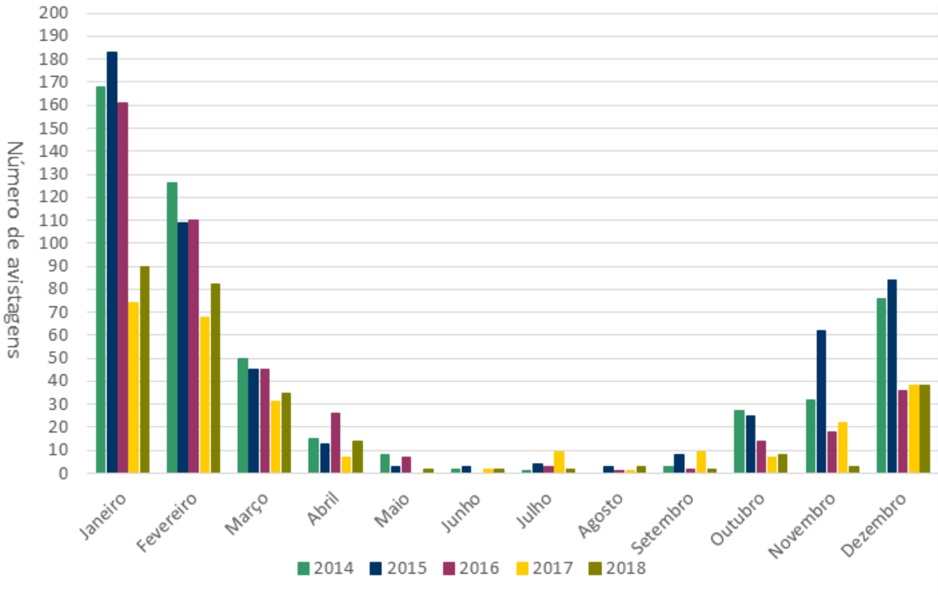

FIGURE 4 – Monthly variation of cetacean sighting records from 2014 to 2018 in the Anhatomirim Environmental Protection Area.
SOURCE: prepared by the authors.

showing a significant reduction in the frequency of sightings. In 2018, the frequency of sightings was 12.29%. One hypothesis for this decrease in the frequency of sightings, as will be discussed in the analysis, is related to a change in the route adopted by some vessels, which ceased to go to the southern part of the conservation unit, an area with a higher frequency of cetacean sightings.

When comparing sighting records per vessel, significant differences are observed. There are vessels that sighted cetaceans 396 times during this period, whereas others only made 11 records in these five years. Considering that some vessels go out more frequently than others, a correlation was also conducted between departures and success in cetacean sightings. Regarding this ratio between sightings and departures (S/D), vessel "Andorinha V" has the highest frequency of sightings, recording cetaceans in 66.44% of its trips. At the other end, vessel "Fantástico" only recorded cetaceans in 4.94% of its trips (Figure 5). These numbers highlight the different tour proposals of each vessel (four vessels primarily focus on dolphin watching, while others follow linear routes) and the consequent need for the data generated by each of them to be treated differently, which will be further explored at the end of the article.

The Guiana dolphin (*Sotalia guianensis*) was the most frequently observed species, with 1,459 records throughout the study period. The year 2014 recorded the most sightings, as well as the highest sighting index for the period, whereas 2017 presented the lowest values for both variables. Another noteworthy aspect is a significant decline in the sighting index from 2015 to 2017.

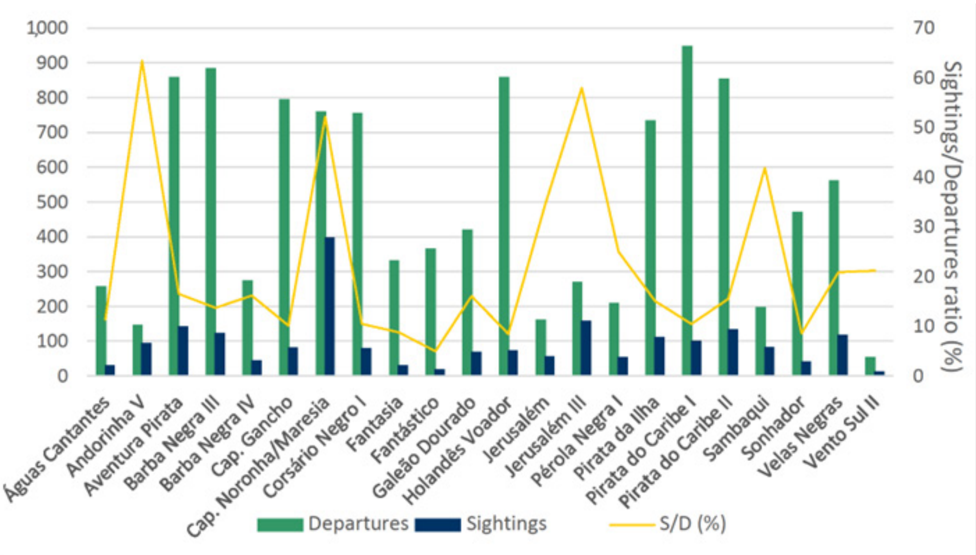

FIGURE 5 – Quantification of sightings and departures among the registered tourist vessels in the Anhatomirim Environmental Protection Area from 2014 to 2018.

SOURCE: prepared by the authors.

Bottlenose dolphins (*Tursiops truncatus*) had a total of 546 sightings during the study years, with 2015 recording the highest number of encounters. The lowest number of records was in 2018, indicating a 71.14% reduction in the total sightings when compared to 2015.

For Guiana dolphins, there was a significant difference in the sighting index across seasons, whereas for bottlenose dolphins, the values showed a lesser seasonal variation. For both species, the lowest sighting rate was in winter, although they differ regarding the season with the highest percentage: summer for Guiana dolphins and spring for bottlenose dolphins (Figure 6).

3.3. Geographical spatialization of the sighting records

Projected in a Geographic Information System (GIS), the records promptly reveal sightings cataloged in locations entirely distant from the monitoring area. It is possible to observe several records distant from the boat routes, even in terrestrial environments (Figure 7 and Figure 8). These points are evidently errors in the recording of geographical coordinates for the sighting locations and have been excluded from the analyses herein presented.

3.3.1. Tursiops truncatus

Regarding the spatial distribution of the cataloged sightings for bottlenose dolphins (N=546),

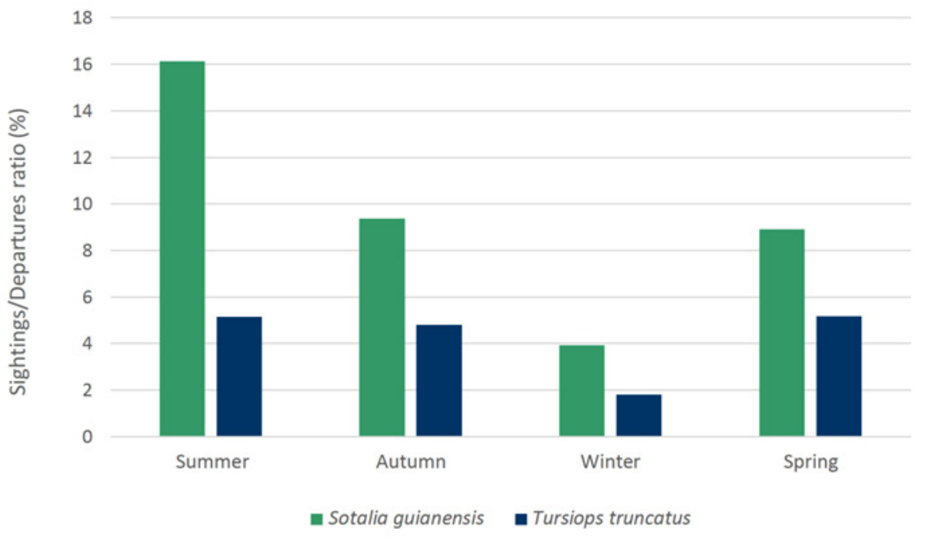

FIGURE 6 – Seasonal relationship of the sightings/departures ratio for *Sotalia guianensis* and *Tursiops truncatus* in the AEPA and adjacent areas for 2014-2018 period.

SOURCE: prepared by the authors.

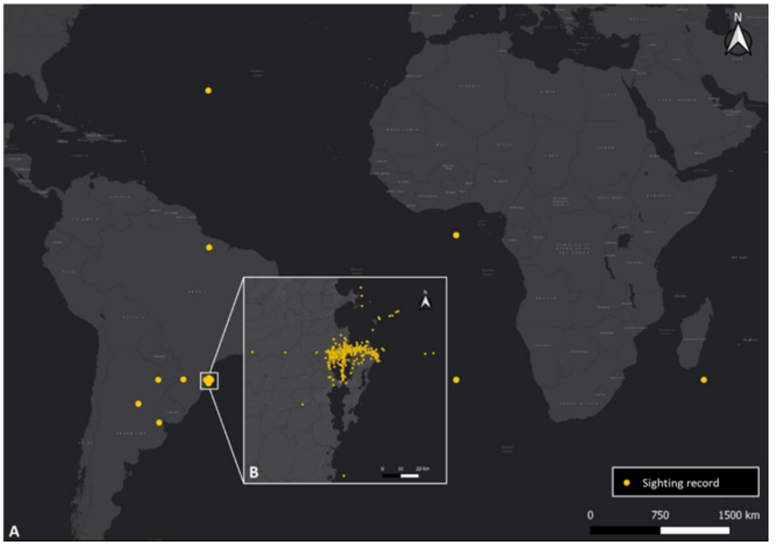

FIGURE 7 – Geographical distribution of the sightings recorded by the cetacean monitoring program of the Anhatomirim Environmental Protection Area (A), with a zoomed-in view of the Santa Catarina Island region – Brazil (B).

SOURCE: prepared by the authors.

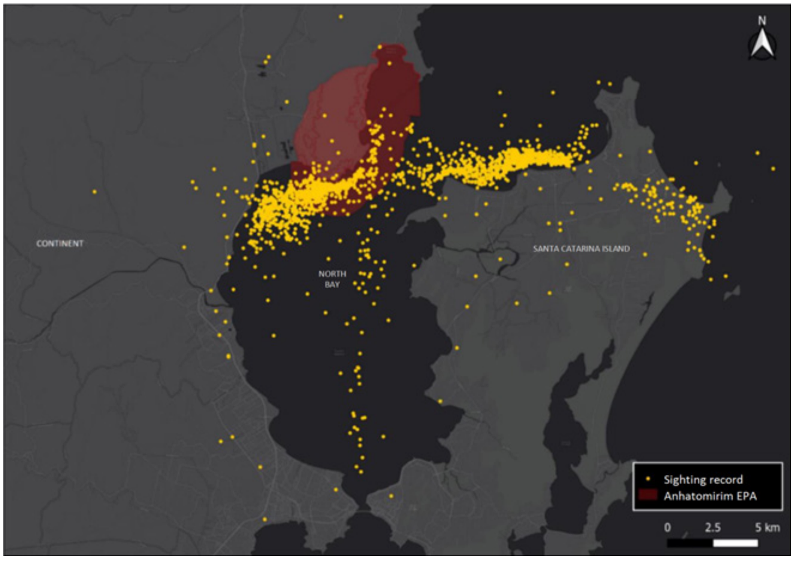

FIGURE 8 – Spatial distribution of the cetacean sighting records from the Boat-based Tourism Monitoring Program of the Anhatomirim Environmental Protection Area, covering the North Bay region and adjacent areas, highlighting the conservation unit's limits and zoning.

SOURCE: prepared by the authors.

73.44% were in the region in front of the North face of Santa Catarina Island. Nearly 12% were also recorded within the North Bay limits, and 8% within the AEPA (Figure 9). Considering zoning of the unit, the Extensive Use Zone (*Zona de Uso Extensivo*, ZUEX) presented the highest number of records for the species (N=19), followed by the Bottlenose Dolphin Protection Zone (*Zona de Proteção dos Botos*, ZPB) (N=15).

3.3.2. Sotalia guianensis

The Guiana dolphin sightings records (N=1,459) were mainly concentrated in the south area of the AEPA, West of the North Bay (Figure 10). In relation to zoning of the AEPA, 61% (N=890) of the records were outside the unit's limits. Among the sightings within the unit (N=569), as expected based on previous studies, the Bottlenose Dolphin Protection Zone (ZPB) concentrated the highest number of occurrences (N=427).

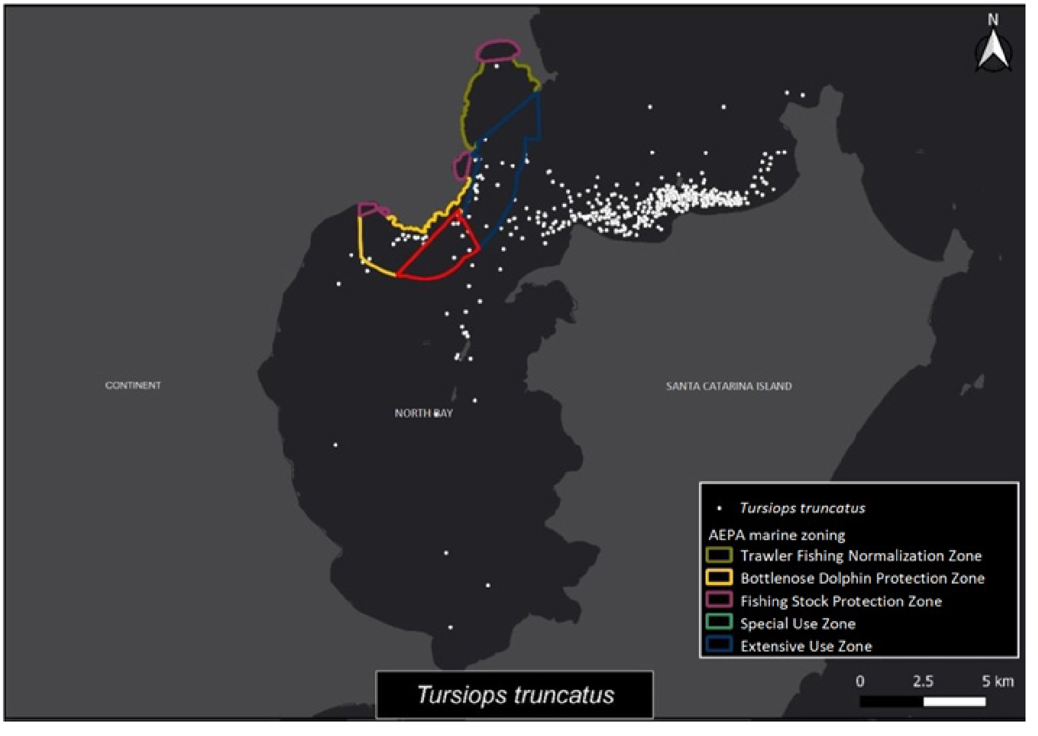

FIGURE 9 – Spatial distribution of bottlenose dolphin (*Tursiops truncatus*) sighting records from the Boat-based Tourism Monitoring Program of the Anhatomirim Environmental Protection Area, covering the North Bay region and adjacent areas, highlighting the conservation unit's limits and zoning.

SOURCE: prepared by the authors.

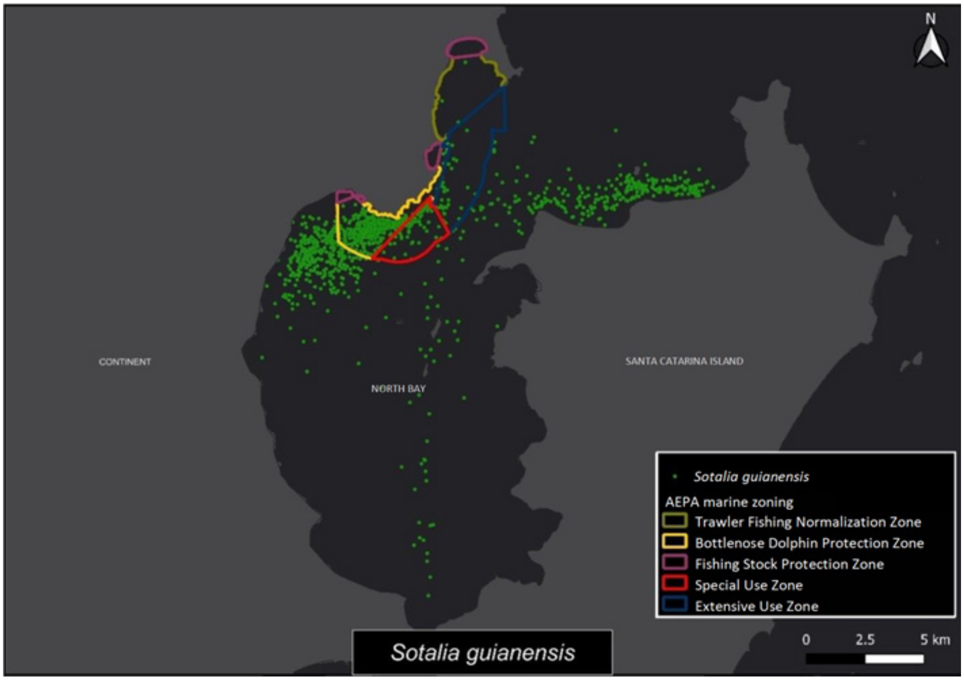

FIGURE 10 – Spatial distribution of Guiana dolphin (*Sotalia guianensis*) sighting records from the Boat-based Tourism Monitoring Program of the Anhatomirim Environmental Protection Area, covering the North Bay region and adjacent areas, highlighting the conservation unit's limits and zoning.

SOURCE: prepared by the authors.

3.3.3. Kernel density

Both Guiana dolphins and for bottlenose dolphins, the 95% Kernel density identified a wide and similar distribution area for the sightings. When applying 50% Kernel, the differences between both species became evident. The method indicated a significant concentration of Guiana dolphin sightings in the southern region of the AEPA, with a considerable portion of the area outside the unit's limits, in the western part of the North Bay (Figure 11). In contrast, for bottlenose dolphins, a higher concentration of sightings was evidenced in the region in front of the North face of Santa Catarina Island (Figure 12).

3.4. Estimated size of the groups

Of all 2022 cetacean sighting records considered in this research, groups containing more than 20 individuals were predominant (42.9%). In addition to that, a total of 158 records had no group size reported.

This dominance of larger groups is very evident among the Guiana dolphin (*Sotalia guianensis*) records. For this species, 58.4% of the sightings

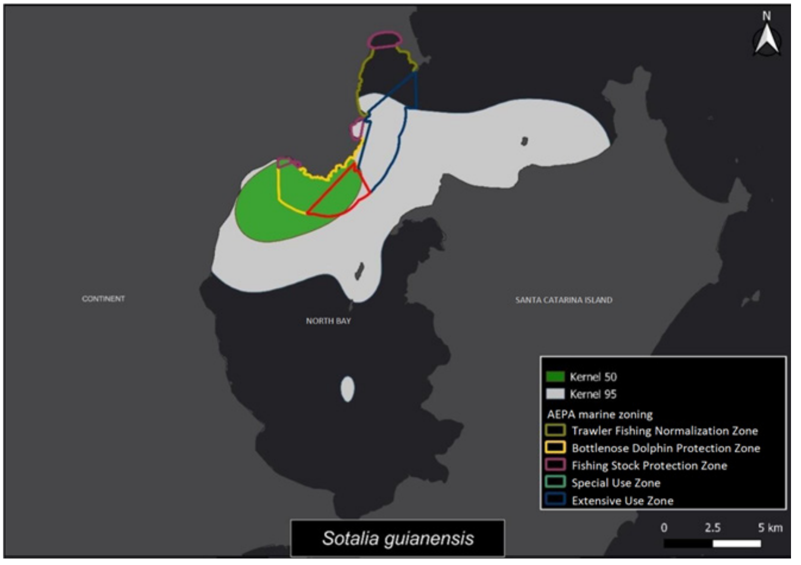

FIGURE 11 – Kernel density map for Guiana dolphin (*Sotalia guianensis*) sightings in the North Bay region and adjacent areas. 95% Kernel (white) and 50% Kernel (green). Built with data from the Boat-based Tourism Monitoring Program of the Anhatomirim Environmental Protection Area.

SOURCE: prepared by the authors.

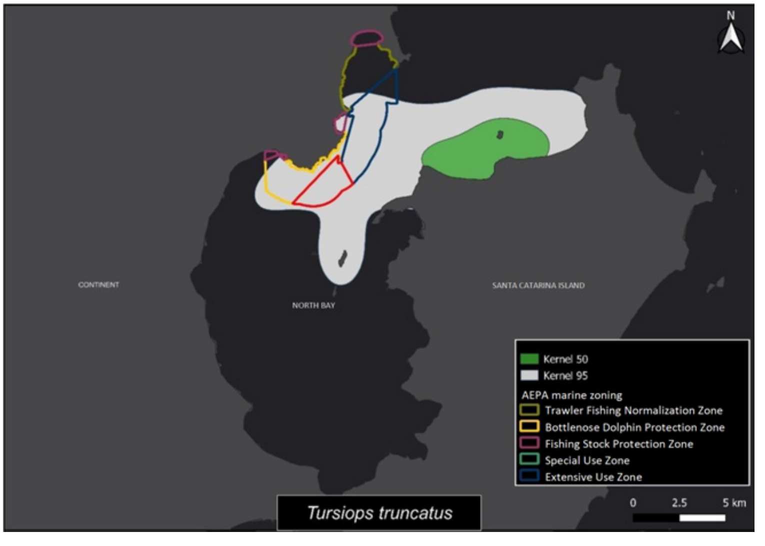

FIGURE 12 – Kernel density map for bottlenose dolphin (*Tursiops truncatus*) sightings in the North Bay region and adjacent areas. 95% Kernel (white) and 50% Kernel (green). Built with data from the Boat-based Tourism Monitoring Program of the Anhatomirim Environmental Protection Area.

SOURCE: prepared by the authors.

were of groups of 20 or more individuals, 30.6% between 5 and 20 and only 11.2% of records with 1 to 5 individuals. On the other hand, for bottlenose dolphins (*Tursiops truncatus*), groups with up to 5 individuals accounted for 57.1% of the records, sightings between 5 and 20 individuals for 40.3%, and sightings with more than 20 individuals corresponded to only 2.6% of the sightings.

For the analysis purpose, considering data from previous research studies on the spatial distribution and group sizes of both species, the Guiana dolphin sighting records were analyzed separately within and outside the North Bay area. In this case, the data show that the Guiana dolphin groups recorded within the North Bay predominantly present group sizes above 20 individuals (n=76.9%), with sightings of small groups being rare. On the other hand, records in other areas commonly show smaller groups, with up to 20 individuals, and sightings of large groups are uncommon (Figure 13). As discussed in the next section, these data are further evidence of the existence of errors in identifying the species.

4. Discussion and conclusion

Upon revisiting our research questions, we can initially assert that the analysis of the data obtained by tourist vessels operating in the Anhatomirim Environmental Protection Area shows, in the practice, the potential of the Boat-based Tourism Monitoring Program through citizen science for better understanding the cetacean distribution patterns, primarily due to the substantial amount of data provided. On the other hand, a series of weaknesses in these data became evident, evidencing the consequent need for improvements in the Program.

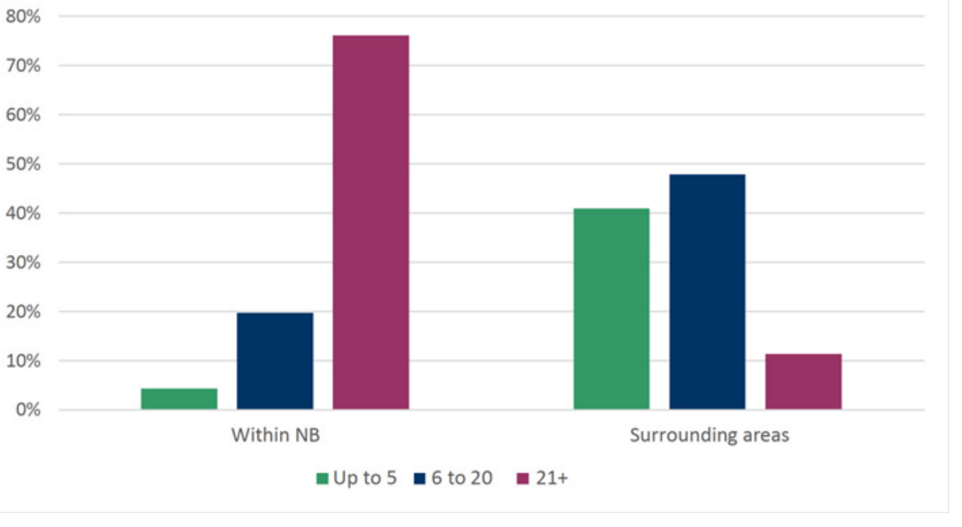

FIGURE 13 – Number of individuals per group recorded for Guiana dolphins (*Sotalia guianensis*) in the North Bay (NB) area and adjacent areas.
SOURCE: prepared by the authors.

The first positive aspect relates to the extensive sampling effort, resulting in a high number of recorded sightings. The adopted practice, in which all twenty-two tourist vessels are required to record cetacean sightings during all their trips, enabled a field effort of over 40,000 hours at sea during the five years analyzed in this study. This effort would be practically unattainable if carried out by individual researchers or small research groups.

In addition to the greater sampling effort, there is an evident lower execution cost associated with this monitoring strategy when compared to the high cost of traditional monitoring of cetacean abundance and distribution (Kaufman *et al*., 2011; Moura *et al*., 2012; Davidson *et al*., 2014; Hupman *et al*., 2014). In addition to enhancing understanding of the cetacean distribution patterns in the region and the boat-based tourism activity, this extensive and cost-effective database also has the potential to contribute to informed decision-making related to management of the conservation unit. As examples, the data collected have been used to support the definition of visit strategies for the Santa Cruz de Anhatomirim Fortress, in the context of its UNESCO World Heritage candidacy. Additionally, the data contribute to devising the Public Use Plan for the Anhatomirim Environmental Protection Area, expected to be completed in 2022, which will establish new regulations for the activity.

On the other hand, problems in part of the collected data become evident, primarily stemming from errors in the data collection process, highlighting the need to intensify efforts in training those responsible for data collection. Even though ICMBio conducts mandatory biannual training courses for all environmental guides in the Anhatomirim Environmental Protection Area, issues persist and a series of improvements are possible, as pointed out by Marques (2020), who analyzed the content of previous editions and made several recommendations that are to be incorporated into the 2022 course. In addition to the author's suggestions, we can recommend that the course not only focuses on teaching techniques for collecting cetacean data but that it also eases better understanding the data that the guides themselves collect, thus enabling guides to reflect on the data and share them with the tourists.

It is important to emphasize that this issue is not exclusive to the AEPA but recurrent in various locations that promote participatory monitoring of cetaceans (Buultjens *et al*., 2016; Lodi & Tardin, 2018).

During data analysis, both incomplete sighting records and those with erroneous geographic coordinates were observed, as evidenced when projected on the GIS platform. As illustrated throughout the text, a series of cetacean records were identified in regions far away from the vessels' routes, even in terrestrial environments.

Concerning the problems with the geographic coordinates recorded, it is possible that the device used for data collection may have influenced the data. While twenty vessels use GPS devices on board, the two vessels that had the most errors in recording coordinates rely on mobile apps for geographic positioning, indicating a possible correlation.

There are also indications of errors in identifying the species, specifically in distinguishing between Guiana dolphins (*Sotalia guianensis*) and bottlenose dolphins (*Tursiops truncatus*). In the cartographic projections, a significant number of Guiana dolphin records can be seen in front of the Canasvieiras and Jurerê beaches (North region of the Santa Catarina Island), which was unexpected because studies conducted in the area over the past decades indicate the presence of this species exclusively in the North Bay area (Simões-Lopes, 1988; Simões Lopes & Paula, 1997; Daura-Jorge *et al*., 2004, 2005), mainly concentrating in the western region (Flores & Bazzalo, 2004; Flores & Fontoura, 2006, Wedekin *et al*., 2010).

In addition to that, the group size recorded in the sightings in the Canasvieiras and Jurerê region does not align with the expectations for Guiana dolphins as established by previous research studies. While the literature indicates that bottlenose dolphins are generally found in small groups, typically fewer than ten individuals, Guiana dolphins are typically found in large groups, with an average group size of approximately 29 individuals, with records of groups with fewer than ten individuals being uncommon (Daura-Jorge *et al*., 2005; Flores & Fontoura, 2006). However, the observations in the Guiana dolphin records made by the vessels reveal that, while within the North Bay area, as expected, most of the records were of large groups, in the region in front of the North face of the Santa Catarina Island, there was predominance of small groups, with rare records of groups with more than 20 individuals. This predominance of small groups is more similar to the group size found in the literature for bottlenose dolphins, increasing the indications that there were errors in identifying the species.

On the other hand, despite these indications of potential errors in coordinate recording and species identification, considering the high number of sightings, which enables a quantitative analysis of the records, applying the 50% Kernel method to the data collected by the vessels revealed concentrations of Guiana dolphins mainly in the western strip of the North Bay and of bottlenose dolphins in the region in front of the North face of the Santa Catarina Island. This corroborates and reinforces the findings of previous studies. However, regarding this topic and considering that the data were collected through a platform of opportunities rather than from a systematically periodic study, it is important to emphasize that the Kernel densities presented in this paper only identify the concentration area of the sighting records; they should not be used uncritically to infer the home range and habitat use of these animals.

Another weakness concerns instability in the data collection frequency. A large number of records were verified in the summer months, as well as concentration of departures between 10 am and 12 pm. This irregular sampling effort, concentrated in the summer and during specific periods of the day, represents a time sampling limitation, one of the weaknesses of platform of opportunities monitoring highlighted in various studies, such as those by Kiszka *et al*. (2007) in the Bay of Biscay and by Hupman *et al*. (2014) in New Zealand.

Analyzing the proportion between the number of sightings in relation to the departures made by each vessel, the different tourism proposals they offered are evident. Four vessels have a large proportion of sightings, some of them with sightings on more than 50% of their trips. Although we did not perform a more systematic analysis by vessel, as it was not within the scope of our research objectives, we believe that this is mainly due to the fact that these four vessels offer tours more focused on dolphin watching activities, oftentimes following broader and nonlinear routes to cover different locations than others, with the aim of finding the animals. There are even reports of communication between the captains of the vessels and between them and local fishermen, thus easing encounters with the animals. Although oftentimes using cetaceans as a marketing attraction for their tours, the other vessels provide an approach with a greater focus on artistic and musical attractions offered on board and on the historical heritage of the area (Marques, 2020). Their routes are linear and there is no active search for cetaceans.

These different purposes in tour approaches highlight that, consequently, there are also two different types of cetacean monitoring through platforms of opportunities in the area. The first type, carried out by vessels primarily devoted to dolphin watching activities, results in records obtained through targeted observations, using active search methods and variable routes based on the animals' location. The second one, due to the linear routes, offers a limited sampling space, which has already been identified in several cases of sampling carried out by means of PoP in the world (Kiszka *et al*., 2007; Kaufman *et al*., 2021). In fact, this linear route is one hypothesis for the reduction in the overall number of sightings since 2015: previously, vessels with linear routes would move to a lunch stop in a southern area of the AEPA (where there is higher concentration of cetaceans) and, from 2016 onwards, due to contractual changes with local restaurants, they started having lunch closer to the Anhatomirim Island, adopting a new route through areas where sightings are not as frequent. This hypothesis is reinforced by the fact that the reduction in the number of sighting records was not observed in vessels primarily devoted to dolphin watching activities.

Beyond the monitoring data *per se*, another positive aspect that should be highlighted is the increased integration of different social actors in the territory in management of the conservation unit as a result of collective practice. Theobald *et al*. (2015) emphasize that social participation in research actions can also be useful locally, and this integration can be directly effective in management of the protected area.

Participatory management and the collective establishment of codes of conduct built collaboratively, involving both the local community and tourism operators, are understood in various studies as the most suitable for activities involving cetaceans (Hoyt, 2001; O'Connor *et al*., 2009; Buultjens *et al*., 2016; Gomes, 2021). This aspect was prominently highlighted in a previous paper developed in the AEPA (Macedo *et al*., 2020), which interviewed all boat-based tourism operators involved in the Monitoring Program in 2016 (three years after the beginning of its implementation). This paper found that development and implementation of the program promoted both a change in the interaction patterns between operators and the conservation unit management (with a reduction in conflicting patterns and an increase in partnerships) and also created a space for dialogue and reflection about the impacts of the activity on the species.

In order to enhance the benefits of this social participation in data production and territory management, while recognizing the different roles of various actors, there is still untapped potential in the Anhatomirim Environmental Protection Area (AEPA): involving not only tourism operators in cetacean monitoring activities but also the tourists themselves. Creating and disseminating platforms that minimize errors inherent to scattered and mass data collection, similar to those commonly used by bird watchers – such as *Wikiaves* (wikiaves.com.

br) and *E-Bird* (ebird.org), for example – might be a way to stimulate the collection of sighting data and promote "scientific tourism" in the region, understood as the process of generating scientific knowledge from travel experiences with the objective of making observations, collecting data, and gathering diverse information for scientific use (Conti *et al*., 2021).

In conclusion, it is evident that, despite having great potential and already yielding significant results for territory management, the participatory monitoring program developed in the AEPA has its limitations and requires improvements. Many of the limitations are solvable, such as errors in recording coordinates and identifying species. Regarding these limitations, we suggest a greater effort in training those responsible for data collection, aiming at more precise and reliable information: this would enable grounding ecological inferences about the animals. Other limitations, such as concentration of the sampling effort in the summer and the spatial limitation due to the linear routes, are inherent to the monitoring format adopted. These limitations inherent to platform of opportunities monitoring show that the data collected should be complemented with data obtained by traditional scientific means.

Finally, although it is not the objective of this paper, absence of studies evaluating the impacts of boat-based tourism specifically on cetaceans in the North Bay was noticed. Such studies would allow understanding the need – or not – for additional mitigating measures and/or restrictions to preserve local biodiversity.

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