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Guiana dolphin movements across three decades between Sepetiba and Ilha Grande bays in southeastern Brazil

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ABSTRACT

Guiana dolphins in the Costa Verde estuarine complex of southeastern Brazil are relatively well-studied, but there is still limited knowledge about their movement patterns between the two management units in the region. This study was based on the identification of the individual dolphins that transited between the two Costa Verde management units. Dolphins were photo-identified within the study area from 1994 to 2020, and two photo-identification catalogs were compiled based on this material. These catalogs were systematically compared on the finFindR software, which found 80 individuals that had transited between both management units, between 904 in Sepetiba bay and 808 in Ilha Grande Bay. The most common type of movement was a one-way (no return) movement from Sepetiba to Ilha Grande bay (62.5 %).

Keywords: Sotalia guianensis, Costa Verde estuarine complex, Transient individuals, Dispersion, Conservation

The movements by individuals between adjacent areas may influence local populations — such as demographic parameters and survival rates (Smith and Peterson, 2021), increasing gene flow (Mura-Jornet et al., 2018), and potentially affecting conservation perspectives by increasing predation rates (Estes et al., 1998). These movements may be driven by shifts in the quality of the environment, food supply, and reproductive and energetic needs (Azevedo et al., 2016; Cassini, 2013).

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Many cetaceans have large home ranges and undergo long-distance displacements either on systematic migrations (e.g., *Megaptera novaeangliae*, Bedriñana et al., 2022) or temporary movements (e.g., *Tursiops truncatus*, Dinis et al., 2016). In other cases, species may reside in a given area, such as a bay or an estuary, with little or no dispersal to adjacent areas. In Italy, for example, *T. truncatus* undergo very limited displacements in the waters around Sicily (Blasi et al., 2022). Recent research (IWC Scientific Committee workshop for assessing the status of knowledge on the Guiana dolphin [*Sotalia guianensis*]) indicates that some residents may visit neighboring areas, although this type of behavior has been largely overlooked, as in the case of the Guiana dolphin, *Sotalia guianensis* (van Bénéden, 1864).

Sotalia guianensis is a small dolphin that occurs in eastern Central and South America between Honduras and southern Brazil, inhabiting coastal areas, bays, and estuaries (Simões-Lopes, 1988; Carr and Bonde, 2000). Many *S. guianensis* populations show a high level of site fidelity, with individuals remaining year-round in home areas that encompass their feeding and breeding grounds (Araújo et al., 2003; Rossi-Santos et al., 2007; Nery et al., 2008; Espécie et al., 2010; Wedekin et al., 2010; Santos et al., 2010a). However, movements between populations remain poorly documented (IWC Scientific Committee workshop for assessing the status of knowledge of Guiana dolphin [*Sotalia guianensis*]).

In center-south of Rio de Janeiro State has three bays Guiana dolphins inhabit: Guanabara, Sepetiba, and Ilha Grande bays (Azevedo et al., 2004; Maciel et al., 2023; Espécie et al., 2010). The latter two bays form the Costa Verde Estuarine Complex (22°50'–23°20' S, 44°00'–44°45' W; Figure 1), and are linked by open water with no natural barriers that would impede the displacement of individuals between the two neighboring management units. This estuarine complex is a productive area that encompasses a number of different microhabitats, including islands, rocky coasts, and mangroves (sinks of organic matter from local river systems) and accumulates large amounts of biomass (Signorini 1980).

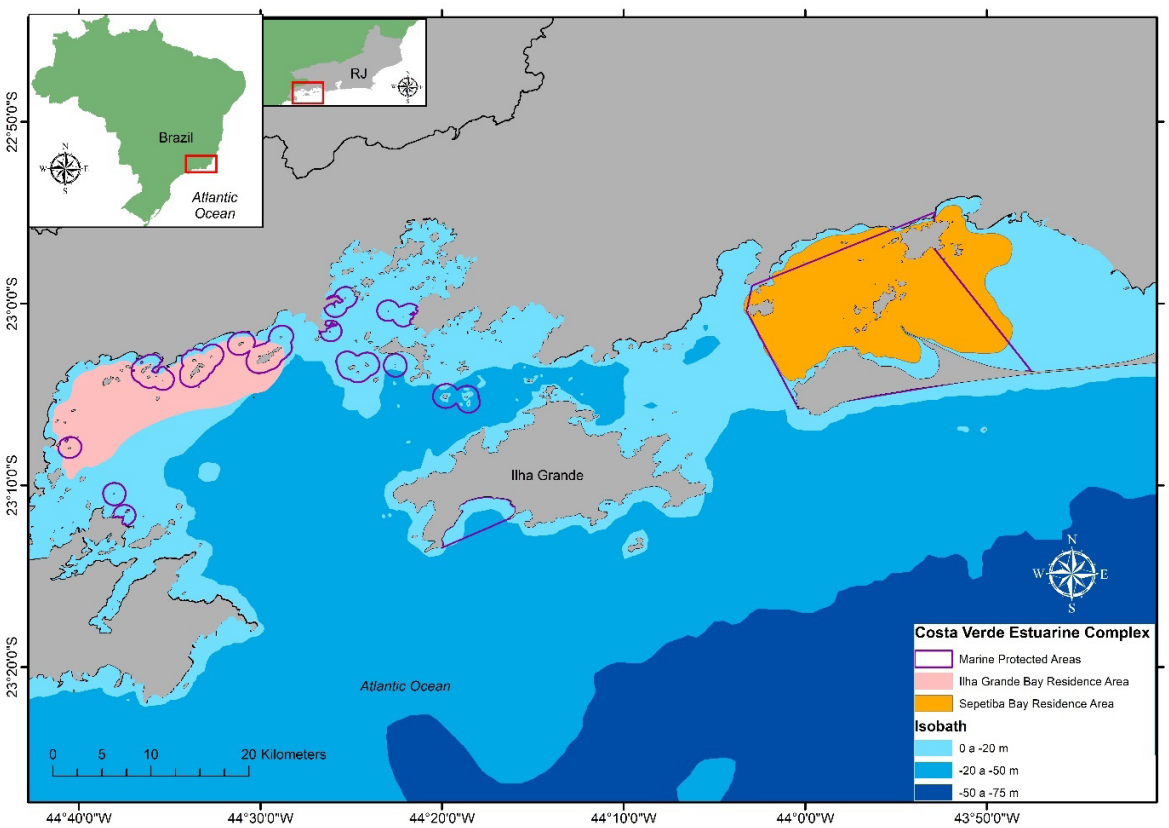

Figure 1. Map showing the areas occupied by the resident populations of Guiana dolphins within the Costa Verde Estuarine Complex in Rio de Janeiro State (RJ), southeastern Brazil.

The Sepetiba bay forms the eastern sector of the complex (Figure 1). This bay is a shallow, semi-enclosed estuary surrounded by extensive urban development, with industrial complexes, large-scale shipping terminals, and densely populated residential areas distributed across three municipalities. This bay is impacted by overfishing (Freitas and Rodrigues, 2014), eutrophication (Amado-Filho et al., 1999; Magalhães et al., 2003), urban development

(Molisani et al., 2004; Cunha et al., 2006), and chemical and organic pollution (Lacerda and Molisani, 2006; Fonseca et al., 2013), which all cause environmental degradation (Molisani et al., 2006). The *S. guianensis* population at the Sepetiba bay has low residence (36.4% residence rate) and a high frequency of calves (80% of the groups) in the social groups throughout the year and uses the bay for resting, feeding, and reproduction (Flach et al., 2008; Nery, 2008; Nery and Simão, 2012; Oliveira et al., 2013). The environmental impacts in the bay have cumulative effects on the population, which have led to a progressive decrease in group size, frequency of vocalizations, and individual feeding time (Maciel et al., 2023).

The Ilha Grande bay, in the western sector of the complex, is a more open estuary, with depths from 10 to 50 meters. The area surrounding the bay is also less developed and industrialized than the Sepetiba bay. It is a productive habitat that receives organic matter and nutrients from terrestrial sources, as well as from the sea, by the South Atlantic Central Water (SACW) (Signorini, 1980; Mahiques and Furtado, 1989). The bay is divided into eastern, central, and western sectors, with the former two sectors being more influenced by fishing, tourism by small to medium vessels, and shipping (ANTAQ, 2022). The western part of the bay has a resident population of Guiana dolphins, which occupies primarily the area between the Pico and Sandri islands (Figure 1; Tardin et al., 2020). As in the Sepetiba population, calves are also observed throughout the year, and 79.5% of the population show some degree of residency (Espécie et al., 2010; Espécie, 2015).

For Santos (2015), Guiana dolphins inhabiting both bays should be considered as distinct management units (MU). However, Caballero et al. (2018) propose one single population that is undergoing a process of segregation into two distinct units. Stable isotope studies reflected differences in food preferences between the two bays (the Ilha Grande population primarily feeds on oceanic prey, whereas the Sepetiba dolphins tend to feed on estuarine prey (Bisi et al., 2013)) and a profile of organic pollutants and contaminants (Lailson-Brito et al., 2010; Gonçalves et al., 2018). Thus, this study considers that the Sepetiba and Ilha Grande bays constitute distinct management units.

While individuals of both MU seem to show some degree of residency, movements between the two areas were first observed by the photo identification (photo-ID) of individuals of unknown sex (Galvão, 2013) and the genetic identification of males (Hollatz et al., 2011). As the two bays face different levels of anthropogenic pressure that may drive dolphin movements, this study investigated the frequency and direction of the movements of Guiana dolphins between the Sepetiba and Ilha Grande bays using a photo ID approach. Our operational hypothesis was that movements are infrequent and more likely from the Sepetiba to the Ilha Grande bay due to the gradient of human pressures.

The photo-ID method (Würsig and Würsig, 1977) was used to identify the natural markings on the dorsal fins of the individuals resident in the Sepetiba bay in 1994-2006 and then from 2017-2020 and those in Ilha Grande bay in 2007–2019, resulting in two distinct photo-ID catalogs. The photographs were taken using Canon EOS 40 and 70D cameras equipped with a 70–300 mm Canon lens. The surveys were conducted under calm conditions (Beaufort scale < 3) onboard 12-15-m vessels at speeds of no more than 15 km h^{-1}. Every time a group was sighted, speed was reduced, and the boat maintained a distance at least 50 m from the focal individuals. Due to logistic and financial constraints, the sampling design needed to be adjusted, following two sampling strategies: (i) in 1994–2006 (Sepetiba bay) and 2007–2013 (Ilha Grande bay), the boat followed haphazard routes in an effort to maximize the amount of identified individuals (Nery et al., 2008, Espécie et al., 2010) and (ii) in 2017–2020, in both bays, the boat followed planned routes (Supplementary Material - Figure S1).

The Sepetiba and Ilha Grande catalogs were compared and used to create a third catalog, composed only of transient individuals. The finFindR software (Thompson et al., 2022) was used to identify transient dolphins. A transient dolphin was defined as an individual that was

captured (photographically) in one of the two bay and recaptured in the other bay, not necessarily including its return to its original area.

The frequency of movements of transient individuals from one bay to another and the direction of the movement (i.e., where the individual was captured and subsequently recaptured) were compiled for the dataset.

The capture-recapture interval of the transient individuals was estimated by calculating the mode, maximum, mean, and minimum interval in days accounting for the dry (autumn and winter) and rainy (summer and spring) seasons (Soares et al., 2014).

In the Sepetiba bay, an overall of 34,399 photos taken from 1994 to 2020 were analyzed and 904 individuals were cataloged. In the Ilha Grande bay, 28,990 photos taken from 2007 to 2020 were analyzed, totaling 808 cataloged resident individuals. In total, 80 dolphins (4.9%), of 1632, were found to be transient, i.e., captured in one bay and recaptured in another bay. Overall, 62.5% (N = 50) of transient dolphins were first captured in the Sepetiba and recaptured in the Ilha Grande bay without being recaptured again in the Sepetiba bay (Figure 2). A total of 26 (32.5%) transient dolphins were first captured in the Ilha Grande bay and recaptured in the Sepetiba Bay without being recaptured again in the Ilha Grande bay (Figure 2). Only 5% (N = 4) of dolphins were first captured in the Sepetiba bay, recaptured in the Ilha Grande bay, and later recaptured in the Sepetiba bay (Figure 2). The maximum interval between capture and the last recapture for transient individuals totaled 8,101 days (22.1 years – individual CV006) and the minimum, 22 days (individuals CV017 and CV005). The mean totaled 2126.55 days, or 5.8 years (± 1907.17 days, or 5.2 years) days. In general, individuals were recaptured in both seasons (Table 1). A full list of the 80 transient individuals detailing direction and frequency of movements can be found in Table S1.

Cetaceans are apex predators that have a high energy demand (Lockyer, 2007). While the Guiana dolphin is a resident species (Nery, 2008; Espécie, 2015), a reduction in the availability of prey may stimulate movements to areas with a greater supply of food. Previous studies (Araújo et al., 2016; Araújo et al., 2017) indicate that the environmental degradation of the Sepetiba bay has provoked a progressive decline in the abundance and diversity of fish, including species that are part of dolphins' diet, which may partially explain the predominance of one-way movements from the Sepetiba bay to the Ilha Grande bay. By dispersing to the Ilha Grande bay, transient individuals would potentially have a greater probability of survival given that the resources available in the Ilha Grande bay appear to be adequate to support a large and healthy population of dolphins (Espécie, 2015). Even so, dispersing dolphins may also face the negative effects of fisheries, noise pollution, or potential collisions with large ships, which are all more common in the eastern and central sectors of the Ilha Grande bay. Potential predation by sharks (Selachimorpha) or killer whales, *Orcinus orca*, in these areas is also possible (Lodi and Hetzel, 1998; Aximoff et al., 2022). The sum of these factors may influence the decision-making process of the transient individuals dispersing between bays.

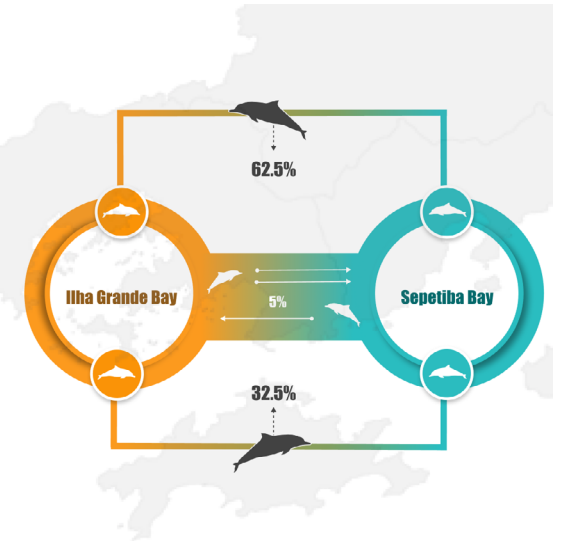

Figure 2. Percentages of the total movements of transient Guiana dolphins recorded between the Ilha Grande and Sepetiba bays, showing individuals that moved from the Sepetiba to the Ilha Grande bay (top), individuals that moved from the Ilha Grande to the Sepetiba bay (bottom), and individuals that moved from the Sepetiba to the Ilha Grande bay and then returned to the Sepetiba bay (center). The orientation of Guiana dolphins head points the direction of the movements. The two arrows in the center from the Ilha Grande bay to the Sepetiba bay indicate that dolphins leave from Ilha Grande bay, rather than otherwise.

Table 1. Seasonal variation in the capture-recapture rates of the Guiana dolphins between the Sepetiba and Ilha Grande bays in the Costa Verde Estuarine Complex, Rio de Janeiro State, Southeastern Brazil.

	Transient individuals' movements		
Capture-Recapture on Season	**Only Dry**	**Dry and Rainy**	**Only Rainy**
Σ Individuals	4	51	25
% Individuals	5	63.7	31.3

Although Santos et al. (2019) reported three individuals traveling between the Sepetiba and Guanabara bays, a distance of 135 km over open sea, research on Guiana dolphin movements remains limited. Santos et al. (2010, 2019) detected similar movements in four individuals that were observed traveling between the Cananéia and Paranaguá estuaries in southern Brazil from 1995 to 2010.

In the rainy season, the SACW increases the nutrient concentrations available in the Ilha Grande bay (Signorini, 1980), which may support an increase in the abundance of planktonic and nektonic organisms (Salvador and Bersano, 2017). A greater availability of prey during the rainy season in the Ilha Grande bay may stimulate an increase in movements from the Sepetiba bay, motivated by the potential for an increase in foraging success and the capacity to meet individual energetic demands. During the dry season, mullet (*Mugil* sp.) enter the Sepetiba bay to spawn (Morado et al., 2021), which may stimulate the resident dolphins to remain in the area, which is supported by the low recapture rates recorded from the Sepetiba bay to the Ilha Grande bay during this season, and the fact that mullet is an important type of *S. guianensis* prey (Cremer et al, 2012).

In addition to the possible motivations discussed for the transient movements between populations, an epidemiological singularity was encountered. From November 2017 to March 2018, an outbreak of morbillivirus was detected in the study area, which resulted in the deaths of 210 dolphins in the Sepetiba bay and 67 in the Ilha Grande bay (Cunha et al, 2021). The first cases of morbillivirus were detected in 2017 at Ilha Grande, with the disease being recorded at Sepetiba in early 2018 (Cunha et al, 2021). Although the circumstances of this morbillivirus outbreak are still unclear, individuals captured in Ilha Grande during this study before the outbreak were recaptured in Sepetiba after the outbreak.

Given that the virus was first detected in the Ilha Grande bay, this observation suggests that the pathogen may have been transferred to the Sepetiba population by one or more contaminated transient dolphins from Ilha Grande that engaged in social interactions in the Sepetiba bay.

While the dataset presented here is robust and extensive, as well as providing synchronized observations covering the 2017–2019 period, it still has discontinuities resulting from certain logistical and financial constraints. However, these periods fail to compromise the reliability of the results in terms of the objectives of the study given that it was possible to systematically compare the catalogs.

Although movements of the Guiana dolphins between the Costa Verde populations are infrequent, the continued monitoring of these movements is extremely important. An increase in the frequency of displacements from the Sepetiba to Ilha Grande bays may reflect a deterioration in the conditions available in the former, including a decline in prey availability (Maciel et al., 2023), and an increase in anthropogenic stressors, such as shipping, fishing, and urban development (ANTAQ, 2021; Araújo et al., 2016; Araújo et al., 2017). From an epidemiological perspective, movements between populations may introduce pathogens into otherwise healthy populations, as observed in other cetaceans, such as *Steno bredanensis* and *Tursiops truncatus* at Guanabara bay (Cunha et al., 2021) and *Megaptera novaeangliae* on the Abrolhos Bank (Groch et al., 2021). The movement of individuals between bays may also maintain genetic diversity, which can support the capacity of individuals to adapt to anthropogenic pressures. In the future, a more systematic understanding of the movements between populations, together with genetic data,

may help determine whether, in fact, research will find two distinct populations (at the Sepetiba and Ilha Grande bays) or a single metapopulation with two subpopulations connected by the dispersal of transient individuals. A systematic understanding of the population dynamics of the Guiana dolphin is an important prerequisite for the development of effective conservation and management measures.

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AUTHOR CONTRIBUTIONS

D.A.: Conceptualization; Data Curation; Investigation; Formal Analysis Methodology; Writing – Original Draft; Writing – Review & Editing.

R.T.: Conceptualization; Supervision; Funding Acquisition; Investigation; Methodology; Writing – Review & Editing.

I.M.; G. M.: Investigation; Methodology; Writing – Review & Editing.

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