Oecologia Australis
29(1):69–79, 2025
http://doi.org/10.4257/oeco.2025.2901.05

CAN AN OUTBREAK OF MORBILLIVIRUS AFFECT THE SOCIAL STRUCTURE OF THE GUIANA DOLPHIN (*Sotalia guianensis*)? A CASE STUDY OF THE POPULATION OF SEPETIBA BAY IN SOUTHEASTERN BRAZIL

Distinto Marcos Alberto Kinguari[1,2*], *Guilherme Maricato*[2,3,4], *Israel de Sá Maciel*[2,4] & *Rodrigo Hipolito Tardin*[2]

[1] Universidade Federal do Maranhão, Programa de Pós-Graduação em Ciência & Tecnologia Ambiental, Avenida Portugueses, 1966, CEP 65080-805, São Luís, MA, Brazil.

[2] Universidade Federal do Rio de Janeiro, Departamento de Ecologia, Laboratório de Ecologia e Conservação Marinha, Avenida Carlos Chagas Filho, 373, CEP 21941-971, Rio de Janeiro, RJ, Brazil.

[3] Universidade Federal do Rio de Janeiro, Instituto de Biologia, Programa de Pós-Graduação em Ecologia, Avenida Carlos Chagas Filho, 373, CEP 21941-971, Rio de Janeiro, RJ, Brazil.

[4] Universidade do Estado do Rio de Janeiro, Instituto de Biologia Roberto Alcantara Gomes, Programa de Ecologia e Evolução, Rua São Francisco Xavier, 524, CEP 20550-019, Rio de Janeiro, RJ, Brazil.

E-mails: distintokg@gmail.com (*corresponding author); guilherme.713@gmail.com; oceanmaciel@gmail.com; rhtardin@gmail.com

Abstract: Studies show that the infection of cetaceans by socially transmitted diseases may impact the ecology and behavior of individuals and populations. Little is known about the effects of intense, short-term outbreaks of disease, typical of cetacean morbillivirus (CeMV). Understanding these effects is important in the case of resident populations exposed to multiple anthropogenic impacts, as in the case of the Guiana dolphins, *Sotalia guianensis*, of Sepetiba Bay (BSEP), Rio de Janeiro, Brazil. Two hundred and ten Guiana dolphins died of CeMV in BSEP between November 2017 and March 2018. We investigated whether the outbreak affected the occurrence of Guiana dolphins in the BSEP and whether the size, composition, and cohesion of the dolphin groups shifted significantly. We conducted 25 surveys in BSEP from 2017 to 2019 and found no significant variation between the two periods (pre-CeMV and post-CeMV) in either the occurrence of dolphins or the size, composition, or cohesion of groups. During the pre-CeMV period, 32 groups were observed, with a mean group size of 16.60±21.12 individuals, all groups containing at least one calf, while the "tight" group cohesion pattern was observed most frequently. Eighteen groups were sighted during the post-CeMV period, with a mean size of 23.67±27.51 individuals, with 87.50% of groups containing at least one calf and "mixed" cohesion being the most frequent. We indicate that, over the short term, there was no significant change in the social dynamics of the Guiana dolphin groups in the BSEP after the morbillivirus outbreak, although further monitoring over a longer time scale, and focusing on specific aspects of the species would be necessary to provide more ample insights into the impacts of morbillivirus on this dolphin population. This is important in the context of the cumulative impacts of human activities on this population that have occurred over the past decade.

Keywords: cetaceans; respiratory disease; group size; group composition; cohesion.

INTRODUCTION

The considerable behavioral plasticity of cetaceans means that many aspects of their social organization are still poorly understood, given that variation in environmental and social factors may influence the response of the animals at individual, group, and population levels (Tardin *et al.* 2013, Cantor *et al.* 2021). Socially transmissible diseases can affect the ecology and behavior of individuals and populations, for example in sex-dependent survival, dispersal patterns, and mating behavior (Guardo *et al.* 2005). However, the exact effects of acute, short-term outbreaks, which are typical of the cetacean morbillivirus, are still unclear.

The cetacean morbillivirus (CeMV) is a species of the genus Morbillivirus, a member of the family Paramyxoviridae, order Mononegavirales (see Van Bressem *et al.* 2014). Globally, this virus has caused recurrent mortality events in populations of several cetacean species, reported since 1988 (Aguilar and Raga 1993, Domingo *et al.* 1990, 1992, Duignan *et al.* 1992, 1996, Lipscomb *et al.* 1994, 1996, Raga *et al.* 2008, Van Bressem *et al.* 1999, 2009). These species include the Mediterranean striped dolphins, *Stenella coeruleoalba*, bottlenose dolphin, *Tursiops truncatus*, Indo-Pacific bottlenose dolphin, *Tursiops aduncus*, common dolphin, *Delphinus delphis*, harbor porpoise, *Phocoena phocoena*, and pilot whale, *Globicephala melas* (reviewed by Van Bressem *et al.* 2014, Kemper *et al.* 2016). However, none of these studies evaluated potential impacts on their social structure.

The CeMV is transmitted primarily through the production of aerosols by infected individuals (Black 1991), which is probably facilitated by the gregarious behavior and high densities of cetacean groups (Raga *et al.* 2008, Van Bressem *et al.* 1999). Infected droplets may be inhaled from bubbles exhaled during synchronized travel and feeding bouts or social interactions (Banyard *et al.* 2008, Rijks *et al.* 2012, Van Bressem and Raga 2011).

Infection by CeMV may affect the lungs, brain, gastrointestinal tract, urinary, and immune systems, causing pneumonia and erratic behavior. In most cases, affected animals are also vulnerable to secondary infections by opportunistic pathogens due to the immunosuppressive effects of the virus (Van Bressem *et al.* 2014).

As live, infected cetaceans are rarely observed during outbreaks, the clinical signs of CeMV are poorly documented in free-living cetaceans. However, Duignan *et al.* (2018) and Flach *et al.* (2019) have described several symptoms, including: disorientation; ataxia; tremors; emaciation with impeded swimming capacity; difficulty maintaining a course, balance, and buoyancy; and an increased load of ectoparasites and epibionts.

In November 2017, an abnormal peak of 67 Guiana dolphins was found dead in Ilha Grande Bay in southeastern Brazil, with subsequent deaths occurring in the adjacent Sepetiba Bay persisting until the end of March 2018. During this event, at least 210 Guiana dolphins, primarily females and immature individuals, perished in Sepetiba Bay (Cunha *et al.* 2021).

The CeMV outbreak in Sepetiba Bay killed 60 mature females, 38 calves, 33 immature males, 23 immature females and 17 mature males. However, in Ilha Grande Bay a different pattern was observed, with 21 calves, 9 immature males, 6 immature and mature females (both), and 5 mature males found dead (Cunha *et al.* 2021). The CeMV event profiles in the two Bays were significantly different: in Sepetiba Bay, there was an increase in deaths of immature and mature females, while the number of immature and mature males deaths decreased. In Ilha Grande Bay, there was an increase in mortality of calves and immature females (Cunha *et al.* 2021).

Sotalia guianensis (Cetacea, Delphinidae) is classified as Near Threatened by the International Union for Conservation of Nature (IUCN 2022), and Brazilian populations are considered Vulnerable (ICMBio 2018). This species inhabits coastal and estuarine environments at depths of up to 50 m, with an apparent preference for waters from 23 to 27 ºC (Flores and da Silva 2009, Lodi and Borobia 2013). These dolphins are gregarious and are found in groups ranging from pairs to hundreds of individuals (Nery and Simão 2012, Lodi and Hetzel 1998, Daura-Jorge *et al.* 2005, Geise *et al.* 1999).

One of the largest known *S. guianensis* populations is found in Sepetiba Bay, where estimates of the size of the population range from 1,004 to 2,196 individuals (Nery and Simão 2012, Flach *et al.* 2008). This implies that the resources available in this region are sufficient to sustain a large population of dolphins and, in fact, *S. guianensis* is considered to be

a resident species in this bay, where it is represented primarily by females and calves, which spend most of their time feeding (Flach *et al.* 2008, Nery *et al.* 2008, Nery *et al.* 2010, Nery and Simão 2012, Oliveira *et al.* 2013). In recent decades, however, there has been a progressive increase in human activities, including the installation of two high-capacity shipping terminals and shipyard, unregulated urban growth, and the growth of local tourism and fisheries (Araújo *et al.* 2017, Araújo *et al.* 2016, Gomes-Gonçalves *et al.* 2020). Recent observations indicate that these processes have had a significant impact on the size of the local dolphin groups, with evidence that increasing anthropogenic pressures have resulted in reduced group size, alterations in surface behavior, and modifications in the vocal behavior of the dolphins (Maciel *et al.* 2023).

While the CeMV outbreak led to a marked increase in mortality rates in the *S. guianensis* population, its impacts on the social organization and other aspects of the dolphin's behavior remain unknown. Given this, the present study compared the social structure of the Guiana dolphins in Sepetiba Bay before and after the CeMV outbreak, verifying possible shifts in the occurrence, size, composition, and cohesion of the local dolphin groups. We tested the hypothesis that the *S. guianensis* groups were significantly smaller after the CeMV outbreak, with a reduced proportion of juveniles, and a decrease in cohesion.

MATERIALS AND METHODS

Study area

Sepetiba Bay is in the southern extreme of the Brazilian state of Rio de Janeiro (Figure 1), between latitudes 22°54' S and 23°04' S and longitudes 43°34' W and 44°10' W. It is a semi-enclosed coastal lagoon, with an area of 519 km². Sepetiba Bay is relatively shallow, with mean depths of up to 10 m, except in the shipping channel, which is dredged to depths of up to 30 m (Borges 1990). This bay encompasses several different aquatic habitats, such as islands, sandbanks, beaches, mangroves, rocky shores, and intertidal marshes, which support the reproduction, foraging, and survival of many different aquatic species (FEEMA/GTZ 1997). Despite the rapid recent increase in human interference, the bay is an area of "extremely high" priority for the conservation of the Brazilian coastal zone by the Brazilian Environment Ministry (MMA 2018).

Data collection

We collected data between January 2017 and July 2019. Depending on availability, we surveyed the study area using either a 7 m trawler-type vessel with a 45 HP inboard engine or a 7.3 m speedboat with an outboard 45 HP motor. In both cases, the surveys were conducted at a constant speed of approximately 7 km/h.

Surveys were conducted along three pre-defined routes (Figure 1) which were established to optimize the monitoring of the Guiana dolphin groups in Sepetiba Bay, as well as standardizing the sampling effort to avoid potential spatial and temporal bias in the collection of data. Each route was surveyed in either direction (clockwise or counter-clockwise), with a total of six possible routes. The route to be surveyed on a given day was chosen randomly before the survey and was not altered subsequently. Preferably, the route with the lowest sample number was followed, so that the entire bay was sampled equally.

Data was collected using focal group sampling (Altmann 1974). Whenever a group was sighted, the boat approached it on a parallel route, maintaining a distance of at least 50 m. The group was then monitored, with the number of individuals, their age structure, and cohesion of the group members being recorded on a standard field worksheet. The distance was measured with the naked eye by experienced observers.

We measured group occurrence using the Gi index following Tardin *et al.* (2013) to standardize the differences in the amount of observation time for each sampling period: Gi = N/n*100. Where, Gi = standardized proportion of the number of groups observed in sampling period I; N = number of groups observed in sampling period I; and n = number of hours of effort for each sampling period.

We classified a group as an association of at least two individuals within 10 m of each other, following the chain rule of Smolker *et al.* (1992). Immature animals (calves and juveniles) were identified based on their body size, *i.e.*, less than two-thirds the size of a typical adult (Geise *et al.* 1999). We classified group cohesion based on the distance between individuals and group coordination (Taylor and

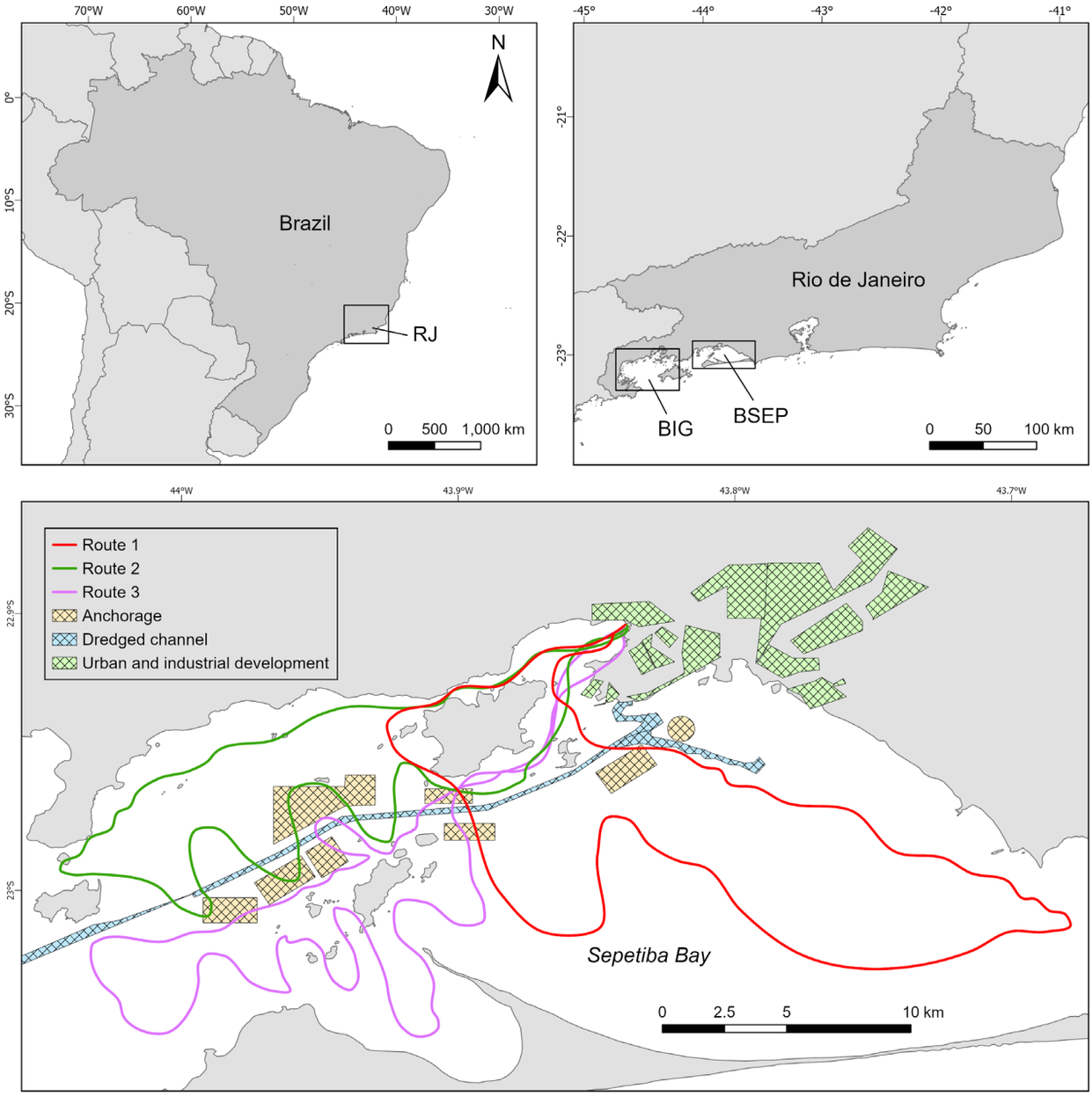

Figure 1. Map of the study area in Sepetiba Bay, southeastern Brazil, showing the pre-defined survey routes used to collect data on the behavior of the local Guiana dolphin, *Sotalia guianensis*. BIG = Ilha Grande Bay; BSEP = Sepetiba Bay; RJ = Rio de Janeiro State.

Davis 2018). Group cohesion was defined by one of three distance classes (Table 1).

Data analysis

As the CeMV outbreak apparently began in November 2017, given the peak in mortality recorded that month, we defined the period between January and November 2017 as the "pre-morbillivirus" (Pre-MV) period, while that between January 2018 and July 2019 was the "post-morbillivirus" (Post-MV) period. We used the Monte Carlo test with 5000 simulations to test whether the occurrence of groups varied significantly between these two periods. We applied Wilcoxon-Mann-Whitney's *U* to assess whether the number of groups observed per day and the size of these groups varied significantly between periods. We used the Chi-square test for two or more samples to determine whether group cohesion shifted significantly between the two periods (Zar 1984, Siegel 1975). For all analyses, $\alpha = 0.05$.

Table 1. Definition of the categories of group cohesion (following Tardin *et al.* 2013).

Pattern	Definition
Tight cohesion	Animals no more than one body length apart from each other
Loose cohesion	Animals two to five body lengths apart from each other
Mixed cohesion	Group of animals presenting both tight and loose cohesion

RESULTS

We conducted 25 surveys (15 Pre-MV and 10 Post-MV), with a total of 131.17 h of sampling effort (78.16 h Pre-MV and 53.01 h Post-MV), including 28.56 h of direct observation of the dolphins (19.16 h Pre-MV and 9.4 h Post-MV) (Supplementary Table 1).

Occurrence of dolphins and group size

A total of 32 groups were recorded during the Pre-MV period, with one to four groups being recorded per day, accounting for a Gi of 42.2 (Figure 2); group size ranged from two to 100 animals ($\bar{x}$ = 16.56 ± 21.12, Mo =10). During the Post-MV period, 18 groups were recorded, with one to three groups recorded per day, accounting for a Gi of 33.9; between one and three groups were recorded per day, with sizes ranging from two to 100 animals ($\bar{x}$ = 23.67 ± 27.51, Mo =20). Despite these differences, neither the occurrence (X^2 = 3.92, d.f. = 1, p = 0.07) nor the size of the groups (W = 244.5, p = 0.4) varied significantly between periods (Pre-MV and Post-MV). Also, there was no significant variation between periods in the occurrence (X^2 = 1, d.f = 1, p = 0.3) and the number of groups per day (W = 67, p = 0.6).

Group composition

In the Pre-MV period, information was obtained on the composition of 29 (90.6%) of the 32 groups recorded, and all 29 of these groups (100%) contained

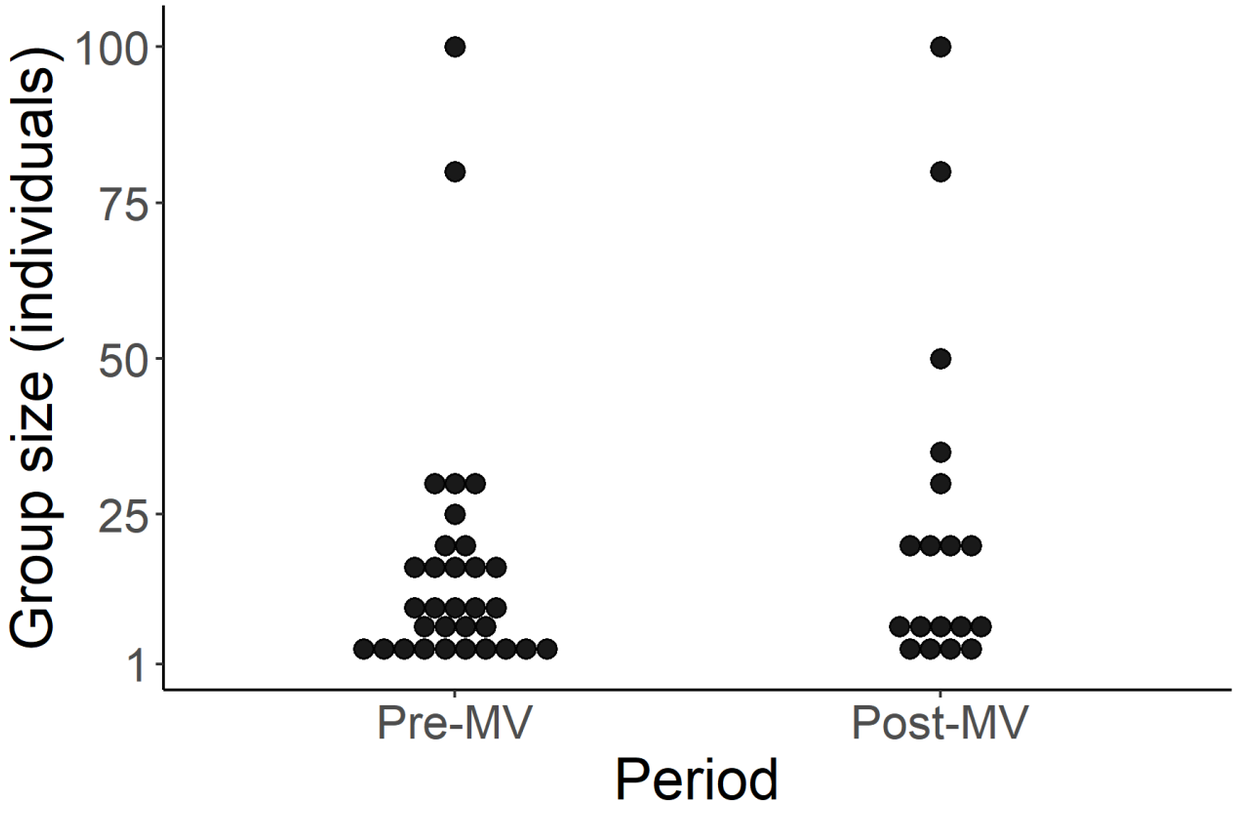

Figure 2. Variation in the size of the Guiana dolphin (Sotalia guianensis) groups sighted during the pre- (Pre-MV) and post-morbillivirus (Post-MV) study periods in Sepetiba Bay, southeastern Brazil.

at least one immature individual. Adults and immature individuals were recorded in the groups observed throughout the Pre-MV period. During the Post-MV period, information was obtained on 18 groups observed during the surveys, and 14 (77.7%) of these groups contained at least one immature dolphin. The composition of the groups did not vary significantly between the Pre-MV and Post-MV periods (W= 244.5, p = 0.4).

Group cohesion

During the Pre-MV period, a majority of the records were assigned to the "tight" cohesion category (Figure 3), whereas in the Post-MV period, the most frequent category was "mixed" cohesion. Despite the overall difference between periods, there was no significant variation in group cohesion ($X^2 = 6.0$, d.f = 5, p = 0.07).

DISCUSSION

We observed no clear short-term shifts in the social structure of the Sepetiba Bay *S. guianensis* population when comparing the pre- and post-morbillivirus periods. We expected a significant change in group size and composition, mainly because females and calves were affected disproportionately by the outbreak compared to historical data that report a higher mortality of males. The mortality ratio shifted from 2:1 males/females to 1.5:1 females/males during the morbillivirus outbreak (Cunha *et al.* 2021).

Three alternative explanations appear to be possible – (i) the time scale of the study was inadequate for the detection of significant changes in grouping patterns, (ii) individuals had immigrated from areas surrounding Sepetiba Bay, and (iii) the social groups had undergone substantial reorganization and the realignment of social alliances. In the first case, the impacts of the morbillivirus outbreak may only become apparent over a longer time interval than that covered by the present study. In particular, the male-biased shift in the sex ratio may eventually lead to lower birth rates and a decrease in population size. A deviation in the sex ratio may not be immediately apparent on a scale of one or two years, especially given the slow sexual maturation of *S. guianensis* (Van Bressem *et al.* 1999).

Females reach sexual maturity between 5 and 8 years, their gestation time is estimated at 12 months and lactation is estimated at 8.7 months. (Rosas and Monteiro-Filho 2002). Birth intervals can vary between two and three years (Santos *et al.* 2001) and they usually have one individual per offspring and long parental care of approximately 6 years (Ramos 1997, Tardin *et al.* 2013).

A second possible alternative is the dispersal of Guiana dolphins from Ilha Grande Bay, located to the west of Sepetiba Bay, which would have buffered any significant decreases in the size or occurrence of groups (Tardin *et al.* 2020). This alternative seems unlikely, however, given the limited home range of the individuals in Ilha Grande Bay (less than 10km – Espécie, 2015) and that previous studies have recorded a low turnover of individuals between populations (approximately 10%). Specifically, movements from individuals of Ilha Grande Bay to Sepetiba Bay were even lower, accounting for 3.25% (Galvão 2013, Anibolete 2022).

It is important to recognize that the CeMV outbreak originated in Ilha Grande Bay, resulting in significantly fewer fatalities - only 67 individuals compared to 210 in Sepetiba Bay (Cunha *et al.* 2021). This discrepancy could be linked to the diminished immunity of dolphins in Sepetiba Bay, attributed to ongoing chronic and cumulative human disturbances (Maciel *et al.* 2023, Silva *et al.* 2024).

Although we have not conducted a social network analysis, the third possible alternative seems less likely because we would expect to observe dolphins forming more groups, in smaller sizes and with mixed social cohesion. We expected mixed cohesion to increase following the morbillivirus outbreak, given that individuals that had previously been unlikely to associate, would now aggregate to accrue the benefits of group living, such as enhanced foraging efficiency and protection from predators (Beauchamp 2013). However, dolphins have a fission-fusion type of social organization, based on relatively short-lived associations and with no stable groups, which allows absorption of new members. It is important to notice that our sample size was small and our p values were marginally significant. Further behavioral data and more samples will nevertheless be necessary to better define the level of association between the different individuals.

Over the last two decades, the *S. guianensis* population in Sepetiba Bay has experienced a 63.4% decline in group size, leading to increased

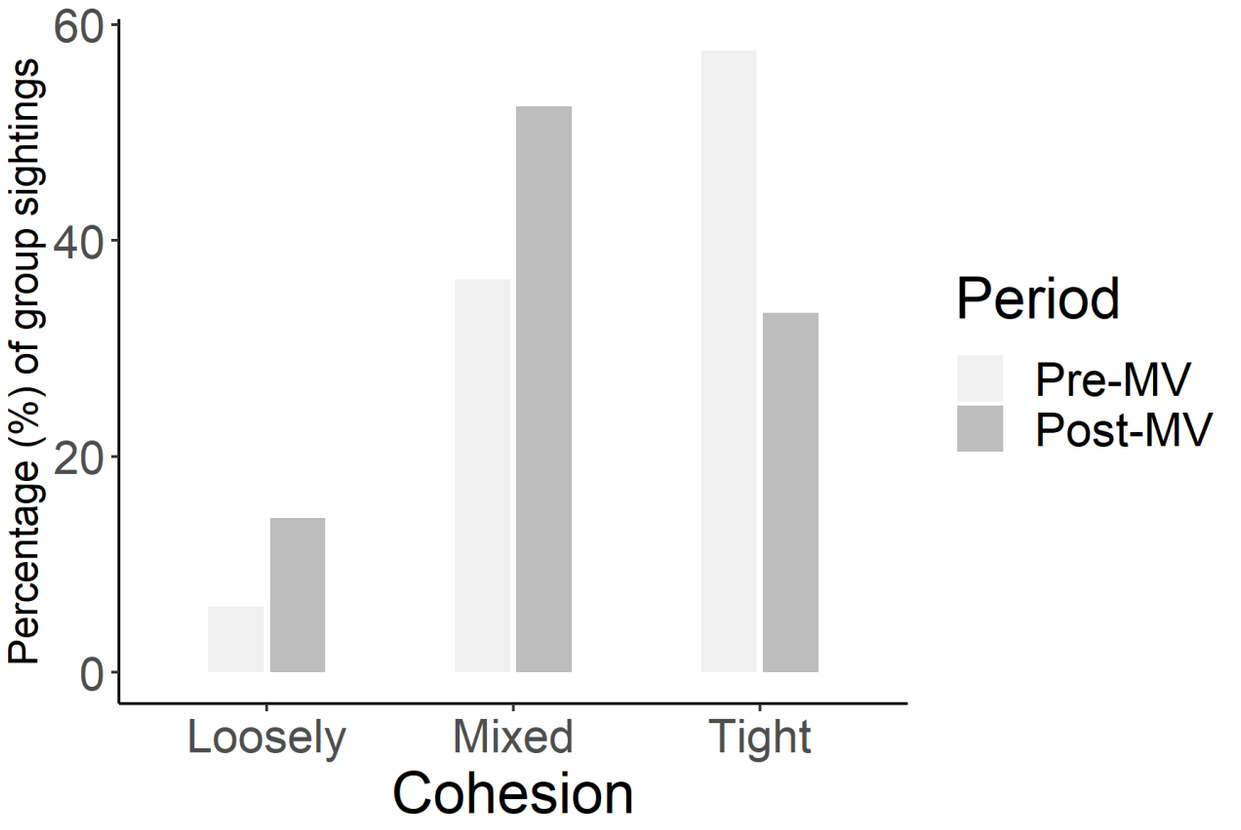

Figure 3. Cohesion of the groups of Guiana dolphin, Sotalia guianensis, observed in the pre- and post-morbillivirus periods in Sepetiba Bay, southeastern Brazil.

foraging time at the expense of feeding, attributed to synergistic and cumulative human impacts (Maciel *et al.* 2023). However, the groups observed in Sepetiba Bay are still relatively large in comparison with many other Brazilian populations, in which groups typically contain no more than 15 individuals (Mucuripe estuary of Ceará state – up to eight individuals (Meirelles *et al.* 2022); Cananéia, in São Paulo state - up to eight individuals (Molina 2017); estuary of the Doce River, in Espírito Santo – up to 10 individuals, (Pinheiro 2014); Guanabara bay, Rio de Janeiro state - of up to 13 individuals (Azevedo *et al.* 2005)). Overall, then, while Sepetiba Bay has suffered increasing anthropogenic pressure, exacerbated by the morbillivirus outbreak, the local *S. guianensis* groups are still relatively large, with a large proportion of offspring, which reinforces its importance as a breeding area.

This study investigated the influence of the morbillivirus outbreak on the standard parameters of social structure used in cetacean behavioral studies (Tardin *et al.* 2013, Flach *et al.* 2019, Szott *et al.* 2022) and, although no significant variation was found between study periods, this does not mean that the outbreak did not impact the study population. To begin with, the demise of more than 210 individuals (Cunha *et al.* 2021) of a Vulnerable species in an altered environment is likely to have a major, long-term impact on the population. The impacts of the morbillivirus outbreak may in fact be apparent in other aspects of the population that were not evaluated directly here, including patterns of residence, abundance, habitat use, growth rates, and social interactions. Over the short term, however, no significant shifts were found in the occurrence, size, composition, or cohesion of the *S. guianensis* groups found in Sepetiba Bay after the outbreak. Further, more detailed research over a longer period will be necessary to provide more conclusive insights into the real impacts of the morbillivirus on this population.

ACKNOWLEDGMENTS

The authors would like to thank the entire team at the Marine Ecology and Conservation Lab (ECoMAR - UFRJ) for their efforts during data collection during field trips. We also thank Nuhu Ayuba for translating

the manuscript into English at no cost and Stephen Ferrari for English proofreading. We thank the Secretariat of Fisheries and Agriculture of Itaguaí (SEMAAP) and the Fisheries Association of Madeira Island (APLIM) for supporting the fieldwork with the provision of a boat. The Rio de Janeiro State Research Foundation (FAPERJ: Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro) currently supports G.M. (post-doctoral fellowship process E-26/200.032/2024) and R.H.T. (JCNE process E-26/200.238/2023). The Brazilian National Council for Scientific and Technological Development (CNPq: Conselho Nacional de Desenvolvimento Científico e Tecnológico) currently supports I.S.M. (post-doctoral fellowship - PDJ process 151239/2023-1).

REFERENCES

Aguilar, A., & Raga, J. A. 1993. The striped Dolphin epizootic in the Mediterranean Sea. Ambio, 22 (8), 524–528.

Altmann, J. 1974. Observational study of behavior: sampling methods. Behavior, 49(3–4), 227–267. DOI: 10.1163/156853974x00534.

Anibolete, D. 2022. Quo vadis: Adequabilidade de áreas e movimentos do boto-cinza [*Sotalia guianensis* (van Bénéden, 1864)] entre as baías de Sepetiba e da Ilha Grande, Estado Rio de Janeiro – Sudeste do Brasil. Master thesis. Programa de Pós-Graduação em Ciências Biológicas da Universidade Federal do Estado do Rio de Janeiro. p. 61.

Araújo, F. G., Pinto, S. M., Neves, L. M., & De Azevedo, M. C. C. 2017. Inter-annual changes in fish communities of a tropical bay in southeastern Brazil: What can be inferred from anthropogenic activities? Marine Pollution Bulletin, 114(1), 102–113. DOI: 10.1016/j.marpolbul.2016.08.063.

Araújo, F. G., Pinto, S. M., Neves, L. M., De Azevedo, M. C. C., & Guedes, A. P. P. 2016. Inter-decadal changes in fish communities of a tropical bay in southeastern Brazil. Regional Studies in Marine Sciences, 3, 107–118. DOI: 10.1016/j.rsma.2015.06.001.

Azevedo, A. F., Viana, S. C., Oliveira, A. M., & Van Sluys, M. 2005. Group characteristics of marine tucuxis (*Sotalia guianensis*) (Cetacea: Delphinidae) in Guanabara Bay, south-eastern Brazil. Journal of the Marine Biological Association of the UK, 85, 209–212. DOI: 10.1017/S0025315405011082h.

Banyard, A. C., Grant, R. J., Romero, C. H., & Barrett, T., 2008. Sequence of the nucleocapsid gene and genome and antigenome promoters for an isolate of porpoise morbillivirus. Virus Res., 132, 213–219. DOI: 10.1061/j.virusres.2007.11.003.

Black, F. 1991. Epidemiology of Paramyxoviridae. In: D. W. Kingsburry (Ed.), The Paramyxoviruses. pp. 509–536. New York: Plenum Press.

Borges, H. V. 1990. Dinâmica sedimentar da Restinga da Marambaia e Baía de Sepetiba (RJ). Master thesis. Programa de Pós-Graduação em Geologia da Universidade Federal do Rio de Janeiro. p. 99.

Cantor, M., Maldonado-Chaparro, A. A., Beck, K. B., Brandl, H. B., Carter, G. G., He, P., Hillemann, F., Klarevas-Irby, J. A., Ogino, M., Papageorgiou, D., Prox, L., & Farine, D. R. 2021. The importance of individual-to-society feedbacks in animal ecology and evolution. Journal of Animal Ecology, 90(1), 27–44. DOI: 10.1111/1365-2656.13336

Cunha, H. A., Santos-Neto, E. B., Carvalho, R. R., Ikeda, J. M., Groch, K. R., Diaz-Delgado, J., Guari, E. B., Brião, J. A., Oliveira, R. B., Flach, L., Bisi, T., Catão-Dias, J. L., Azevedo, A. F., & Lailson-Brito, J. R. J. 2021. Epidemiological features of the first Unusual Mortality Event linked to cetacean morbillivirus in the South Atlantic (Brazil, 2017-2018). Marine Mammal Science, 37(4), 1375–1390. DOI: 10.1111/mms.12824.

Daura-Jorge, F. G., Wedekin, L. L., Piacentini, V. Q., & Simões-Lopes, P. C. 2005. Seasonal and daily patterns of group size, cohesion and activity of the estuarine dolphin, *Sotalia guianensis* (P. J. Van Bénéden) (Cetacea, Delphinidae), in southern Brazil. Revista Brasileira de Zoologia, 22, 1014–1021. DOI: 10.1590/S0101-81752005000400029.

Domingo, M., Ferreira, L., Pumarola, M., Marco, A., Plana, J., Kennedy, S., Mcalisey, M., & Rima, B. K. 1990. Morbillivirus in dolphins. Nature, 348(6296), 21. DOI: 10.1038/348021a0.

Domingo, M., Visa, J., Pumarola, M., Marco, A. J., Ferreira, L., Rabanal, R., & Kennedy, S. 1992. Pathologic and immunocytochemical studies of morbillivirus infection in striped dolphins (*Stenella coeruleoalba*). Veterinary Pathology, 29(1), 1–10. DOI: 10.1177/030098589202900101.

Duignan, P. J., Van Bressem, M. F., Cortés-Hinojosa, G., & Kennedy-Stoskopf, S. 2018. Virus de mamíferos marinhos. In: L. A. Dierauf & F. M. D. Gulland (Eds.), CRC Handbook of Medicine

de Mamíferos Marinhos: Saúde, Doença e Reabilitação-Reabilitação. p. 341–365. Florida: CRC Press.

Duignan, P. J., Geraci, J. R., Raga, J. A., & Calzada, N. 1992. Pathology of morbillivirus infection in striped dolphins (*Stenella coeruleoalba*) from Valencia and Murcia, Spain. Canadian Journal of Veterinary Research, 56, 242–248.

Duignan, P. J., House, C., Odell, D. K., Wells, R. S., Hansen, L. J., Walsh, M. T. S. T., Aubin, D. J., Rima, B. K., & Geraci, J. R. 1996. Morbillivirus infection in bottlenose dolphins: Evidence for recurrent epizootics in western Atlantic and Gulf of Mexico. Marine Mammal Science, 12 (4), 499–515. DOI: 10.1111/j.1748-7692.1996.tb00063.x.

Espécie, M. D. A. (2015). O que seis anos de marcação-recaptura revelam sobre a população de boto-cinza da parte oeste da Baía da Ilha Grande, litoral sul do Rio de Janeiro. Doctoral thesis. Programa de Pós-graduação em Biologia Animal, Universidade Federal Rural do Rio de Janeiro, Seropédica – RJ, p.120.

Feema/GTZ. 1997. Mapeamento dos sedimentos da Baía de Sepetiba. Contaminação por metais pesados da Baía de Sepetiba. FEEMA/GTZ, Rio de Janeiro. p. 14.

Flach, L., Alonso, M. B., Marinho, T., Van Waerebeek, K., & Van Bressem, M. 2019. Clinical signs in free-ranging Guiana dolphins *Sotalia guianensis* during a morbillivirus epidemic: case study in Sepetiba Bay, Brazil. Diseases of Aquatic Organisms, 133(3), 175–180. DOI: 10.3354/dao03343.

Flach, L., Flach, P. A., & Chiarello, A. G., 2008. Density, abundance and distribution of the Guiana dolphin (*Sotalia guianensis* van Bénéden, 1864) in Sepetiba Bay, Southeast Brazil. Journal of Cetacean Research and Management, 10 (1), 31–36. DOI: 10.47536/jcrm.v10i1.657.

Flores, P. A., & Da Silva, V. M., 2009. Tucuxi and Guiana Dolphin: *Sotalia guianensis fluviatilis* and *S. guianensis*. In: W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), Encyclopedia of Marine Mammals. pp. 1188–1192. Cambridge: Academic Press.

Galvão, C. C. G. 2013. Comparação dos catálogos de foto-identificação das populações de *Sotalia guianensis* (Cetartiodactyla, Delphinidae) da Baía de Sepetiba de Ilha Grande, Rio de Janeiro, Brasil. Undergraduate Monograph da Escola de Ciências Biológicas da Universidade Federal do Estado do Rio de Janeiro. p. 43.

Geise, L., Gomes, N., & Cerqueira, R. 1999. Behaviour, habitat use and population size of *Sotalia fluviatilis* (Gervais, 1853) (Cetacea, Delphinidae) in the Cananéia estuary region, São Paulo, Brazil. Revista Brasileira de Biologia, 59, 183–194. DOI: 10.1590.s0034-71081999000200002.

Gomes-Gonçalves, R. S., Aguiar, F. S., Azevedo, M. C. C., & Araújo, F. G. 2020. Functional stability despite anthropogenic influences on the ichthyofauna of a tropical bay. Marine Environmental Research, 159, 1–10. DOI: 10.1016/j.marenvres.2020.105016.

Guardo, G. D., Marruchella, G., Agrimi, U., & Kennedy, S. 2005. Morbillivirus infections in Aquatic Mammals: A Brief Overview. Journal of Veterinary Medicine Series A, 52 (2), 88–93. DOI: 10.1111/j.1439-0442.2005.00693.x.

ICMBio, 2018. Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Mamíferos. 2 ed. Brasília, DF: ICMBio/MMA.

IUCN, 2022. IUCN Red List of Threatened Species. Versão 2022-2. Retrieved on July 11, 2023, from http://www.iucnredlist.org

Kemper, C. M., Tomo, I., Bingham, S. S., Wang, J., Gibbs, S. E., Woolford, L., Dickason, C., & Kelly, D. 2016. Morbillivirus-associated unusual mortality event in South Australian bottlenose dolphins is largest reported for the Southern Hemisphere. Royal Society Open Science. 3(12), 160838. DOI: 10.1098/rsos.160838.

Lipscomb, T. P. F., Schulman, Y., Moffett, I., & Kennedy, S. 1994. Morbilliviral disease in Atlantic bottlenose dolphin (*Tursiops truncatus*) from the 1987-1988 epizootic. Journal of Wildlife Diseases 30 (4), 567–571. DOI: 10.7589/0090-3558-30.4.567.

Lipscomb, T. P., Kennedy, S., Moffett, D., Krafft, A., Klaunberg, B. A., Lichy, J. H., Regan, G. T., Worthy, G. A. J., & Taubenberger, J. K. 1996. Morbilliviral epizootic in bottlenose dolphin of the Gulf of Mexico. Journal of veterinary Diagnostic Investigation, 8 (3), 283–290. DOI: 10.1177/104063879600800302.

Lodi, L., & Hetzel, B. 1998. Grandes agregações do boto-cinza (*Sotalia fluviatilis*) na Baía da Ilha Grande, Rio de Janeiro. Bioikos, 12 (2), 26–30.

Lodi, L., & Borobia, M. 2013. Baleias, botos e golfinhos do Brasil: guia de identificação. Technical Books Editora: p. 480.

Maciel, I. S., Maricato, G., Marqui, L., Anibolete, D., Belderrain, T., Figueiredo, L. D., França, S., Oliveira, B., Alves, M. A. S., & Tardin, R. H. (2023). 20 years of research on the Guiana dolphin population of Sepetiba Bay, southeastern Brazil: What has changed?. Aquatic Conservation: Marine and Freshwater Ecosystems, 33(9), 940–954. DOI: 10.1002/aqc.3985

Meirelles, A. C. O. D., Choi-Lima, K. F., Vila Nova, T. M. C., Monteiro-Filho, E. L. D. A., & Lotufo, T. M. D. C. 2022. Abundance and effect of health status on apparent survival of Guiana dolphins, *Sotalia guianensis*, in an open embayment in north-eastern Brazil. Aquatic Conservation: Marine and Freshwater Ecosystems, 32(6), 1022–1040. DOI: 10.1002/aqc.3804.

Molina, J. M. B. 2017. Uso de área pelo boto-cinza, Sotalia guianensis, no estuário de Cananéia. Master thesis. Instituto Oceanográfico da Universidade de São Paulo. p. 115.

Nery, M. F., Simão, S. M., & Pereira, T. 2010. Ecology and behavior of the estuarine dolphin, *Sotalia guianensis* (Cetacea, Delphinidae), in Sepetiba Bay, southeastern Brazil. Journal of Ecology and the Natural Environment, 2(8), 194–200.

Nery, M. F., Espécie, M. A., & Simão, S. M. 2008. Site fidelity of *Sotalia guianensis* (Cetacea: Delphinidae) in Sepetiba Bay, Rio de Janeiro, Brazil. Revista Brasileira de Zoologia, 25, 182–187. DOI: 10.1590/s0101-81752008000200004.

Nery, M. F., & Simão, S. M. 2012. Capture-recapture abundance estimative of Guiana dolphin in southeastern Brazil. Ciencias Marinas, 38(3), 529–541. DOI: 10.7773.cm.v38i3.2012.

Oliveira, E. C. S., Tardin, R. H., Poletto, F. R., & Simão, S. M. 2013. Coordinated feeding behavior of the Guiana Dolphin, *Sotalia guianensis* (Cetacea: Delphinidae), in southeastern Brazil: a comparison between populations. Zoologia, 30(6), 585–591. DOI: 10.1590/s1984-46702013005000013.

Pinheiro, F. C. F. 2014. Padrões de uso de habitat do boto-cinza (*Sotalia guianensis*) na região da foz do rio Doce, costa norte do Espírito Santo, Sudeste do Brasil. Master thesis. Mestrado em Biologia Animal da Universidade Federal do Espírito Santo. p. 40.

Raga, J. A., Banyard, A., Domingo, M., Corteyn, M., Van Bressem, M. F., Fernandez, M., Aznar, F. J., & Barrett, T. 2008. Dolphin morbillivirus epizootic resurgence, Mediterranean Sea. Emerging Infectious Diseases, 14 (3), 471–473. DOI: 10.3201/eid1403.071230.

Ramos, R.M.A. 1997. Determinação de idade e biologia reprodutiva de Pontoporia blainvillei e da forma marinha de *Sotalia fluviatilis* (Cetacea: Pontoporiidae e Delphinidae) no norte do Rio de Janeiro. Master thesis. Universidade Estadual do Norte Fluminense. p. 95.

Rijks, J. M., Osterhaus, A. D. M. E., Kuiken, T., & Frolich, K. 2012. Morbillivirus infections. In: D. Gavier-Widén, J. P. Duff, & A. Meredith (Eds.), Infectious Diseases of Wild Mammals and Birds in Europe. pp. 99–118. Oxford: Wiley-Blackwell.

Rosas, F.C.W., & Monteiro-filho, E. L. A. 2002. Reproduction of the estuarine dolphin (*Sotalia guianensis*) on the coast of Paraná, Southern Brazil. Journal of Mammalogy, 83(2), 506–515. DOI: 10.1644/1545-1542(2002)0832.0.CO;2

Santos, M.C.O., Barão-acuña, L., & Rosso, S. 2001. Insights on site fidelity and calving intervals of the marine tucuxi dolphin (*Sotalia fluviatilis*) in south-eastern Brazil. Journal of Marine Biological Association of the United Kingdom, 81(6), 1049–1052.

Siegel, S. 1975. Estatística não paramétrica. São Paulo: McGraw-Hill. Silva, D., Maricato, G., Cezimbra, T., Mello, L., Maciel, I.S., & Tardin, R. 2024. Assessment of Body Condition in a Threatened Dolphin Population in an Anthroízed Area in Southeastern Brazil. Animals, 2024, 14, 1887. DOI: 10.3390/ani14131887.

Smolker, R. A., Richards, A. F., Connor, R. C., & Pepper, J. W. 1992. Sex differences in patterns of association among Indian Ocean bottlenose dolphins. Behaviour, 123(1–2), 38–69. DOI: 10.1163/156853992X00101.

Szott, E. A., Brughtwell, K., & Gibson, Q. 2022. Assessment of social mixing and spatial overlap as a pathway for disease transmission in northeast Florida estuarine dolphin community. Mammalian Biology, 102, 1267–1283. DOI: 10.1007/s42921-022-00282-y.

Tardin, R. H., Maciel, I., Espécie, M., Melo-Santos, G., Simão, S. M., & Alves, M. 2020. Modelling habitat use by the Guiana Dolphin, *Sotalia guianensis*, in south-eastern Brazil: Effect of environmental and anthropogenic variables, and the adequacy of current management measures. Aquatic Conservation: Marine and Freshwater Ecosystems, 30, 775–785. DOI: 10.1002/aqc.3290.

Tardin, R. H., Espécie, M. A., Lodi, L., & Simão, S. M. 2013. Parental care behavior in the Guiana dolphin, *Sotalia guianensis* (Cetacea: Delphinidae), in Ilha Grande Bay, southeastern Brazil. Zoologia (Curitiba), 30, 15–23. DOI: 10.1590/S1984-46702013000100002.

Tardin, R. H., Galvão, C., Espécie, M., & Simão, S. 2013. Group structure of Guiana dolphins, *Sotalia guianensis* (Cetácea, Delphinidae) in Ilha Grande Bay, Rio de Janeiro, southeastern Brazil. Latin American Journal of Aquatic Research, 41(2), 313–322. DOI: 10.3856/vol141-issue2-fulltext-10.

Taylor, J., & Davis, A. 2018. Social cohesion. The International Encyclopedia of Anthropology, 1–7. DOI: 10.1002/9781118924396.wbiea2297.

Van Bressem, M. F., Duignan, P. J., Banyard, A. Barbieri, M., Colegrove, K. M., De Guise, S., Di Guardo, G., Dobson, A., Domingo, M., Fauquier, D., Fernández, A., Goldstein, T., Grenfell, B., Groch, K. R., Gulland, F., Jensen, B., Jepson, P., Ailsa, S., Kuiken, T., Mazzariol, S. Morris, S. E., Nielsen, O., Raga, J. A., Rowles, T. K., Saliki, J., Sierra, E., Stephens, N., Stone, B., Tomo, I., Wang, J., Waltzek, T., & Wellehan, J. F. 2014. Cetacean morbillivirus: current knowledge and future directions. Viruses, 6(12), 5145–5181. DOI: 10.3390/v6125145.

Van Bressem, M. F., & Raga, J. A. 2011. Viruses of Cetaceans. In: C. Hurst (Ed.), Studies in Viral Ecology. pp. 309–332. New Jersey: John Wiley & Sons.

Van Bressem, M. F., Raga, J. A., Di Guardo, G., Jepson, P., Duignan, P., Siebert, U., Barret, T., Santos, M. C. O., Moreno, I., Siciliano, S., Aguilar, A., & Waerebeek, V. K. 2009. Emerging infectious diseases in cetaceans worldwide and the possible role of environmental stressors. Diseases of aquatic organisms, 86, 143–157. DOI: 10.3354/dao02101.

Van Bressem, M. F., Van Waerebeek, K., & Raga, J. 1999. A review of virus infections of cetaceans and the potential impact of morbilliviruses, poxviruses and papillomaviruses on host population dynamics. Diseases of aquatic organisms, 38(1), 53–65. DOI: 10.3354/dao038053.

Zar, J. H. 1984. Biostatistical Analysis. New Jersey: Prentice Hall: p. 718.

SUPPLEMENTARY MATERIAL

Table S1. Sampling effort details of Guiana dolphins' data collection in Sepetiba Bay from 2017 to 2019. Dates are in the format DD/mmm/YYYY, h = hour.

Submitted: 21 November 2023
Accepted: 24 August 2024
Published online: 16 October 2024
Associate Editor: Natalie Olifiers