Short Communication

Association of Franciscana (Pontoporia blainvillei) Occurrence with the Doce River Plume

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***Pontoporia blainvillei*, known as the franciscana, is a small dolphin endemic to the Southwestern Atlantic. The collapse of the mining tailings dam in Mariana in 2015 altered the ecosystem dynamics near the mouth of the Doce River, an ecologically crucial area for the species that is both genetically and geographically isolated. Using drone monitoring of an isolated and threatened population of franciscan dolphins, we analyzed the relationship between the Rio Doce sediment plume and the occurrence of this species in the region. Franciscana sightings outside the plume were significantly higher compared to those inside the plume. With the arrival of the tailings plume, there was a considerable increase in sediment load, potentially causing acoustic attenuation.**

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Pontoporia blainvillei, commonly known as the franciscana dolphin, is a small dolphin species endemic to the region from Brazil (18° 25') to Argentina (42° 10%27)[1][2][3]. It is commonly observed in shallow waters up to 30 meters deep[3]. This small cetacean inhabits the turbid waters of estuarine environments and river mouths, often moving across diverse habitats[4][5][6]. Genetically and geographically isolated[2][7], the Espírito Santo population is designated as FMA Ia (Franciscana Management Area)[8][9] and is concentrated near the Doce River estuary[10][11].

The franciscana dolphin is considered the most threatened cetacean in the Southwestern Atlantic Ocean (SAO)[12][13], mainly due to high bycatch rates in gillnet fisheries and contamination of its

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habitats[14][11][10][15]. It is classified as “Vulnerable” by the IUCN[16] and “Critically Endangered” by the Brazilian Ministry of the Environment and Climate Change’s Red List[17]. Recently, it has been suggested that the FMA I population, occupying the species’ northernmost range, be designated a separate subspecies, *Pontoporia blainvillei pukusi*[13], underscoring its vulnerability. The November 2015 mining dam collapse in Mariana, southeastern Brazil, altered the habitat use dynamics and affected biodiversity near the Doce River estuary (Gomes et al., 2017; Do Carmo et al., 2017). Franciscana dolphins and other apex predators are already experiencing the effects of these contaminants (Oliveira-Ferreira, 2022;[15]). Understanding how these endangered animals respond to this new threat is essential for conservation strategies. However, franciscana dolphins display a limited behavioral repertoire at the surface[4][18] and are generally difficult to observe in the wild[19], adding even greater complexity in interpreting the response to new threats.

To address these knowledge gaps, drones have been widely applied in various wildlife science studies, including in marine environments[20][21][22][23]. These devices enable the monitoring of ecological patterns, such as the behavior and population size of marine mammals, with significantly reduced impact compared to more traditional techniques, allowing the animals' natural behaviors to remain undisturbed (Yaney-Keller et al., 2021; San Martin et al., 2021). Therefore, we analyzed the relationship between the sediment plume from the Doce River and the occurrence of this species in the region.

Monitoring efforts took place in the area with the highest concentration of the franciscana dolphin, located just south of the Doce River estuary[23][10][11][24]. Aerial transects were carried out from three launch points: Doce River (19°39’S 39°48’W), Comboios (19°42'S 39°54'W), and Piraquê-Açu River (20°0'S 40°0'W). The first sampling point covers a coastal area directly over the mouth of the Doce River. In contrast, the last sampling point flies over the area immediately in front of the Piraquê-Açu River estuary, serving as a control point due to its greater distance from the species' main concentration area. At the Comboios launch point, we monitored an area in front of the Comboios Biological Reserve, which yielded the highest number of dolphin records using this methodology[23]. This location was selected to evaluate the association between the sediment plume from the Doce River and the dolphins, as it frequently displays a noticeable boundary between the Doce River sediment plume and the adjacent seawater.

The flights were conducted using a DJI Mavic 2 Zoom drone, occurring monthly from 2018 to 2022 (excluding the 2020 pandemic restriction period) as part of the Aquatic Biodiversity Monitoring Program, which studies the impacts of material from the Fundão dam on the marine and coastal environment[24]. Sampling was performed in standardized flights at 50 m altitude and a speed of 40 km/h, with the camera positioned laterally and angled at -27°, covering transects with a swept area of 4 km^2. This configuration was designed to maximize area coverage with minimal overlap and higher detectability, as determined by Barreto et al.[21]. Video samples, recorded in 4k 30fps, were analyzed in the laboratory by at least two experienced researchers. Only flights where both dolphin sightings and the sediment plume boundary occurred were selected (Fig. 1). To identify a pattern of franciscana incidence inside or outside the sediment plume, records were grouped quarterly and classified based on the group's position relative to the plume. Results were compared using the non-parametric Mann-Whitney test[25], where all analyses yielded significant results ($p < 0.05$). A total of 14 quarters of aerial surveys were analyzed, resulting in 70 sightings in the study region. Sightings of franciscanas outside the plume were significantly higher, comprising about 82% of sightings, compared to 18% inside the plume (Fig. 1).

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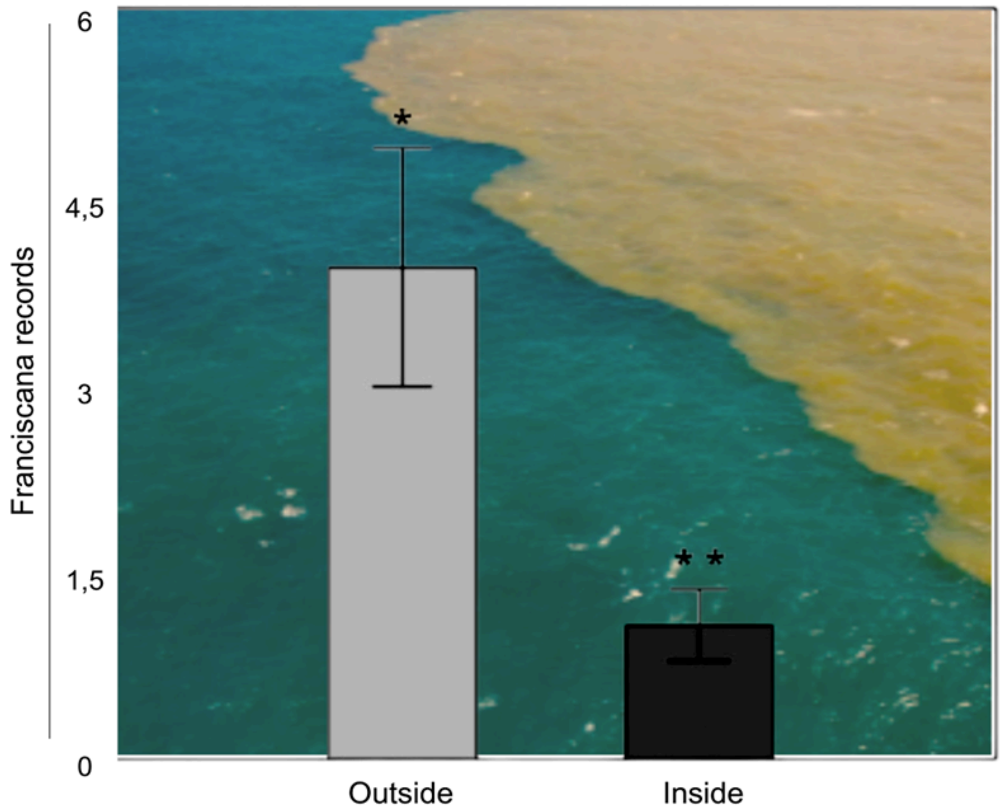

Figure 1. Frequency of franciscana (*Pontoporia blainvillei*) records in Comboios, Southwestern Atlantic Ocean, between 2018 and 2022. Bars represent the mean number of records Inside or Outside the plume. Lines represent standard deviations, and different numbers of asterisks indicate significant differences between samples. The image in the background represents the plume, captured during drone-monitoring.

The high flow rate of the Doce River provides a significant input of nutrients, resulting in high food availability for species inhabiting the region, especially during rainy seasons when productivity intensifies and sediment input from the river increases (Lemos et al., 2022;[24]). However, the arrival of the waste plume led to a considerable increase in sediment loads, which likely contributed to an increase in acoustic attenuation affecting resident species in the region, including *P. blainvillei*. This effect may cause sound waves to encounter obstacles, thereby hindering echolocation (Frainer et al., 2018;[10]). Certain features of the biosonar anatomy of small cetaceans may exacerbate echolocation limitations in juvenile and young individuals[26].

The presence of sediments alters the acoustic impedance of the water column, directly impacting the propagation of sound waves. Sound attenuation in waters with suspended particles occurs due to energy loss as the wave passes through the sediments[27]. Attenuation is influenced by various factors, such as sound frequency, particle type and size, as well as the depth and type of seabed[28][29]. Estuarine environments are acoustically more complex[30][31], and organisms that have evolved in these environments are adapted to seasonal variations in sediment discharge. However, in the presence of excessive sediment, as with a mud plume, the ability to echolocate may be impaired, as an environment with high suspended particle concentration leads to sound scattering, altering the direction and intensity of the sound. Depending on the wavelength, excess sediment may have an even greater effect, especially on the high-frequency sounds used by the species for echolocation. Studies of sound emissions in *P. blainvillei* show that they produce narrowband high-frequency sounds, with a peak frequency of 139 kHz[32] and a center frequency of 130 kHz[33][34]. These wavelengths are more prone to be attenuated.

Paitach et al.[33] found differences in the acoustic parameters of *P. blainvillei* sound emissions between two coastal environments in Santa Catarina, with frequencies being higher in Babitonga Bay compared to the open sea. This suggests that the physical characteristics of the environments may influence the variability of the species' acoustic behavior. Studies on acoustic behavior, including the types, spectral properties, and emission rate of sounds used within and outside the plume in the Doce River mouth region, would help clarify the strategies used by these animals to adapt to specific contexts. Behavioral context should also be considered, as in echolocating species, the rate of sound production is directly linked to activity[35]. For instance, some species, such as *Phocoena phocoena*, emit 20 to 60 clicks per second while traveling, increasing to hundreds of clicks per second during foraging[35].

A possible hypothesis is that the animals may use the outer edge of the plume to take advantage of the acoustic impedance difference between seawater and river water. The greater the difference in acoustic impedance between the two media, the greater the reflection and the lower the transmission. At the plume/sea interface, the acoustic impedance — a measure of how similar or different the acoustic properties of two regions are[27] — may create a differential sufficient for the animals to use this acoustic "boundary" as a hunting strategy, where prey temporarily disoriented by changes in water color, temperature, and density might become trapped. Some species, such as the bottlenose dolphin, *Tursiops truncatus*, are known to employ a wide range of strategies, feeding tactics, and local opportunities to enhance foraging success[36], often involving the use of physical barriers such as the sea surface[37], coastline[38], as well as the walls and sides of boats[39][40], limiting routes of prey escape[41].

It is therefore possible that areas with high sediment input and other suspended particles in the water column are avoided by franciscanas. Considering the typical coastal nature of this species[3], habitat impacts may be further exacerbated by the species' difficulty in competing for resources with larger cetaceans in regions farther from the coast. Moreover, the low genetic variability of this population, which has been genetically isolated for 1.8 million years[13], makes it even more vulnerable.

It is also important to note that even if results show more records outside the tailings plume, this does not mean the species avoids entering the plume entirely, as overlap with the impacted area does occur[23]. The franciscana population in FMA Ia may be subjected to still unknown impacts, including the chronic effects of the mining tailings plume. Therefore, we suggest the adoption of synergistic methodologies that allow for collecting information regarding habitat use preferences of this threatened species within an impacted environment.

Statements and Declarations

Author contributions: Conceptualization: A.M., J.B., A.J.V. Data curation: A.M., J.B., A.J.V. Formal analysis: J.B., A.J.V. Funding acquisition: A.M. Investigation: J.B., A.M., A.J.V, C.X., C.R., V.T., M.E.R., L.S.H., N.B., A.G., J.B.T. Methodology: A.M., J.B., A.J.V. Project administration: A.M., J.B.T., Supervision: A.M., J.B.T. Validation: A.M., J.B.T. Writing – original draft: J.B., A.J.V., A.M. Writing – review & editing: J.B., A.M., A.J.V, C.X., C.R., V.T., M.E.R., L.S.H., J.B.F., D.V.

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References

1. ^Crespo EA, Harris G, González R (1998). "Group size and distributional range of the franciscana, Pontoporia blainvillei." Marine Mammal Science 14 (4): 845-849. doi:10.1111/j.1748-7692.1998.tb00768.x.
2. a, bSiciliano S, Di Beneditto AP, Ramos RMA. (2002). A Toninha, Pontoporia blainvillei (Gervais & d'Orbigny, 1844) (Mammalia, Cetacea, Pontoporiidae), nos estados do Rio de Janeiro e Espírito Santo, costa sudeste do Brasil: caracterizações dos habitats e fatores de isolamento das populações. Bol. Mus. Nac. 476: 1–15.
3. a, b, cDanilewicz D, Secchi ER, Ott PH, Moreno IB, Bassoi M, Borges-Martins M (2009). "Habitat use patterns of franciscana dolphins (Pontoporia blainvillei) off southern Brazil in relation to water depth." Journal of the Marine Biological Association of the United Kingdom 89(5):943-949. doi:10.1017/S002531540900054X.
4. a, bBordino P, Thompson G, Iñíguez M (1999). "Ecology and behaviour of the franciscana (Pontoporia blainvillei) in bahía anegada, argentina." Journal of Cetacean Research and Management 1:213-222.
5. ^Failla M, Iniguez MA, Tossenberger V, de Haro C (2004). "Bioecology of franciscana (Pontoporia blainvillei) in Northern Patagonia, Argentina." Paper submitted to the 56th Annual Meeting of the Scientific Committee of the International Whaling Commission, SC/56/SM24, Sorrento, Italy, 4 pp.
6. ^Zappes CA, Gama RM, Domit C, Gatts CEN, Di Beneditto APM. (2016). "Artisanal fishing and the franciscana (Pontoporia blainvillei) in Southern Brazil: ethnoecology from the fishing practice". Journal of the Marine Biological Association of the United Kingdom. 98(4): 867-877. doi:10.1017/S0025315416001788.
7. ^Danilewicz D, Zerbini AN, Andriolo A, Secchi ER, Sucunza F, Ferreira E, Denuncio P, Flores PA (2012). "Abundance and distribution of an isolated population of Franciscana dolphins (Pontoporia blainvillei) in southeastern Brazil: Red alert for FMA I?." In International Whaling Commission, SC/64/SM17. 129–144.
8. ^Cunha HA, Medeiros BV, Barbosa LA, Cremer MJ, Marigo J, Lailson-Brito J, Azevedo AF, Solé-Cava AM (2014). "Population Structure of the Endangered Franciscana Dolphin (Pontoporia blainvillei): Reassessing Management Units." PLoS ONE 9(1): e85633. doi:10.1371/journal.pone.0085633.
9. ^Cunha HA, Dos Santos TEC, Alvarenga LC, Cavaleiro NP, Cremer MJ, Colósio A, Barbosa LA, Lazoski C (2021). "Microsatellite markers for the endangered franciscana dolphin (Pontoporia blainvillei)." Mol Biol Rep. 48(3):3011-3016. doi:10.1007/s11033-021-06263-7.

10. ^a, b, c, d^ *Amorim TOS, Castro FR, Ferreira GA, Neri FM, Duque BR, Mura JP, Andriolo A (2022). "Acoustic identification and classification of four dolphin species in the Brazilian marine area affected by the largest tailings dam failure disaster." J. Acoust. Soc. Am. 152, 3204–3215. doi:10.1121/10.0016358.*
11. ^a, b, c^ *Sucunza F, Danilewicz D, Ott PH, Neves M, Farro AC, Martins AS, Zerbini AN. (2023). "Distribution, population size and IUCN Red Listing of an isolated population of the threatened franciscana". Endang Species Res 52: 17-26. doi:10.3354/esr01262.*
12. ^ *Secchi ER. (2010). Review on the threats and conservation Status of Franciscana, Pontoporia blainvillei (Cetacea, Pontoporiidae). In Biology, Evolution and Conservation of River Dolphins within South America and Asia, Vol. 1, eds J. M. Shostell and M. Ruiz-Garcia (Hauppauge, NY: Nova Science Publishers Inc.), 323–339.*
13. ^a, b, c^ *Nara L, Secchi ER, Cunha HA (2024). "Divergence, diagnosability, and description of a new subspecies of franciscana dolphin Pontoporia blainvillei (Gervais & d'Orbigny, 1844)." Journal of Mammalian Evolution, 31-32. doi:10.1007/s10914-024-09718-3.*
14. ^ *Pinheiro FCF, Pinheiro HT, Teixeira JB, Martins AS, Cremer MJ. (2019). "Opportunistic Development and Environmental Disaster Threat Franciscana Dolphins in the Southeast of Brazil". Tropical Conservation Science. 12. doi:10.1177/1940082919847886.*
15. ^a, b^ *Manhães BMR, Vannuci-Silva M, Brião JA, Guari EB, Botta S, Colosio AC, Ramos HGC, Barbosa LA, Cunha IAG, Azevedo AF, Cunha HA, Bisi TL, Lailson-Brito J (2022). "Temporal trends of trace elements bioaccumulation by a vulnerable cetacean (Pontoporia blainvillei) before and after one of the largest mining disasters worldwide." Science of The Total Environment. 804, 150196. doi:10.1016/j.scitotenv.2021.150196.*
16. ^ *Zerbini AN, Secchi E, Crespo E, Danilewicz D, Reeves R. (2017). Pontoporia blainvillei. The IUCN Red List of Threatened Species.*
17. ^ *Ministério do Meio Ambiente (2022). "Atualização da Lista Nacional de Espécies Ameaçadas de Extinção." Portaria MMA Nº 148.*
18. ^ *Cremer MJ, Simões-Lopes PC (2005). "Ocorrência de Pontoporia blainvillei (Gervais & d'Orbigny) (Cetacea, Pontoporiidae) em uma região estuarina no sul do Brasil." Rev. Bras. Zool. 22 (3). doi:10.1590/S0101-81752005000300032.*
19. ^ *Crespo EA, Pedraza SN, Grandi MF, Dans SL, Garaffo G (2010). "Abundance and distribution of endangered Franciscana dolphins in Argentine waters and conservation implications." Marine Mammal Science 26: 17-35. doi:10.1111/j.1748-7692.2009.00313.x.*

20. ^Chabot D, Bird DM (2015). "Wildlife research and management methods in the 21st century: Where do unmanned aircraft fit in?." Journal of Unmanned Vehicle Systems 3(4): 137-155. doi:10.1139/juvs-2015-0021.
21. a, bBarreto J, Cajaíba L, Teixeira JB, Nascimento L, Giacomo A, Barcelos N, Fettermann T, Martins A (2021). "Drone-Monitoring: Improving the Detectability of Threatened Marine Megafauna." Drones 5, 14. doi:10.3390/drones5010014.
22. ^Torres LG, Nieukirk SL, Lemos L, Chandler TE. (2018). Drone Up! Quantifying Whale Behavior From a New Perspective Improves Observational Capacity. Front. Mar. Sci. 5: 319. doi:10.3389/fmars.2018.00319.
23. a, b, c, dGiacomo ABD, Barreto J, Teixeira JB, Oliveira L, Cajaíba L, Joyeux CJ, Barcelos N, Martins AS (2021). "Using drones and ROV to assess the vulnerability of marine megafauna to the Fundão tailings dam collapse." Science of The Total Environment, 800, 149302. doi:10.1016/j.scitotenv.2021.149302.
24. a, b, cPMBA. (2024). Programa de Monitoramento da Biodiversidade Aquática, Área Ambiental I, estabelecido pelo Acordo de Cooperação Técnico-Científica nº 30/2018 entre a Fundação Espírito-Santense de Tecnologia (FEST) e a Fundação Renova.
25. ^Wilcoxon F. (1945). "Individual Comparisons by Ranking Methods". Biometrics Bulletin. 1(6): 80–83. doi:10.2307/3001968.
26. ^Huggenberger S, Rauschmann MA, Vogl TJ, Oelschläger HHA (2009). "Functional morphology of the nasal complex in the harbor porpoise (Phocoena phocoena l.)." The Anatomical Record, 292, 902 – 920.
27. a, bColosi JA (2016). Sound Propagation through the Stochastic Ocean. Cambridge University Press.
28. ^Au WWL, Hastings MC (2008). Principles of Marine Bioacoustics. Springer, New York, NY.
29. ^Bradley DL, Stern RR (2008). "Underwater Sound and the Marine Mammal Acoustic Environment: A Guide to Fundamental Principles." Bethesda, MD: Marine Mammal Commission.
30. ^Luczkovich J, Sprague M, Krahforst C, Dean Carpenter J (2013). "Acoustics and estuarine ecology: using active and passive methods to survey the physical environment, vegetation and animals in North Carolina's coastal estuaries." Proc. Mtgs. Acoust. 2(1), 005006. doi:10.1121/1.4799135.
31. ^Milanelli A, Rossi-Santos MR, Fruet P, Assumpção R, Cavalcanti AM, Dalla Rosa L (2024). "Temporal patterns in the soundscape of the port area in an urban estuary." Estuarine, Coastal and Shelf Science, 297, 108596. doi:10.1016/j.ecss.2023.108596.
32. ^Melcón ML, Failla M, Iñíguez MA (2016). "Towards understanding the ontogeny of echolocation in franciscana dolphins (Pontoporia blainvillei)." Mar Mamm Science, 32(4), 1516-1521. doi:10.1111/mms.123

36.

33. ^a, b^ *Paitach RL, Amundin M, Teixeira G, Cremer MJ. (2021). Echolocation variability of franciscana dolph ins (Pontoporia blainvillei) between estuarine and open-sea habitats, with insights into foraging patter ns. J Acoust Soc Am 150(5): 3987.*
34. ^ *Giardino GV, Cosentino M, Buscaino G, Bastida R, Rodríguez D (2024). "Acoustic Detection of Francisca na Dolphins Near Artisanal Fishing Nets in Argentina." In: Popper AN, Sisneros JA, Hawkins AD, Thomse n F (eds) The Effects of Noise on Aquatic Life. Springer, Cham. doi:10.1007/978-3-031-50256-9_54.*
35. ^a, b^ *DeRuiter SL, Bahr A, Blanchet M-A, Hansen SF, Kristensen JH, Madsen PT, Tyack PL, Wahlberg M (2 009). "Acoustic behaviour of echolocating porpoises during prey capture." J Exp Biol 212:3100–3107. do i:10.1242/jeb.030825.*
36. ^ *Pace DS, Tumino C, Silvestri M, Giacomini G, Pedrazzi G, Pavan G, Papale E, Ceraulo M, Buscaino G, Ar dizzone G (2022). "Bray-call sequences in the Mediterranean common bottlenose dolphin (Tursiops tru ncatus) acoustic repertoire." Biology. 11(3), 367. doi:10.3390/biology11030367.*
37. ^ *Pace DS, Pedrazzi G (2024). "Bottlenose dolphin predation on flathead grey mullets using barrier feedi ng techniques: a visual and acoustic case study in the Mediterranean Sea." Ethology Ecology & Evolutio n, 1-9. doi:10.1080/03949370.2024.2411507.*
38. ^ *Shane SH. (1990). Behaviour and ecology of the bottlenose dolphin at Sanibel Island, Florida. In: Leath erwood S, Reeves R, editors. The bottlenose dolphin. San Diego (CA): Academic Press Inc.; p. 245–266.*
39. ^ *Wells RS. (2019). Common bottlenose dolphin foraging: behavioral solutions that incorporate habitat f eatures and social associates. In: Würsig B, editor. Ethology and behavioral ecology of odontocetes. Cha m (Switzerland): Springer; p. 331–344.*
40. ^ *Weinpress-Galipeau M, Baker H, Wolf B, Roumillat B, Fair PA. (2021). "An adaptive bottlenose dolphin foraging tactic, "shipside feeding," using container ships in an urban estuarine environment". Mar Ma mm Sci. 37(3): 1159–1165. doi:10.1111/mms.12806.*
41. ^ *Hansen MJ, Domenici P, Bartashevich P, Burns A, Krause J (2023). "Mechanisms of group-hunting in v ertebrates." Biol Rev. 98(5),1687–1711. doi:10.1111/brv.12973.*

Declarations

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