

Carcass non-recovery rate of franciscana dolphin (*Pontoporia blainvillei*), calibrated with a drift mark-recapture study at FMA Ia, Brazil

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Abstract

The franciscana dolphin (*Pontoporia blainvillei*) is one of the smallest dolphins globally and the most threatened in the Southwest Atlantic Ocean. Beach monitoring helps to investigate cetacean strandings within their distributions and assess impacts that cause mortality. Using drifters in mark-recapture studies helps to estimate recovery rates when carcasses are unavailable. The study aims to estimate the non-recovery rate of franciscana carcasses from FMA Ia by comparing the spatial distribution between carcasses and drifters along the coast; correlating the influence of cold fronts with the recovery rate of drifters; estimating the non-recovery rate of carcasses according to the drifters' results and the meteorological profile in the pre-stranding period; characterizing the death diagnostic with temporal

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distribution of franciscanas by considering the stranding index and the carcass non-recovery rates. We repeated the release of 54 drifters in two campaigns close to the coast within the range of franciscana dolphins, where beaches are monitored daily, in the north region of Espírito Santo state, Brazil. The carcass stranding hotspots (21%) and drifters (18%) were 10 km apart. Cold fronts significantly increase the number of strandings. Considering the incidence of cold fronts in the pre-stranding period and linear regression from drifters, the median carcass recovery rate is 0.26, 95% IC [0.22 - 0.29], which means that for each stranding, the carcass non-recovery rate varies from 0.78 to 0.71. The range between 265 to 350 estimates the total of carcasses from 77 strandings observed from 2003 to 2021. The record year of strandings was 2014 (n = 14). About 52% of records occurred in summer, and January is the month with the highest occurrence of strandings. Of the conclusive diagnoses (n = 43), around 77% (n = 33) were attributed to incidental capture in gillnets. Estimating the number of carcasses based on stranding records is essential for population viability analyses and conservation purposes, especially considering small and isolated populations as in the present study. To prevent local extinction, a solution to avoid incidental capture, especially along summers, must be addressed quickly.

Introduction

Stranding is part of the mortality that occurs at sea, so the indicator of mortality rate from stranding is essential to be estimated for conservation programs for marine mega-vertebrates (Peltier et al., 2012). The problem is that the quantity of carcasses found on beaches depends on mortality rates and the forces operating in floating and delivering carcasses (Moore et al., 2020). Prado et al. (2013) analyzed twenty-one ecologically plausible

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models, demonstrating that wind alone is the best model to answer the probability of a franciscana washing ashore, with a deviance information criterion (DIC) of 97.9. Differences between wind regimes and seasons can cause the absence of strandings even for eventual high at-sea mortality (Epperly et al., 1996; Prado et al., 2016). Considering that recovery rates are subject to several processes such as sinking, decaying, scavenging, and drifting, it is essential to consider that the small number of carcasses found on the beach does not necessarily reflect few mortality events (Williams et al., 2011; Koch et al., 2013; Prado et al., 2016). Knowing the proportion of total stranding mortality due to anthropogenic impacts is vital for population viability analysis, especially for threatened species. In 2012, Peltier and colleagues presented a review of twelve publications related to the launching of carcasses, strandings, and discovery rates for marine predators, with publications ranging from 1977 to 2006 and covering studies mainly related to birds (Bibby & Lloyd, 1977; Jones et al., 1978; Bibby, 1981; Hlady & Burger, 1993; Harris & Wanless, 1996; Flint & Fowler, 1998), but also sea turtles (Epperly et al., 1996; Hart et al., 2006) and sea otters (Degange et al., 1994; Garshelis, 1997); the stranding rates varied considerably among the studies.

The at-sea mortality estimation can be achieved by using drift experiments such as releasing tagged carcasses or drifters and counting the number of beach recoveries (Epperly et al., 1996; Hart et al., 2006; Peltier et al., 2012; Koch et al., 2013; Young et al., 2019). In tropical areas, there is a significant lack of research on the release of marked cetacean carcasses. The only published data found in the Southwest Atlantic Ocean (Prado et al., 2013) involves franciscana dolphins endemic to the area. The geographic location is in the Rio Grande do Sul, a different region than the population studied here. These experiments are crucial for explaining phenomena regarding recovery rates associated with distance from the coast and the seasons' effects for each study area (Peltier et al., 2012; Hart et al., 2006; Koch et al., 2013).

The franciscana dolphin (*Pontoporia blainvillei*) is a small coastal cetacean, considered the most threatened in the Southwest Atlantic Ocean. Franciscana dolphins are classified as Vulnerable by the Red List of the International Union for Conservation of Nature (Zerbini et al., 2017) and Critically Endangered according to the Red Book of Brazilian Fauna Threatened with Extinction (ICMBio, 2018). In general, they inhabit turbid waters shallower than 30 m. Due to the coastal characteristics of their distribution, they are subject to a series of disturbances and anthropogenic threats, especially incidental catch in fishing nets (Secchi et al., 2003; Danilewicz et al., 2009; Prado et al., 2013) and contamination by environmental degradation and chemical pollution (Lailson-Brito et al., 2002; 2011; 2012; Manhães et al., 2022).

Secchi et al. (2003) proposed four "Franciscana Management Areas" (FMAs) which aim is to guide conservation efforts on a regional basis: two of these areas are located in southeastern and southern Brazil (FMA I and II), one in southern Brazil and Uruguay (FMA III) and one in Argentina (FMA IV). The FMA I includes animals from Espírito Santo and the northern region of Rio de Janeiro and was later subdivided into two by Cunha et al. (2014) due to the recognition of genetic differentiation between them; therefore, the population located in Espírito Santo is now classified as FMA Ia and that of Rio de Janeiro as FMA Ib. The

FMA Ia subpopulation is the most isolated and threatened (Manhães et al., 2022). It is the smallest, with approximately 595 individuals (Sucunza et al., 2020). Its distribution is restricted to the north coast of Espírito Santo state, completely isolated from FMA Ib by 200 km (Cunha et al., 2014; de Oliveira et al., 2020; Sucunza et al., 2020).

Release and recapture experiments of tagged carcasses are essential to generate at-sea mortality indicators inferred from stranding; however, carcasses for drift experiments are not always available, especially with small populations where necropsy is mandatory. Therefore, drifters become a good replacement option in experiments that aim to understand the phenomena related to the carcass recovery rate. This work aims to estimate the non-recovery carcass rate of franciscana from FMA Ia, where there is a daily beach monitoring program and the possibility of conducting drift mark-recapture experiments. The specific objectives are to: I) compare the spatial distribution between carcasses and drifters along the coast; II) evaluate the drifters recovery rate between different wind patterns and climatic scenarios on monitored beaches; III) estimate the non-recovery rate of franciscana carcass based on a) calibration with the drifter's experiment, and b) evaluation of the meteorological profile in the pre-stranding period; IV) characterize the death diagnostic with temporal distribution of franciscanas by considering the stranding index and the carcass non-recovery rates.

Materials and methods

Study area

This study was conducted in the Tropical Southwest Atlantic Ocean, along the north coast of the state of Espírito Santo, Brazil. This region contains the southern portion of Abrolhos Bank and is home to diverse wildlife, including megafauna species of great conservation importance, such as the franciscana dolphin. This area covers the distribution of the species, particularly the FMA Ia population (Cunha et al., 2014). The area studied is situated within a region characterized by rainfall in the austral summer and spring, and droughts in autumn and winter. Rainfall due to the penetration of polar air masses can also occur in austral autumn and winter. The most frequent and intense winds come from the NE-ESE and SE, associated with trade winds and polar fronts. The former blow most of the year, while the latter is related to periodic cold fronts (Albino & Suguio, 2011). The climate is seasonal and marked by dynamic oceanographic processes. When the Brazilian Current prevails from December to March, the waters are typically warm (over 24°C). From June to September, the Malvinas Current and stormy weather conditions prevail, with a higher incidence of cold fronts with winds coming from the south and southeast, increasing northward currents in the region (Teixeira et al., 2013). The Beach Monitoring Program (BMP) from Campos and Espírito Santo basins has been implemented in the study area. The BMP arises from the environmental licensing of PETROBRAS, an energy company focusing on oil and gas exploration and production; the program has ensured daily monitoring along the coast with high efficiency for carcass detection and also drifters (Mayorga et al., 2020).



Figure 1. The comparison between the bamboo drifter as dummies and a 1.15 m long franciscana carcass (A). The drifters being found on the beach (B).

Drifter release campaigns

Two drifter release campaigns were carried out in the franciscana distribution area to simulate this species' drift and beaching processes. The first campaign released 54 drifters between the 4th and 5th of April 2018 (early austral autumn), and the second also released 54 drifters between the 12th and 13th of March 2019 (end of austral summer). Because the releases do not cover all seasons, the present simulation better represents a regional climate period. Release points were the same for both campaigns and were chosen by considering the species distribution and different latitudinal and depth gradients. The 54 drifters were released in pairs and distributed in 27 drop locations, nine points per transect. The transects were organized in three latitude ranges, 18°56'S, 19°13'S, and 19°37'S for each transect (*a*, *b*, and *c*, respectively; see Fig. 2), and in strata with varying depths between 5 and 35 m to simulate carcasses occurring offshore. The distance from the coast for the released points varies accordingly: transect *a* 1.32 to 51.2 km; transect *b* 4.38 to 37.66 km; and transect *c* 2.24 to 16.16 km. The drifters were made with three bamboo segments approximately 100 cm in length and 8 cm wide, tied with natural fiber to avoid pollution in case the drifters were lost at sea. No cover was provided for the bamboo center hole, no GPS sensor was used, and the total weight of each drifter was between 6 to 8 kg. Bright colored stripes were painted at the ends to help distinguish the object from garbage and to enable identification during the beach monitoring effort. Each drifter had written on it a phone number to call in case locals found it. Each drifter also received an identification code according to the release point to register an assumed straight distance between the releasing and recovery coordinates. The bamboo model was chosen after a flotation test (15 days in a tank) with other objects, such as watermelons, melons, and eucalyptus segments. Bamboo floats well and is accessible in the region. An *in situ* pilot test for the drifting velocity and direction between the bamboo drifter and carcass was compared for one hour of GPS (Garmin Etrex 20x®) track analyses. The differences between objects were 1.05% in declination and 11.49% in velocity for the drifter, probably due to the drag wind.

Stranding data

The drift recovery effort for both campaigns consisted of daily monitoring of the beaches conducted by BMP, TAMAR (Conservation of Sea Turtles Project), and local calls. After the

release process concluded, we started daily beach monitoring by motorcycle for 14 days. The records of stranding franciscanas were obtained from the Brazilian Humpback Whale Institute/ Instituto Baleia Jubarte (IBJ), an NGO operating in the region, a member of the Brazilian Aquatic Mammals Stranding Network (REMAB). Since October 2010, the records also integrated the database from the Campos and Espírito Santo Basins Beach Monitoring Project when beaches have been surveyed daily. The period before October 2010 includes records obtained only through information from the community - the total period comprised 208 months between December 2003 and March 2021. The basic data reported were date, stranding coordinates, and decomposition code (Geraci & Lounsbury, 2005); all animals collected were sent for necropsy and collection of biological samples for further studies. The comparison between the bamboo drifter and a franciscana carcass and the aspect of the drifters being stranded is presented in Fig. 1.

Weather data

Meteorological data over the study time, such as wind velocity and direction, were obtained by consulting the automatic meteorological station in Vitória from INMET (National Institute of Meteorology), from 88 to 180 km from the drifters' release points. This station is close to the coast and is representative of the study area.

Data Analysis

Data were sorted and analyzed using QGIS 3.12.3 (QGIS Development Team, 2020), WRPlot View (Lakes Environmental, 2010), Past 4.03 (Hammer et al., 2001), RStudio (RStudio Team, 2019), and Microsoft Office Excel®.

The first objective used the QGIS with the "Heat Map (Kernel Density Estimation)" algorithm to compare the hotspot's positions on the beach between carcasses and drifters along the coast. Kernel density quantifies the relationships of points within a radius (*R*) of influence (100 m in this case) based on a given statistical function and analyzes the patterns traced by a given set of stranding data, estimating their density along the coast. The objective of these analyses is to present a comparison of Kernel density maps to show the incidence of strandings on the coast of Espírito Santo, comparing, on one side the historical data of franciscana carcasses strandings for the period between December 2003 and March 2021 ($n = 77$), and on the other side

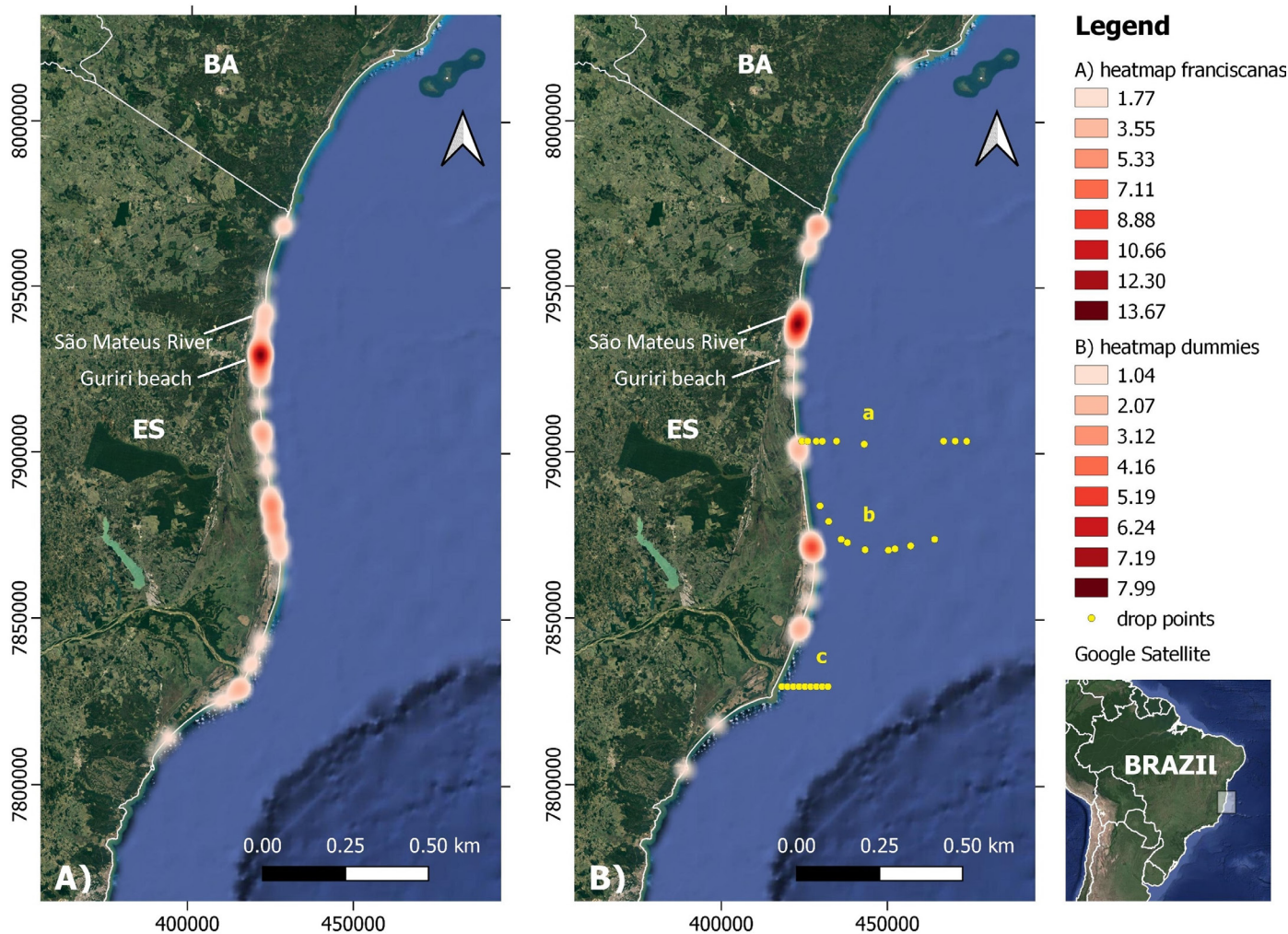


Figure 2. Heatmap of franciscana carcass strandings observed between 2003 and 2021 (A) and drifter strandings released during 2018 and 2019 along the distribution area, with details of the three transects and release points (B).

the strandings of drifters from both campaigns (n = 38). The efficiency of drifters as suitable carcass substitutes is evaluated using Kernel analysis and comparing the similarity of stranding hotspots along the beach.

For the second objective regarding the evaluation of drift recovery rate in different climatic scenarios (cold front/warm front), the general organization of wind and drifters data were solved in Microsoft Office Excel®, and the daily mean values for wind direction were determined by the “as.circular” function of the “circular package” and the use of the RStudio software (RStudio Team, 2019). A cold front was determined according to the daily prevalence coming from the southwest, south, and southeast, and a warm front was based on north, northeast, and east winds. WRPlot View was used to plot compass wind rose plots for each campaign during the 14 days of beach monitoring. We used the Past Software Mann Whitney pairwise test to compare the drift recovery between campaigns and cold front index along the pre-stranding period regarding carcass decomposition codes. With this software, we performed the Watson-Williams test for homogeneity of means between circular data and wind direction. We analyzed them as medians, standard deviations, 95% confidence intervals, correlation coefficients adjusted to normal probability, and linear regressions.

For the franciscana carcass recovery estimation objective based on stranding data, two steps were implemented: a) first, the calibration with the drifters experiment by using the straight-line equation obtained from the correlation between the percentage of the cold front index and corresponding non-recapture rate from both campaigns; b) considering the meteorological profile (especially cold fronts index) in the pre-stranding period for each carcass. The pre-stranding period of franciscana carcasses was defined accordingly with Post-Mortem Interval (PMI) following a proposed approximation rule based on a decomposition study (H. G. C. Ramos, unpub. data): two previous days were used to represent the pre-stranding period for code 2 of decomposition, four days to represent code 3, and six days for code 4. Decomposition codes are classified from 1 to 5, with 1 for live animals, 2 for fresh carcasses, 3 for the early decomposition stage, 4 for the advanced decomposition stage, and 5 for mummified carcasses (Geraci & Lounsbury, 2005). The pre-stranding period was determined backward from 09h00 when beach monitoring was usually performed.

The amount of carcasses is given by the sum of stranding records with the carcass non-recovery rates estimated. Finally, the percentages regarding causes of death are presented.

Results

Franciscana and drifters strandings

From 2003 to 2010, all franciscana carcasses found were stranded within the state of Espírito Santo coast limits between the latitudes 18°21'S and 19°48'S. A hotspot with a relatively greater frequency of occurrences ($n = 14/77 - 21\%$) was detected between Guriri beach (São Mateus municipality) and the south bank of the São Mateus River in Cricaré (Conceição da Barra municipality). The region also had a hotspot for drifter strandings ($n = 8/38 - 18\%$). The distance between the center of both hotspots is about 10 km (Fig. 2). The drift recovery rate from both campaigns was 79% ($n = 30$) by BMP effort, 11% ($n = 4$) by locals, 5% ($n = 2$) by TAMAR beach monitoring, and 5% ($n = 2$) by motorcycle monitoring.

During the 2018 campaign, drifter recovery rates were 83.3% and 88.9% for transects *a* and *b*, respectively. At least one drifter from each drop point was recaptured from these two transects. For transect *c*, the recapture rate was much lower, 16.7%. Recovery rates were related to the closest drop points 1, 2, and 5 from the coast. During the 2019 campaign, only four drifters from transect *a* were detected, 22.2%. They were found on the two days following their release and with the prevalence of trade winds. These drifters were released at the three points closest to the coast, ranging from 1.3 to 5.6 km. The final linear distance between drop/recovery points under these weather conditions was between 2.1 and 30.6 km. Considering the entire simulation and following carcasses code 2 (within 24 hours of death), there was a correspondence of 11 drifts in the same condition, *i.e.*, that washed ashore after this interval. They were released between 1.32 and 6.28 km from the coast, and the linear

Table 1. Prevalence of cold or warm fronts and recapture numbers of drifters for both campaigns during the 14 days of beach surveys following the release of the drifters.

Campaign	April 2018		March 2019		
	Days	Front	Recapture	Front	Recapture
1*	cold	0	warm	0	0
2*	cold	0	warm	3	3
3	warm	4	warm	1	1
4	warm	3	warm	0	0
5	cold	0	warm	0	0
6	cold	0	warm	0	0
7	cold	5	warm	0	0
8	warm	0	warm	0	0
9	cold	0	warm	0	0
10	cold	2	cold	0	0
11	warm	7	cold	0	0
12	cold	10	cold	0	0
13	cold	2	cold	0	0
14	cold	1	cold	0	0

* Drifters were released during these first two days.

distance between drop/recovery points ranged from 2.09 to 33.9 km. No drift found fits the characteristics of a code 3 carcass (4 days death). For code 4 (6 days death), we observed five drifters released between 2.24 and 16 km from the coast and a straight line between drop/recovery points varying from 22.49 to 39.79 km. The general regression equation for linear distance from drop/recovery points (y) and days (x) is given by the formula: $y = 6.3448x + 5.9775$ ($N=38$, $R^2 = 0.68$). As there were no drifters corresponding to code 3, by applying the formula, the distance between the place of death and the stranding site would be around 25.01 km (12.29 and 36.84 minimum and maximum averages).

Drifter recapture and cold fronts

The two campaigns differed significantly in terms of drifters recaptured (Mann-Whitney $U = 52$, $p < 0.05$), with the 2018 campaign having 63% recapture ($n = 34$) and the 2019 campaign 6% ($n = 4$) (Table 1). The two campaigns also differed significantly in terms of the cold fronts index (Watson-Williams $F = 4.04$, $p < 0.05$), with the 2018 campaign having 71% cold fronts and 2019 36%. Regarding the carcasses, the cold front index related to the pre-stranding period between codes reveals a significant difference between codes 2 and 4 (Mann-Whitney $U = 131$, $p < 0.05$). The wind rose analyses also reveal a significant difference between the campaigns, with the resultant vector for 2018 at 140 deg with 69% intensity and 2019 at 45 deg with 24% (Fig. 3).

Carcass recovery estimation

The linear equation $y = -0.8028x + 94$ was obtained from the drifters experiment results (2018 campaign with 71% of cold fronts and 37% of non-recovery rate against 2019 with 0% of cold fronts and 94% non-recovery). This equation provides the non-recovery rate (y), corresponding to each carcass, with the cold front index (x) observed during the pre-stranding period. The carcass recovery estimation (given by knowing the opposite proportion of the carcass non-recovery rate) is presented for each code and PMI, as well as other measures of tendency, including the correlation coefficient adjusted to a normal probability (Table 2).

Table 2. Decomposition code (CODE) according to Geraci and Lounsbury (2005); Post-Mortem Interval (PMI); Number of carcasses (N); Mean (\bar{x}); Standard deviation (SD); Confidence interval (IC 95%); and Correlation coefficient (CC).

CODE	PMI	N	\bar{x}	SD	IC 95%	CC
2	2	12	0.17	0.15	0.08 [0.08 - 0.25]	0.85
3	4	26	0.27	0.19	0.07 [0.20 - 0.34]	0.95
4	6	38	0.27	0.16	0.05 [0.22 - 0.32]	0.97
(2-4)	(2-6)	76	0.26	0.17	0.04 [0.22 - 0.29]	0.96

Strandings and carcass maximum non-recovery estimation

About 52% ($n = 40$) of stranding records occurred under summer conditions, 26% ($n = 20$) in the spring, 16% ($n = 12$) in the winter, and 6% ($n = 5$) in the autumn. The record year for strandings was 2014 (Table 3), and January is the month with the highest occurrence frequency (Table 4).

The remaining proportion (0.71 - 0.78) gives the carcass non-recovery estimation for all codes considering the carcass recovery

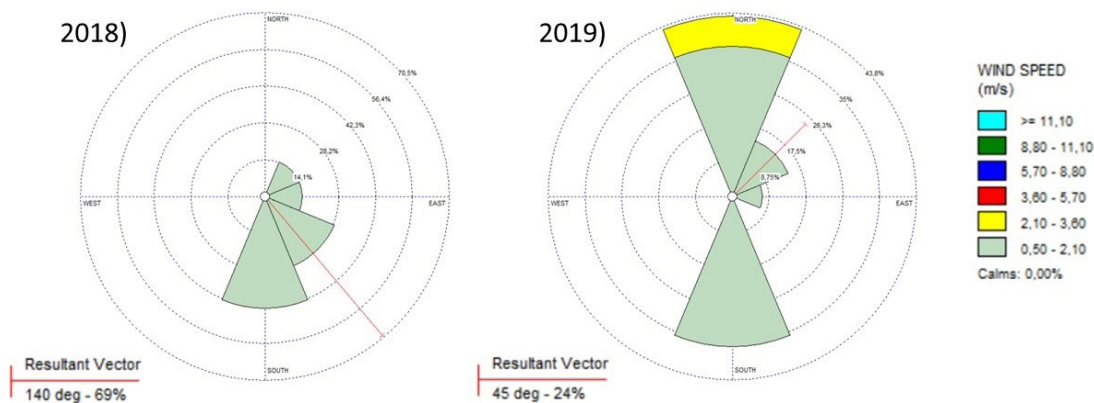


Figure 3. Wind patterns over the monitoring days during the 2018 and 2019 campaigns with the resulting vector pointing in the predominant direction.

estimation calculated (0.29 - 0.22); these proportions represent those animals that were not stranded or discovered. The amount of carcasses is expressed by the sum of the stranded animals and the non-recovery rate estimation that is presented by years and months (Tables 3 and 4).

Cause of death

Of the animals found dead, 44% (n = 34) of the causes could not be determined. Of those with a conclusive diagnosis (n = 43), around 77% (n = 33) were attributed to incidental capture in gillnets, 19% (n = 8) to infections, 2% (n = 1) to multiple traumas, and 2% (n = 1) to neonatal mortality. Regarding seasons, about 55% (n = 18) of the entanglements recorded occurred in summer, 3% (n = 1) during autumn, 24% (n = 8) in winter, and 18% (n = 6) in spring. Multiple trauma and neonatal mortality occurrences were detected during the summer. Infectious processes were distributed according to season, with 50% (n = 4) during summer, 13% (n = 1) during the winter season, and 38% (n = 3) during spring.

Table 3. Distribution of franciscana strandings over the years (N). Between square brackets, the minimum and maximum values for the Non-recovery rate of carcasses estimation. The Sum of (N) and the Non-recovery rate provides the minimum amount of carcasses. The period between 2003 to 2010 comprises a time without BMP. 2021 includes only January to March.

Year	N	Non-recovered rate	Sum
2003	1	[2.4 - 3.5]	[3.4 - 4.5]
2010	2	[4.9 - 7.1]	[6.9 - 9.1]
2011	4	[9.8 - 14.2]	[13.8 - 18.2]
2012	1	[2.4 - 3.5]	[3.4 - 4.5]
2013	1	[2.4 - 3.5]	[3.4 - 4.5]
2014	14	[34.3 - 49.6]	[48.3 - 63.6]
2015	8	[19.6 - 28.4]	[27.6 - 36.4]
2016	10	[24.5 - 35.5]	[34.5 - 45.5]
2017	2	[4.9 - 7.1]	[6.9 - 9.1]
2018	6	[14.7 - 21.3]	[20.7 - 27.3]
2019	12	[29.4 - 42.5]	[41.4 - 54.5]
2020	12	[29.4 - 42.5]	[41.4 - 54.5]
2021	4	[9.8 - 14.2]	[13.8 - 18.2]
Total	77	[188.5 - 273.0]	[265.5 - 350.0]

Table 4. Quantity of franciscana strandings along the months (N) for the entire period (2003-2021). Frequency per month is shown as % of the total. Between square brackets, the minimum and maximum values for the Non-recovery rate of carcasses estimation. The Sum of (N) and the Non-recovery rate provides the minimum amount of carcasses. The period between 2003 to 2010 comprises a time without BMP. 2021 includes only January to March.

Month	N	%	Non-recovered rate	Sum
Jan	20	26.0	[49.0 - 70.9]	[69.0 - 90.9]
Feb	10	13.0	[24.5 - 35.5]	[34.5 - 45.5]
Mar	6	7.8	[14.7 - 21.3]	[20.7 - 27.3]
Apr	3	3.9	[7.3 - 10.6]	[10.3 - 13.6]
May	1	1.3	[2.4 - 3.5]	[3.4 - 4.5]
Jun	0	0.0	[0.0 - 0.0]	[0.0 - 0.0]
Jul	2	2.6	[4.9 - 7.1]	[6.9 - 9.1]
Aug	7	9.1	[17.1 - 24.8]	[24.1 - 31.8]
Sep	4	5.2	[9.8 - 14.2]	[13.8 - 18.2]
Oct	5	6.5	[12.2 - 17.7]	[17.2 - 22.7]
Nov	9	11.7	[22.0 - 31.9]	[31.0 - 40.9]
Dec	10	13.0	[24.5 - 35.5]	[34.5 - 45.5]
Total	77	100	[188.5 - 273.0]	[265.5 - 350.0]

Discussion

The first campaign with a high drifter recapture rate coincides with the high incidence of cold fronts. This finding considers regional climate period biases, *i.e.*, campaigns along March and April when cold fronts generally do not prevail. The contrast in the percentage of the cold front between both campaigns provided two different results of recapture rates on beaches that were necessary to happen in order to detect the weather effect. It is necessary to use drifters that stay afloat longer than carcasses, and to monitor the beach where drifters and carcasses are expected for a time longer than the maximum decomposition time inferred from the non-recapture rate for those carcasses where death occurs away from the coast. The 14 days sampled were sufficient time to meet these two assumptions. We believe sampled times allowed a valid conclusion regarding drifters' recapture times and understanding the phenomena related to

the most distant areas from the coast used by franciscanas. No drifters were recovered after 14 days, even though the daily beach monitoring was ongoing. The drifters released in the most distant areas of the franciscana's known distribution helped clarify the proportion of carcasses not usually detected on beaches. This data aided in calculating the proportion of carcasses that do not reach the beach due to decomposition or scavenging, while also accounting for franciscana's distribution area and the study region's wind patterns. The drifter experiment indicates the proportion of carcasses that should be recovered under similar weather conditions and helps to define the number of carcasses based on the sum of the stranding data with the non-recovery rates.

Weather patterns must be considered in studies related to strandings since seasons or wind regimes can alter ocean circulation and affect the number of carcasses found on beaches (Epperly et al., 1996; Hart et al., 2006; Prado et al., 2013). Despite the strong relationship between cold fronts and the observed recapture rate, strandings could occur even in conditions with a complete absence of cold fronts due to the predominance of trade winds, which occurred both for some drifters and carcasses. This scenario affected a few drifters released closer to the coast. Trade wind conditions are not conducive to beaching drifters dropped far away from the coast. In the 2019 campaign, the trade winds prevailed for nine consecutive days, which provided southward current conditions, pushing drifters away from the coast. Recovery was not possible even after the cold front arrived at the end of the period. In the 2018 campaign, the oscillation between cold and warm fronts seems to have favored the succession of northward and southward currents, respectively, favoring an onshore approach of drifters, consequently increasing stranding and recovery rates. According to Hlady and Burger (1993), almost twice as many drifters were recovered with strong onshore winds compared to strong offshore winds.

The wind kinetic energy can be used as a physical descriptor of the transport process of carcasses by its interaction with the portion above the surface and the ocean current to the portion below the surface (Peltier et al., 2012). Nevertheless, the wind drag influences the surface ocean current. Thus, considering the velocity of winds and currents in drift and stranding patterns increases the reliability of beach monitoring whenever these environmental conditions are favorable, helping to detect impacts associated with deaths and helping the investigation, but hiding under unfavorable patterns of weather conditions. Weather stations are more accessible and common than local oceanographic information. Hence, beach monitoring programs need to consider the weather variables that affect the stranding rate to predict tendencies related to the non-recapture rate of carcasses and estimate the number of carcasses for the studied species.

The occurrence of stranding hotspots detected in the analyses of both carcasses and drifters needs further research. These hotspots may be associated with local oceanic circulation variability due to the passage of cold fronts, longshore drift currents in the region, especially up north of the Doce River, confluence against the flow of the São Mateus River, and perhaps beach topography more prone to allow stranding in the area. It is impossible to discern whether the distance of 10 km observed

between hotspots is influenced by climatic variations over the years or due to differences in characteristics between drifters and carcasses. The drifters were located below and above the release point's latitude for a significant portion of the objects launched into the sea. During the 2018 campaign, when the incidence of cold fronts was higher, this phenomenon of changing ocean circulation with increasing northward currents prevailed, as in Teixeira et al. (2013). This phenomenon characterizes a pattern typically favorable for stranding in the region resulting in a greater probability of stranding distribution in a hotspot located to the north of the release points, as observed between the region of Guriri beach and São Mateus River in Conceição da Barra. This means some carcasses washed ashore in these areas may also come from places further south and closer to the Doce River, especially those in advanced decomposition stages. According to Mayorga et al. (2020), the average number of recorded strandings in the region increased by 750% after the start of the BMP; the BMP was fundamental for obtaining the results related to the recovery rates of drifters and characterization of the observed hotspot.

The correlation between the cold front and the non-recapture rates between the two campaigns made it possible to present a non-recovery rate extrapolation linear equation relating drifters to carcasses. The low number of campaigns employed in the study could be a limitation if not for the significant difference in strandings observed and the difference in the cold front index. This was, in part, a lucky circumstance that ensured the necessary contrast to correlate recovery rate within cold fronts and non-recovery within warm fronts.

The carcass recovery estimates from the stranding events were determined by a novel insight, *i.e.*, by considering the incidence of cold fronts in the pre-stranding period, as the time since death is an essential measurement for beached marine animals to help to define how long their carcass was adrift before stranding (Peltier et al., 2012; 2020; Nero et al., 2013; Santos et al., (2018a, b). We considered the decomposition code and corresponding PMI to identify tendencies in the drifting and stranding processes correlated with the occurrences of dead franciscana dolphins in the region. Applying linear regression, the straight distance between the death and stranding sites is 18.67 km for code 2, 25.01 km for code 3, and 31.36 km for code 4.

Using the 95% confidence interval and considering all the codes and carcasses analyzed in the region, franciscana stranding in FMA Ia represents a recovery rate between 0.22 to 0.29. Therefore, the non-recovery rates, based on the strandings and corresponding environmental forces, help to define a minimum amount of carcasses of franciscana in the region. However, as such extrapolation was carried out with bamboo drifters, and scavengers do not consume them, the recovery rate will probably be lower for carcasses, requiring parsimony of the presented extrapolation. For this reason, the lowest interval corresponding to the preferable recovery was 0.22, or the equivalent highest rate of non-recovery, which is proportionally 0.78. For each stranded animal, 3.5 carcasses do not wash ashore due to weather influence. The total of carcasses can be expressed by the sum of stranding records with the estimated non-recovery rate.

A better model to measure mortality could be developed if carcasses could be made available for mark-recapture studies,

which would then measure the recapture rate on beaches, taking into account scavengers' action; unfortunately, this is a limiting factor in regions where necropsies are mandatory. A higher number of carcasses must be considered to ensure equivalent results to our experiment. Prado et al. (2013) showed a 7.6% recovery of franciscana carcasses in the FMA III under a systematic beach survey carried out fortnightly. Differences in the type of beach monitoring effort can affect detectability and make it difficult to proceed with comparisons. In the present study, due to the daily nature of monitoring, the assumed detectability on beaches is close to 100%, contributing to higher detection on stranding beaches. Due to the characteristic of the Abrolhos Bank platform and shallow aspect barely exceeding 30 m, it is also assumed that the refloat rate is close to 100%, with minimum loss of carcasses attributed to compression and low temperatures issues typical of abyssal regions (Moore et al., 2020). The transport of drifters across the platform suggested that carcass drift also responds to wind intensity and direction of ocean circulation, as has been suggested before (Bibby & Lloyd, 1977; Epperly et al., 1996; Hart et al., 2006; Peltier et al., 2012).

The stranding rate varied considerably from 0.03 to 0.95, accordingly to the Peltier et al. (2012) review. The characteristics of each species, location, type of experiment, and especially the relation of the distance to the coast and oceanic circulation patterns and or wind regime are responsible for the wide range of results among references. We observed a significant difference in the drift recovery rate between transects. Transect c positioned south of the Doce River and in an area where the continental shelf is narrow, showed a recovery rate 5.2 times lower than the other two transects located further north. This may be due to a change in ocean dynamics between regions, explaining the rareness of franciscana carcass strandings south of the Doce River. Drifters are suitable substitutes for estimating recovery rates. Young et al. (2019) observed that beaching rates for sea otters were similar between carcasses (0.697) and drifters, (0.667). In 2016, Carretta et al. (2016) presented a table reviewing articles on the cetacean Maximum Carcass-Recovery (MCR). In their study, with a population of *Tursiops truncatus* along the California coast, the MCR rate was 0.33, very close to the present result of 0.29. The other studies reported MCR rates varying from 0.062 to 0.33. Kraus et al. (2005) with *Eubalaena glacialis* in the Northeast United States reported a MCR of 0.17; Moore and Read (2008) with *Phocoena phocoena* in the NE United States, < 0.01; Williams et al. (2011) with multiple species along the Gulf of Mexico, 0.062; Peltier et al. (2012) with *Delphinus delphis* along France, 0.08; Punt and Wade (2012) with *Eschrichtius robustus* from Alaska to Mexico, 0.13; Prado et al. (2013) with *P. blainvillei* from Brazil, 0.18; Wells et al. (2014) with *Tursiops truncatus* from the Southeast United States, also observed 0.33, also close to the present result observed, 0.22 to 0.29.

In this study, the strandings of franciscana dolphins as code 2 occur with a lower prevalence of cold fronts than other advanced decomposition codes. A statistical difference was observed between code 2 and the more advanced stage of decay, code 4, regarding the cold front index during the pre-stranding period. Carcasses code 2 probably include those animals that die near shore where other forces may act, such as waves and tides. On the other hand, carcasses in the advanced decomposition stages

remained drifting longer, requiring more favorable weather and ocean conditions for stranding. It was also possible to infer the distance traveled by the carcasses using the formula provided: code 2 carcasses tend to travel 18.7 km, and codes 3 and 4, 31.4 km and 44 km, respectively.

Although the cold fronts are related to a significant change in strandings, the prevalence of stranding did not follow the seasonality when this condition prevailed, winter. The highest stranding rates occurred in summer conditions (52%), also observed by Mayorga et al. (2020) and Marcondes et al. (2020), probably due to significantly more gillnet fishing activity at this time of year and consequent higher incidence of impact. About 55% of the entanglements were also concentrated in summer. Most records of franciscana entanglement in gillnets in the study region also occurred in summer (Siciliano, 1994; Frizzera et al., 2012). Siciliano (1994) pays attention to another common problem in the study region: the use of carcasses as bait in the shark fishery, in lobster traps, and even for human consumption, causing further underestimation of stranding records of animals killed by fishing activities. Interactions with gillnet fisheries are a problem for franciscanas at different locations throughout the species range (Bertozzi & Zerbini, 2002; Ott et al., 2002; Rosas et al., 2002). In the study region, especially in Regência, the wide variety of nets used is a concern (de Freitas Netto & Di Benedetto, 2008), with the occurrences of entanglements being attributed to different fishing operations (Netto & Siciliano, 2007). Frizzera et al. (2012), through onboard monitoring at the Doce River mouth, estimate the loss of an animal per capture every three days of fishing effort by the local fleet (10 boats). According to Fundação PROZEE/SEAP/IBAMA (2005), the estimated fishing fleet between Conceição da Barra and Aracruz (FMA Ia distribution area) is 295 boats, with an even greater risk of accidental captures for cetaceans in the region.

Inconclusive diagnoses of the cause of death occur due to the advanced stage of carcass decomposition. In our study, it accounted for 44% of cases, which most likely underestimates the mortality attributed to impacts. For this reason, the proportion of inconclusive necropsies was disregarded among the causes of death presented. The attribution of 77% of deaths to entanglements in gill fishing nets is a concern considering a small population, as pointed out by Sucunza et al. (2020), where the FMA Ia was estimated as 595 individuals. It may also be a concern considering a low genetic diversity population, as reported by Cunha et al. (2014) and de Oliveira et al. (2020).

During the summer, especially during the January period with the highest frequency of entanglements, it would be important to implement conservation programs aimed at reducing impacts on the population. The restriction of gillnets where the franciscana dolphin is more abundant, in the range of 20 meters of depth, was proposed by Marcondes et al. (2020).

Infectious processes were the second identifiable cause of death and are associated with natural mortality. However, they can also be attributed to degradation in environmental quality, such as pollution and other disturbances (Lailson-Brito et al., 2002; 2011; 2012). The Fundão dam disaster impacted the FMA Ia region (Mayorga et al., 2020; Marcondes et al., 2020; Manhães et al., 2022). This incident is being monitored to understand the environmental impact over this population. In addition to human-

induced mortality by bycatch and chemical contamination, Marcondes et al. (2020) mention other threats to the franciscana in FMA Ia, including oil spills, marine debris, diseases of concern, climate change, port facilities, and marine noise.

The present study does not consider the loss of individuals that probably happens on days without strandings, especially under unfavorable weather conditions when eventual mortalities happen, and carcasses are lost offshore. A solution to this remains pendant. Another aspect, the drifters do not behave precisely like carcasses. They do not sink or decay, nor are they scavenged. Nevertheless, drifters provide satisfactory approximations, and examples are Koch et al. (2013), using oranges to simulate turtle carcasses, and Young et al. (2019), using half-car tires to simulate sea otter carcasses. Neither the experiment nor the analyses could deal with the multiple associated biases for a mortality estimation. The sum of strandings within the non-recovery rate estimations provides minimum mortality, mainly based on the environmental conditions that affect or avoid stranding rates. Scavenger rates also remain pendant to be understood. Accordingly, it could be helpful to use an adaptation of the equation presented by Peltier et al. (2012), where: the number of dead cetaceans at sea = probability of discovery ÷ probability of strandings ÷ probability of buoyance ÷ number of stranded cetaceans. Peltier et al. (2012) consider the probability of buoyance when a carcass is positively buoyant and can drift, the probability of stranding when a drifting carcass reaches the coast, and the probability of discovery when a stranded cetacean is discovered and reported.

Considering Peltier et al.'s (2012) formula to estimate the number of dead cetaceans at sea, the current study presented the probability of buoyance and discovery close to 100%, considering shallow and warm waters and the daily beach monitoring program. This study could partly respond to the probability of stranding, considering the proportion between strandings and non-recovery rates. Nevertheless, the number of carcasses presented is somewhat lower than the total mortality at sea. Special attention must be taken to the fact that the study does not present total mortality, which is not possible to be estimated by using artificial drifters. To solve this the recommendation would be the use of tagged carcasses. Despite the limitations with drifters, the experiment helps to answer the proportion of carcasses that do not wash ashore given wind patterns and helps to know how much of the recorded stranding represents the non-recovery rate of franciscana carcass. The amounts of stranding together with non-recovery rates do not represent the total mortality for the population but can be considered minimum mortality based on stranding records. Although it may be possible to estimate the observed mortality in fishing nets through questionnaires and onboard monitoring (de Freitas Netto & Di Benedetto, 2008; Frizzera et al., 2012; Marcondes et al., 2018), this may reveal the entanglement rate, and total mortality will remain an unknown factor for population viability analyses, raising concerns about the potential risk of extinction of this threatened population. Different approaches are needed to understand what happens to the species, and releasing tagged carcasses would strongly benefit the understanding of mortality behind stranding rates.

Further investigation with mark-recapture drifters could also serve as a refinement of the present study and be optimized if conducted in comparison with carcasses to cover scavenging rates. Nevertheless, special attention must be given to the carcass

release points, as they must be at a viable distance for strandings and before favorable weather conditions to ensure recoveries. Studies of carcass decomposition may also help to refine the estimation of carcass drifting time. Studies on environmental forces, especially ocean circulation, could help better support the evidence on stranding rates. Finally, it is imperative to take immediate action to reduce the franciscana dolphin bycatch in FMA Ia to avoid potential extinction. An alternative could be to restrict gillnets during summer, when the entanglement threat predominates, thus reducing franciscana mortality by more than half.

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References

- Albino, J. & Suguio, K. (2011). The influence of sediment grain size and composition on the morphodynamic state of mixed siliciclastic and bioclastic sand beaches in Espírito Santo State, Brazil. *Revista Brasileira de Geomorfologia*, 12(2). <https://doi.org/10.20502/rbg.v12i2.237>
- Bertozzi, C. & Zerbin, A. N. (2002). Incidental mortality of franciscana, *Pontoporia blainvillei*, in the artisanal fishery of Praia Grande, São Paulo State, Brazil. *Latin American Journal of Aquatic Mammals*, 1,153-16. <https://doi.org/10.5597/lajam00019>
- Bibby, C. J. (1981). An experiment on the recovery of dead birds from the North Sea. *Scandinavian Journal of Ornithology*, 12, 261–265.

- Bibby, C. J. & Lloyd, C. S. (1977). Experiments to determine the fate of dead birds at sea. *Biological Conservation* 12, 295–309. [https://doi.org/10.1016/0006-3207\(77\)90048-9](https://doi.org/10.1016/0006-3207(77)90048-9)
- Carretta, J. V., Danil, K., Chivers, S. J., Weller, D. W., Janiger, D. S., Berman Kowalewski, M., Hernandez, K. M., Harvey, J. T., Dunkin, R. C., Casper, D. R., Stoudt, S., Flannery, M., Wilkinson, K., Huggins, J., & Lambourn, D. M. (2016). Recovery rates of bottlenose dolphin (*Tursiops truncatus*) carcasses estimated from stranding and survival rate data. *Marine Mammal Science*, 32(1), 349–362. <https://doi.org/10.1111/mms.12264>
- Cunha, H. A., Medeiros, B. V., Barbosa, L. A., Cremer, M. J., Marigo, J., Lailson-Brito, J., Azevedo, A. F., & Solé-Cava, A. M. (2014). Population structure of the endangered franciscana dolphin (*Pontoporia blainvillei*): reassessing management units. *PLoS One*, 9(1), e85633. <https://doi.org/10.1371/journal.pone.0085633>
- Danilewicz, D., Secchi, E. R., Ott, P. H., Moreno, I. B., 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. <http://doi.org/10.1017/S002531540900054X>
- de Freitas Netto, R. & Di Benedetto, A. P. M. (2008). Interactions between fisheries and cetaceans in Espírito Santo State coast, southeastern Brazil. *Revista Brasileira de Zoociências*, 10(1): 55–63.
- Degange, A. R., Doroff, A., & Monson, D. H. (1994). Experimental recovery of sea otter carcasses at Kodiak Island, Alaska, following the Exxon Valdez oil spill. *Marine Mammal Science* 10(4), 492–496. <https://doi.org/10.1111/j.1748-7692.1994.tb00509.x>
- de Oliveira, V. K., Faria, D. M., Cunha, H. A., dos Santos, T.E. C., Colosio, A. C., Barbosa, L. A., Freire, M. C. C., & Farro, A. P. C. (2020). Low genetic diversity of the endangered franciscana (*Pontoporia blainvillei*) in its northernmost, isolated population (FMAIa, Espírito Santo, Brazil). *Frontiers in Marine Science*, 7, 608276. <http://doi.org/10.3389/fmars.2020.608276>
- Epperly, S., Braun, J., Chester, A., Cross, F., Merriner, J., Tester, P., & Churchill, J. H. (1996). Beach strandings as an indicator of at-sea mortality of sea turtles. *Bulletin of Marine Science* 59(2), 289–297.
- Flint, P. L. & Fowler, A. C. (1998). A drift experiment to assess the influence of wind on recovery of oiled seabirds on St Paul Island, Alaska. *Marine Pollution Bulletin*, 36(2), 165–166. [https://doi.org/10.1016/S0025-326X\(97\)00178-1](https://doi.org/10.1016/S0025-326X(97)00178-1)
- Frizzera, F. C., Tosi, C., Pinheiro, H., & Marcondes, M. (2012). Captura acidental de toninha (*Pontoporia blainvillei*) na costa norte do Espírito Santo, Brasil. *Boletim Do Museu de Biologia Mello Leitão*, 29, 81–86.
- Fundação PROZEE/SEAP/IBAMA. (2005). Relatório Final do Censo Estrutural da Pesca Artesanal Marítima e Estuarina nos Estados do Espírito Santo, Rio de Janeiro, Paraná, Santa Catarina e Rio Grande do Sul. Itajaí, 154, Fundação de Amparo à Pesquisa de Recursos Vivos na Zona Econômica Exclusiva/Secretaria Especial de Pesca e Aquicultura da Presidência da República/Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais, Itajaí, SC, Brasil
- Garshelis, D. L. (1997). Sea otter mortality estimated from carcasses collected after the Exxon Valdez Oil Spill. *Conservation Biology*, 11, 905–916. <https://doi.org/10.1046/j.1523-1739.1997.96062.x>
- Geraci, J. R. & Lounsbury, V. J. (2005) *Marine mammals ashore: a field guide for strandings*. National Aquarium in Baltimore, 2005.
- Hammer, Ø., Harper, D. A. T., & Ryan, P. D. (2001). PAST: Paleontological Statistical software package for education and analysis. *Paleontologia Electronica*, 4(1), 1–9. http://palaeo-electronica.org/2001_1/past/issue1_01.htm
- Harris, M. & Wanless, S. (1996). Differential responses of Guillemot *Uria algae* and Shag *Phalacrocorax aristotelis* to a late winter wreck. *Bird Study*, 43(2), 220–230. <https://doi.org/10.1080/00063659609461014>
- Hart, K. M., Mooreside, P., & Crowder, L. B. (2006). Interpreting the spatio-temporal patterns of sea turtle strandings: Going with the flow. *Biological Conservation*, 129(2), 283–290. <https://doi.org/10.1016/j.biocon.2005.10.047>
- Hlady, D. A. & Burger, A. E. (1993). Drift-block experiments to analyse the mortality of oiled seabirds off Vancouver Island, British Columbia. *Marine Pollution Bulletin*, 26(9), 495–501. [https://doi.org/10.1016/0025-326X\(93\)90466-W](https://doi.org/10.1016/0025-326X(93)90466-W)
- ICMBio (2018). Livro Vermelho da Fauna Brasileira Ameaçada de Extinção: Volume II - Mamíferos. Livro Vermelho da Fauna Bras. Ameaçada Extinção.
- Jones, P. H., Monnat, J. Y., Cadbury, C. J., & Stowe, T. J. (1978). Birds oiled during the Amoco Cadiz incident—An interim report. *Marine Pollution Bulletin*, 9(11), 307–310. [https://doi.org/10.1016/0025-326X\(78\)90256-4](https://doi.org/10.1016/0025-326X(78)90256-4)
- Koch, V., Peckham, H., Mancini, A., & Eguchi, T. (2013). Estimating at-sea mortality of marine turtles from stranding frequencies and drifter experiments. *PLoS One*, 8(2), e56776. <https://doi.org/10.1371/journal.pone.0056776>
- Kraus, S. D., Brown, M. W., Caswell, H., Clark, C. W., Fujiwara, M., Hamilton, P. K., Kenney R. D., Knowlton, A. R., Landry, S., Mayo, C. A., McLellan, W. A., Moore, M. J., Nowacek D. P., Pabst, D. A., Read, A. J., & Rolland, R. M. (2005). North Atlantic right whales in crisis. *Science*, 309(5734), 561–562. <https://doi.org/10.1126/science.1111200>
- Lailson-Brito, J., Azeredo, M. A. A., Malm, O., Ramos, R. A., Di Benedetto, A. P. M., & Saldanha, M. F. C. (2002). Trace metals in liver and kidney of the franciscana (*Pontoporia blainvillei*) from the northern coast of Rio de Janeiro State, Brazil. *Latin American Journal of Aquatic Mammals*, 1, 107–114. <https://doi.org/10.5597/lajam00014>
- Lailson-Brito, J., Dorneles, P. R., Azevedo-Silva, C. E., Azevedo, A. D. F., Vidal, L. G., Marigo, J., Bertozzi, C., Zanelatto, R. C., Bisi, T. L., Malm, O., & Torres, J. P. M. (2011). Organochlorine concentrations in franciscana dolphins, *Pontoporia blainvillei*, from Brazilian waters. *Chemosphere*, 84, 882–887. <https://doi.org/10.1016/j.chemosphere.2011.06.018>
- Lailson-Brito, J., Dorneles, P. R., Azevedo-Silva, C. E., Bisi, T. L., Vidal, L. G., Legat, L. N., Azevedo, A. F., Torres, J. P. M., & Malm, O. (2012). Organochlorine compound accumulation in delphinids from Rio de Janeiro state, southeastern Brazilian coast. *Science of The Total Environment*, 433, 123–131. <https://doi.org/10.1016/j.scitotenv.2012.06.030>
- Lakes Environmental (2010). WRPLOT View - Freeware wind rose plots for meteorological data; [cited 29 Sep 2021]. Available from <http://www.weblakes.com/products/wrplot/index.html>

- Manhães, B. M. R., Vannuci-Silva, M., Brião, J. A., Guari, E. B., Botta, S., Colosio, A. C., Ramos, H. G. C., Barbosa, L. A., Cunha, I. A. G., Azevedo A. F., Cunha, H. A. Bisi, T. L., & 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. <https://doi.org/10.1016/j.scitotenv.2021.150196>
- Marcondes, M. C. C., Angeli, M., Fontes, F., Palazzo-Jr, J. T., Campos, R., Dapper, C., & Cremer, M. (2018). Report on franciscana fisheries interaction in FMA Ia, Brazil. Paper SC/67B/SM/03 presented to the Scientific Committee, International Whaling Commission, Slovenia, April-May 2018.
- Marcondes, M. C. C., Colosio, A. C., Ramos, H. G. C., Cremer, M. J., Palazzo-Jr, Barbosa, L., Farro, A. P. C., Andriolo, A., Dapper, C. G., & Campos, O. C. (2020). Threats to Franciscana in FMA Ia. Paper SC/68B/CMP/01 presented to the Scientific Committee, International Whaling Commission, Virtual Meeting, May 2020.
- Mayorga, L. F. S. P., Vanstreels, R. E. T., Bhering, R. C. C., Mamede, N., Costa, L. M. B., Pinheiro, F. C. F., Reis, L. W. D., Trazzi, A., Meirelles, W. L. C., Ribeiro, A. M., & Siciliano, S. (2020). Strandings of cetaceans on the Espírito Santo coast, southeast Brazil, 1975–2015. *ZooKeys*, 948, 129. <https://doi.org/10.3897/zookeys.948.50468>
- Moore, J. E., & Read, A. J. (2008). A Bayesian uncertainty analysis of cetacean demography and bycatch mortality using age at death data. *Ecological Applications*, 18(8), 1914-1931. <https://doi.org/10.1890/07-0862.1>
- Moore, M. J., Mitchell, G. H., Rowles, T. K., & Early, G. (2020). Dead cetacean? Beach, bloat, float, sink. *Frontiers in Marine Science*, 7, 333. <https://doi.org/10.3389/fmars.2020.00333>
- Nero, R. W., Cook, M., Coleman, A. T., Solangi, M., & Hardy, R. (2013). Using an ocean model to predict likely drift tracks of sea turtle carcasses in the north central Gulf of Mexico. *Endangered Species Research*, 21(3), 191-203. <https://doi.org/10.3354/esr00516>
- Netto, R. F. & Siciliano, S. (2007). Contribuição ao conhecimento da distribuição da toninha *Pontoporia blainvillei* (Gervais & d'Orbigny, 1844) no estado do Espírito Santo, sudeste do Brasil. *Boletim do Museu de Biologia Mello Leitão*, 21, 35-45.
- Ott, P. H., Secchi, E. R., Moreno, I. B., Danilewicz, D., Crespo, E. A., Bordino, P., Ramos, R., Di Benedetto, A. P., Bertozzi, C., Bastida, R., Zanelatto, R., Perez, J. E., & Kinas, P. G. (2002). Report of the Working Group on Fishery Interactions. Special Issue on the Biology and Conservation of franciscana. *Latin American Journal of Aquatic Mammals*, 1(1): 55-64. <https://doi.org/10.5597/lajam00008>
- Peltier, H., Dabin, W., Daniel, P., Van Canneyt, O., Dorémus, G., Huon, M., & Ridoux, V. (2012). The significance of stranding data as indicators of cetacean populations at sea: modelling the drift of cetacean carcasses. *Ecological Indicators*, 18, 278-290. <https://doi.org/10.1016/j.ecolind.2011.11.014>
- Peltier, H., Authier, M., Dabin, W., Dars, C., Demaret, F., Doremus, G., Canneyt, O. V., Laran, S., Mendez-Fernandez, P., Spitzza, J., Daniel, P., & Ridoux, V. (2020). Can modelling the drift of bycaught dolphin stranded carcasses help identify involved fisheries? An exploratory study. *Global Ecology and Conservation*, 21, e00843 <https://doi.org/10.1016/j.gecco.2019.e00843>
- Prado, J. H., Mattos, P. H., Silva, K. G., & Secchi, E. R. (2016). Long-term seasonal and interannual patterns of marine mammal strandings in subtropical western South Atlantic. *PLoS One*, 11(1), e0146339. <https://doi.org/10.1371/journal.pone.0146339>
- Prado, J. H. F., Secchi, E. R., & Kinas, P. G. (2013). Mark-recapture of the endangered franciscana dolphin (*Pontoporia blainvillei*) killed in gillnet fisheries to estimate past bycatch from time series of stranded carcasses in southern Brazil. *Ecological Indicators*, 32, 35-41. <https://doi.org/10.1016/j.ecolind.2013.03.005>
- Punt, A. E. & Wade, P. R. (2012). Population status of the eastern North Pacific stock of gray whales in 2009. *Journal of Cetacean Research Management*, 12(1), 15–28.
- QGIS Development Team (2020). QGIS Geographic Information System. Open Source Geospatial Foundation Project. <https://qgis.org>.
- Rosas, F. C. W., Monteiro Filho, E. L. A., & Oliveira, M. R. (2002). Incidental catches of franciscana (*Pontoporia blainvillei*) on the southern coast of São Paulo State and the coast of Paraná State, Brazil. *Latin American Journal of Aquatic Mammals*, 1(1): 161-168. <https://doi.org/10.5597/lajam00020>
- RStudio Team (2019). RStudio: Integrated Development for R. RStudio, Inc., Boston, MA URL: <http://www.rstudio.com/>
- Santos, B. S., Friedrichs, M. A., Rose, S. A., Barco, S. G., & Kaplan, D. M. (2018a). Likely locations of sea turtle stranding mortality using experimentally-calibrated, time and space-specific drift models. *Biological Conservation*, 226, 127-143. <https://doi.org/10.1016/j.biocon.2018.06.029>
- Santos, B. S., Kaplan, D. M., Friedrichs, M. A., Barco, S. G., Mansfield, K. L., & Manning, J. P. (2018b). Consequences of drift and carcass decomposition for estimating sea turtle mortality hotspots. *Ecological Indicators*, 84, 319-336. <https://doi.org/10.1016/j.ecolind.2017.08.064>
- Secchi, E. R., Ott, P. H., & Danilewicz, D. (2003). Effects of fishing by-catch and conservation status of the franciscana dolphin, *Pontoporia blainvillei*. In N. Gales & M. Hindell (Eds.), *Marine Mammals: Fisheries, Tourism and Management Issues* (pp. 174-191). CSIRO Publishing.
- Siciliano S. (1994). Review of small cetaceans and fishery interactions in coastal waters of Brazil. *Report of the International Whaling Commission Special Issue*, 15, 241–250.
- Sucunza, F., Danilewicz, D., Ott, P. H., Neves, M., Berchieri, N., Farro, A. P., Martins, A., & Zerbini, A. N., (2020). Population size and IUCN red listing of the isolated northern population of the franciscana (*Pontoporia blainvillei*). Paper SC/68B/ASI/05 presented to the Scientific Committee, International Whaling Commission, Virtual Meeting, May 2020. [Available from, < <https://archive.iwc.int/>>].
- Teixeira, C. E., Lessa, G. C., Cirano, M., & Lentini, C. A. (2013). The inner shelf circulation on the Abrolhos Bank, 18°S, Brazil. *Continental Shelf Research*, 70, 13-26. <https://doi.org/10.1016/j.csr.2013.09.003>
- Wells, R. S., Allen, J. B., Lovewell, G., Gorzelany, J., Delynn, R. E., Fauquier, D. A., & Barros, N. B. (2014). Carcass recovery rates for resident bottlenose dolphins in Sarasota Bay, Florida. *Marine Mammal Science*, 31(1), 355-368. <https://doi.org/10.1111/mms.12142>

Williams, R., Gero, S., Bejder, L., Calambokidis, J., Kraus, S. D., Lusseau, D., Read, A. J., & Robbins, J. (2011). Underestimating the damage: interpreting cetacean carcass recoveries in the context of the Deepwater Horizon/BP incident. *Conservation Letters*, 4(3), 228-233. <https://doi.org/10.1111/j.1755-263X.2011.00168.x>

Young, C., Eguchi, T., Ames, J. A., Staedler, M., Hatfield, B. B., Harris, M., & Golson Fisch, E. A. (2019). Drift and beaching

patterns of sea otter carcasses and car tire dummies. *Marine Mammal Science*, 35(4), 1512-1526. <https://doi.org/10.1111/mms.12609>

Zerbini, A. N., Secchi, E., Crespo, E., Danilewicz, D., & Reeves, R. (2017). *Pontoporia blainvillei* (errata version published in 2018). *The IUCN Red List of Threatened Species 2017*: e.T17978A123792204. <https://doi.org/10.2305/IUCN.UK.2017-3.RLTS.T17978A50371075.en>