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INTERNATIONAL WHALING COMMISSION

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Abstract

The franciscana (*Pontoporia blainvillei*) is endemic of coastal waters from Brazil (18°25'S) to Argentina (42°10'S). The species is regarded as the most threatened small cetacean in the western South Atlantic Ocean due to high bycatch levels and habitat degradation. The franciscana is listed as Vulnerable in the IUCN Red List of Threatened Species. Recent analysis of mtDNA suggested that individuals found in the species' northern range (Brazilian State of Espírito Santo, ES) represent an isolated population. Aerial surveys following design-based line transect methods were conducted on March 2018 to assess distribution and estimate abundance of franciscanas off ES. A total of 2,986 km on sighting effort was carried out from the shore up to 16.5 km from the coast between Itaúnas (18°25'S) and Presidente Kennedy (21°17'S), north and south ES boundaries respectively. A total of 17 franciscana groups were seen (average group size = 2.41, CV=0.14) in coastal habitats (average distance from the shore = 3.3 km, SE = 2.3 km, range = 0.4 - 8 km). Abundance corrected for visibility and group size biases was estimated at 595 individuals (CV = 0.44, 95% CI = 203 - 1,200). Results suggest that, at least during the summer, franciscanas in ES are distributed in very coastal habitats between Conceição da Barra (18°35'S) and Santa Cruz (19°56'S). This is probably the smallest and the one presenting the

most restricted range among all franciscana populations. The estimated abundance indicate that the ES population qualifies for listing as "Endangered" under the IUCN Red List criterion C2a(ii) because of the small size (less than 2,500 mature individuals) and because of an inferred decline in abundance as a consequence of bycatch and habitat degradation. In order to reduce threats to this population management actions are urgently needed.

Introduction

The franciscana (*Pontoporia blainvillei*), also known as toninha and formerly referred to as the La Plata dolphin, is the only extant member of the family Pontoporiidae (Society for Marine Mammalogy Committee on Taxonomy 2018). The species is endemic of the southwestern Atlantic Ocean waters of Brazil, Uruguay and Argentina (Crespo 2009). Franciscanas occur in coastal and estuarine habitats typically shallower than 30 m, between Itaúnas, Brazil (18°25'), and Golfo San Matías, Argentina (42°10') (Crespo et al. 1998, Siciliano et al. 2002, Danilewicz et al. 2009). There are two gaps in the northern range of the franciscana distribution (Siciliano et al. 2002), one, at about 23°S, subdivides the species into two Evolutionary Significant Units (south and north ESU; Secchi et al. 1998, Cunha et al. 2014). Franciscanas within the northern ESU likely form two demographically isolated populations separated by a latitudinal gap in distribution of approximately 200 km (Fig. 1, Siciliano et al. 2002, Danilewicz et al. 2012, Cunha et al. 2014, Amaral et al. 2018).

The franciscana is considered one of the most threatened cetacean species in South America mainly due to bycatch (i.e. mortality and injury due to incidental fishing) in gillnet fisheries (Ott et al. 2002, Secchi et al. 2003a, Danilewicz et al. 2010a, Secchi 2010). Bycatch is a worldwide recognized threat to marine mammal populations since the 1970s (*see* Perrin et al. 1994, Read et al. 2006, Read 2008, Reeves et al. 2013). Mortality during fishing activities, especially gillnets and trammel nets, is believed to be unsustainable and have been reported along most of the franciscana's range for the last 70 years (Van Erp 1969, Ott et al. 2002, Secchi et al. 2003a). Habitat degradation in its multiple forms have become better documented and nowadays is considered as another important threat to the survival of franciscana populations (Yogui et al.

2010, Lailson-Brito et al. 2011, Alonso et al. 2012, De la Torre et al. 2012, Lavandier et al. 2016). The species is currently listed as "Vulnerable" in the IUCN Red List of Threatened Species (Zerbini et al. 2017) and "Critically Endangered" by the Brazilian Government (MMA 2014).

In order to guide conservation and management actions the franciscana range was divided into four zones known as 'Franciscana Management Areas' (FMAs) (Secchi et al. 2003b): two in Brazil (FMA I and FMA II), one shared between Brazil and Uruguay (FMA III), and one in Argentina (FMA IV) (Secchi et al. 2003b, Anonymous 2015). Studies on genetics, morphology, distribution, and population parameters provide evidence for population substructure within each FMA (Secchi et al. 1998, Crespo et al. 2010, Mendez et al. 2010, Barbato et al. 2013, Cunha et al. 2014) and call for a reassessment of the FMA boundaries in order to enhance franciscana conservation and management actions.

FMA I encompasses the latitudinal range of the northern ESU, including Espírito Santo (ES) State and northern Rio de Janeiro (RJ) State in southeastern Brazil. A recent re-evaluation of franciscana population structure based on the analysis of mtDNA control region sequences proposed that individuals from FMA I comprise two distinct populations, one in the northern coast of ES (referred to as FMA Ia) and the other along the northern coast of RJ (referred to as FMA Ib) (Cunha et al. 2014). Demographic isolation within FMA I may represent an additional challenge for the conservation of the franciscana, especially if anthropogenic threats are greater for smaller units within more restricted habitats.

FMA I is the least known franciscana stocks. Aerial surveys conducted off FMA I indicate that franciscanas occur in relatively low numbers in the area (Moreno et al. 2003, Danilewicz et al. 2012). During an abundance aerial survey conducted in 2012, more than 1,000 km were surveyed but just three franciscana groups were recorded. Neither of these groups were recorded during on effort transect lines (Danilewicz et al. 2012). Although no quantitative bycatch data are available for FMA Ia, reports from the 1990s indicate that the gillnet fisheries along the ES coast overlaps with the franciscana preferred habitat and bycatch of mature and immature franciscanas has been documented in these fisheries (Siciliano 1994). In 2016 the International Whaling Commission (IWC) adopted the first Conservation Management Plan (CMP) for a small cetacean species (IWC 2016). The CMP for Franciscana has the main objective of protecting franciscana habitat and minimizing anthropogenic threats, particularly bycatch. In addition, monitoring of abundance and bycatch, and development of protected areas are included among the CMPs priority actions (IWC 2016). Understanding gaps in distribution along the franciscana range has been recommended as a priority by local and international organizations including the governments of Brazil and Argentina, the International Union for Conservation of Nature (IUCN), and the IWC (Reeves et al. 2003, IWC 2005, ICMBio 2011, Anonymous 2015, IWC 2016).

In this study, aerial surveys were conducted along the range of FMA Ia to estimate abundance and to assess distribution, in particular with respect to the distributional gap between FMA Ia and FMA Ib. It is expected that results from these surveys will address many of the recommendations referred to above and will enhance franciscana conservation in these areas.

Material and Methods

Line-transect aerial surveys (Buckland et al. 2001) were conducted on 17-31 March 2018 between the northern (18^{o}25'S) and southern (21^{o}17'S) boundaries of the ES (Fig. 1). This area includes the whole latitudinal range of FMA Ia as well as the gap in the distribution of the franciscana between FMA Ia and FMA Ib (Fig. 1). A set of 105 parallel transect lines with 16.5 km of length and spaced by ~2.5 km was placed perpendicular to the coast line. This design makes no assumption about the spatial distribution of the animals, maximizes equal sampling probability, and, if needed, allows for poststratification of the study area.

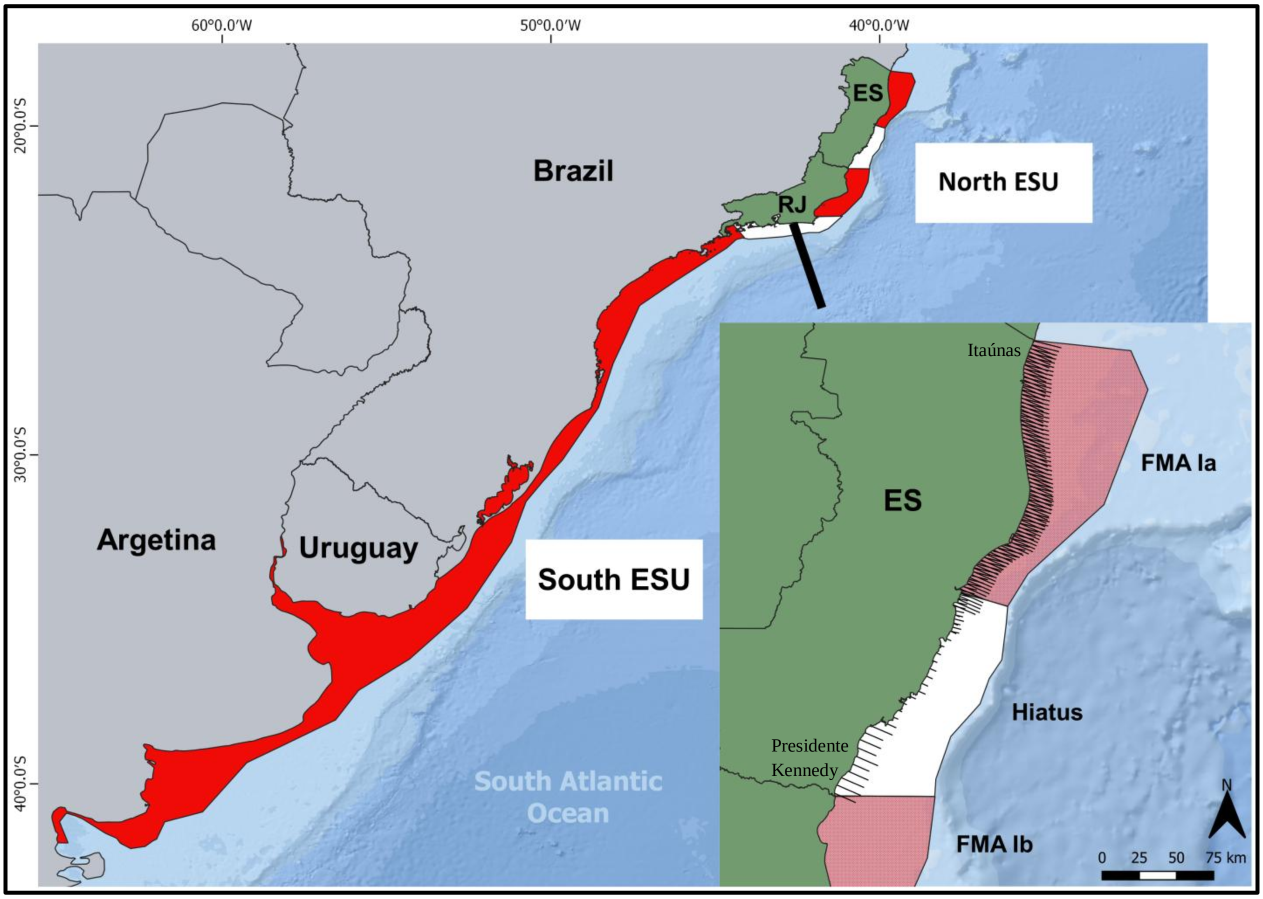

Fig. 1. *large* Map indicative of the franciscana distribution (red areas), the two gaps in the species distribution (white areas) and the two Evolutionary Significant Units (ESU) of the franciscana (boundary pointed by the rectangle). *small* Map of the study area and total realized effort during aerial surveys conducted off the Espírito Santo State (ES) on March/2018. This area encompasses the latitudinal range of the Franciscana Management Area (FMA) Ia, and the hiatus in the distribution of the franciscana between FMA Ia and FMA Ib. RJ = Rio de Janeiro State.

Post-stratification of the study area was carried out by geographic region to accommodate differences in encounter rate (Buckland et al. 2001). Three survey strata were proposed: (1) FMA Ia north stratum (18°36'S - 19°29'S), (2) FMA Ia south stratum (19°29'S - 19°57'S), and (3) the distributional gap in southern ES "Hiatus stratum" (19°57'S - 21°18'S). Total planned effort within the three survey strata corresponded to 1,512 km. Total effort by unit of area was equal to 0.38 within FMA Ia north stratum and equal to 0.37 within FMA Ia south stratum.

Searching for franciscana groups was conducted from a high-wing, twin-engine *Aerocommander 500B* aircraft at an approximately constant altitude of 150 m (500 ft) and a speed of 170-200 km/h (~90-110 knots). The aircraft had four observation positions (two on each side of the plane), with bubble and flat windows available for front and rear observers, respectively. Flights were generally conducted under relatively good weather and visibility conditions (Beaufort sea state <= 3). The searching team consisted of four observers, who recorded environmental data (*e.g.*, Beaufort sea state, glare) at the beginning of each transect and whenever conditions changed. The beginning and the end of the transects were informed to the observers by the pilot. All observers were independent as they were visually and acoustically isolated and did not communicate with each other during the flights. When a group of franciscanas was detected, the size of the group and additional information such as presence of calves in the groups and Beaufort sea state were recorded. The declination angle between the horizontal and the sighting was obtained using an inclinometer when the group passed abeam of the plane. Data were recorded on audio digital recorders. Every record was time-referenced based on a digital watch synchronized to the GPS. This allowed observations to be geo-referenced.

Additional transit lines were proposed in areas of high density of franciscanas to increase sample size for the estimation of detection probability. All sightings recorded in these lines were used, along with “on effort” sightings, for the estimation of detection probability. Only sightings detected while flying actual transect lines were used to estimate density and abundance.

Analytical Methods

All sightings recorded in either FMA Ia north and south strata were used to assess distribution patterns of franciscanas in FMA Ia. For each franciscana group, bathymetry data were extracted from the ETOPO1 1 Arc-Minute Global Relief Model (Amante and Eakins 2009*)* and distance from the shore was calculated using *GPS TrackMaker Pro* software*.* A buffer zone was created from the northern limit of the FMA Ia north stratum to the southern limit of the FMA Ia south stratum with a width equal to the maximum distance from the shore that a franciscana group was recorded and its area was assumed to represent the area of occurrence of franciscanas in FMA I.

Detection probability (P) was estimated using conventional distance sampling methods (Buckland et al. 2001). To increase sample size, sighting data from other franciscana surveys carried out by the same observers off the same study area were combined to better estimate detection probability in this study. Exploratory analyses indicated that ungrouped data resulted in better model fits, and due to the relatively small sample size (n = 64) only the half-normal detection function without covariates or series expansions was proposed to fit perpendicular distance data (Buckland et al. 2001).

A nonparametric bootstrap was used to estimate detection probability, encounter rate, group size, density, abundance, and variance (Manly 2004, Williams and Thomas 2009). Analyses were performed using a set of customized functions in R (Laake et al. 2018, R Development Core Team 2018). Bootstrap resample datasets (n = 10,000) were generated by sampling with replacement from the replicate lines within each stratum, ensuring that the number of lines in the resample equals the number in the original data set and that at least one detection be included in the resample dataset. For each resample dataset, mean group size and mean detection probability were estimated globally, while encounter rate and density were estimated by stratum. Density uncorrected for visibility bias and group size bias (D_u) was then estimated for each resample for each stratum. Density for the whole survey area (FMA Ia) was computed as the weighted average of the strata for each bootstrap replicate (Williams and Thomas 2009).

A correction factor for visibility bias (Marsh and Sinclair 1989) and groups size bias computed to correct abundance estimates of franciscana from aerial survey data (CF = 4.42, CV = 0.04; Sucunza et al. 2020, this meeting) was applied to correct the uncorrected estimate (D_u). Assuming a normal distribution with a mean equal to 4.42 and standard deviation of 0.17, a vector with 10,000 values was created and, for each bootstrap resample, the corrected density estimate (D_c) was computed by multiplying the uncorrected estimate (D_u) by one value of the vector. Abundance was then estimated as the product of correct density and the total area.

Estimates of detection probability, encounter rate, group size and density (D_u and D_c) were taken as the mean of the bootstrap resample estimates (Buckland et al. 1997), and coefficients of variation (CVs) were calculated as standard deviation of the bootstrap estimates divided by the mean. Confidence intervals were obtained using the percentile method (Buckland et al. 2001).

Results

A total of 2,986 km of sighting effort was conducted between Itaúnas (18°25'S) and Presidente Kennedy (21°17'S) (Fig.1), and a total of 17 franciscana groups (on effort = 14, off effort = 3) were sighted in both FMA Ia north and FMA Ia south strata (Fig. 2). No sightings were recorded in the Hiatus stratum. Realized effort was greater than planned effort because additional lines were placed to obtaining sighting data for improving estimates of detection probability. Franciscana groups were sighted within a maximum of 8 km of distance from shore (average = 3.3 km, SE = 2.3 km, range = 0.4 - 8 km). Assuming 8 km as the maximum distance from the shore that franciscanas occurs off FMA Ia, at least during the summer, the area of occurrence was estimated at 1,400 km^2. Group size range from 1 to 6 with a median of 2 individuals per group, and a mean averaged over bootstrap resamples of 2.41 (CV = 0.14, 95% CI = 1.82 - 3.06).

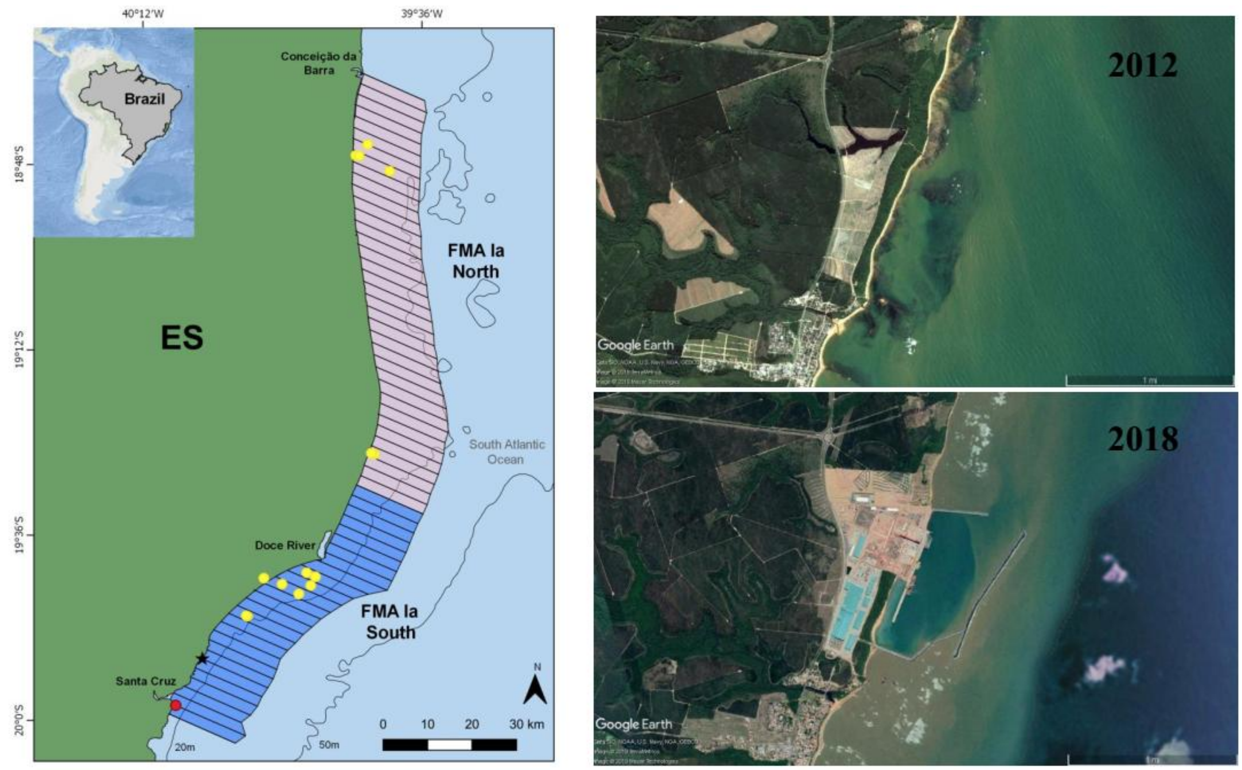

Fig. 2. *left*. Franciscana groups sighted during aerial surveys conducted in 2018 (yellow dots) off the Espírito Santo State (ES), and survey effort used for abundance estimation. The red circle indicates a franciscana group recorded during aerial surveys conducted in 2012 off the ES coast (Danilewicz et al. 2012) and the star indicates the location where a shipyard was built after the 2012 surveys. *right*. Google Earth images of the area before (top) and after (bellow) the construction of the shipyard indicated by the star in the left panel.

The realized effort between Conceição da Barra (18°35'S) and Santa Cruz (19°56'S) (Fig. 2) used for abundance estimation is reported in Table 1. The mean detection probability was 0.68 (CV = 0.10, 95% IC = 0.56 - 0.83) (Fig. 3). Mean uncorrected density averaged over bootstrap resamples, was 0.05 individuals/km^2 (CV = 0.44, 95% CI = 0.02 - 0.11). Density corrected for visibility bias and group size bias ($\widehat{Dc} = \widehat{D_B}$ * FC) was estimated at 0.23 individuals/km^2 (CV = 0.44, 95% CI = 0.08 - 0.47). This estimate corresponds to a total abundance of 595 individuals (CV = 0.44, 95% CI = 203 - 1,200) in FMA Ia (Table 2).

Table 1. Survey strata, covered area, number of transects and aerial survey effort used for abundance estimation of franciscanas off Espírito Santo State, Brazil.

Stratum	Area (km^2)	#Transects	Effort (km)
(1) FMA Ia north	1,444	33	544
(2) FMA Ia south	1,115	25	412
(3) Hiatus	-	30	274
Total	2559	88	1,230

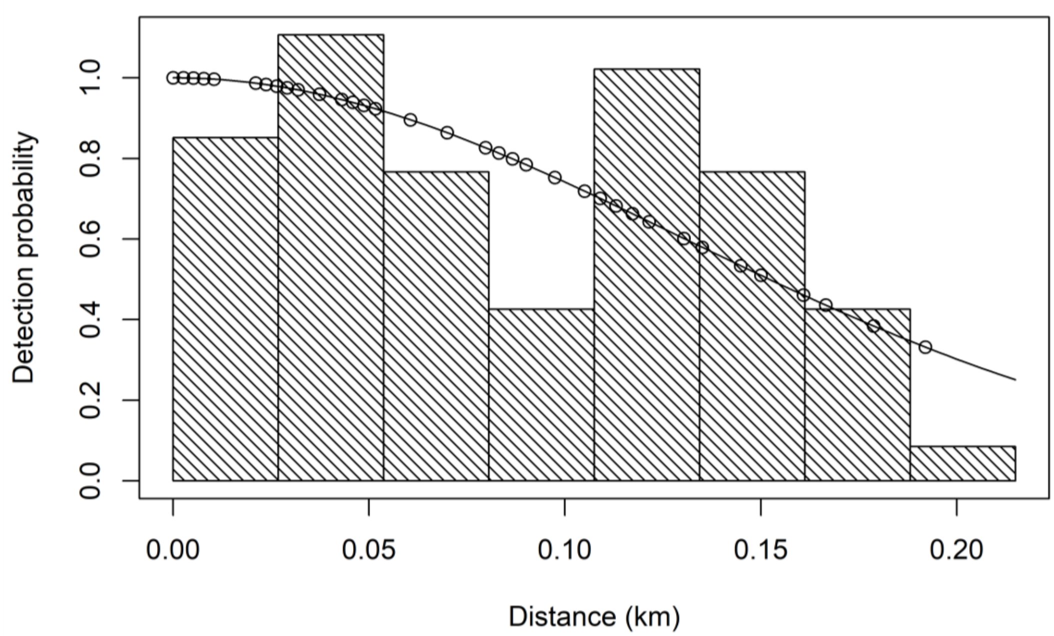

Fig. 3. Half-normal detection function plot with the original distance dataset.

Table 2. Density estimates of franciscanas in Espiríto Santo State, southeastern Brazil, through the study period. Franciscana Management Area Ia (FMA Ia). FMA Ia south and FMA Ia north correspond to geographic regions (i.e. strata) used for density estimation. Coefficient of variation (CV). n = number of sightings used for abundance estimation, ER = number of individuals/km, $\widehat{Si}$ = estimated average group size (averaged over all bootstrap resamples), $\widehat{D_B}$ = estimated uncorrected density of individuals/km^2 (averaged over all bootstrap resamples), $\widehat{Dc}$ = estimated density of individuals/km^2 corrected for visibility bias and group size bias (averaged over all bootstrap resamples), $\widehat{Nc}$ = abundance corrected for visibility bias and group size bias (averaged across all bootstrap replicates), CI = confidence intervals.

Strata	n	ER	$\widehat{Si}$	$\widehat{Du}$	$\widehat{Dc}$	$\widehat{Nc}$	95% IC
FMA Ia north	4	0.004 (0.57)	2.41 (0.14)	0.03 (0.61)	0.14 (0.61)	200(0.61)	69 - 503
FMA Ia south	4	0.01 (0.55)	2.41 (0.14)	0.08 (0.58)	0.35 (0.58)	395 (0.58)	81 - 938
FMA Ia	8	0.006 (0.41)	2.41 (0.14)	0.05 (0.44)	0.23 (0.44)	595 (0.44)	203 - 1,200

Discussion

The present study indicates that FMA Ia population is probably the smallest and the one presenting the most restricted range (maximum of 173 km of coastline between Conceição da Barra [18°35'S] and Santa Cruz [19°56'S]) among all franciscana populations. This population is completely isolated from all other populations, by a distributional gap of at least 200 km of coast, reinforcing the evidence for its demographic isolation (Siciliano et al. 2002, Danilewicz et al. 2012, Cunha et al. 2014, Amaral et al. 2018).

Habitat degradation in the form of overfishing, pollution by debris, chemical and biological agents, noise and disturbance caused by ongoing shipping as well as coastal construction among other human activities, is considered a major threat for the conservation of the franciscana along its entire range (Yogui et al. 2010, Lailson-Brito et al. 2011, Alonso et al. 2012, De la Torre et al.

2012, Lavandier et al. 2016). Recently, one of the most catastrophic environmental disaster of Brazil caused by the collapse of a tailing dam in the Doce river discharged millions of cubic meters of metal-contaminated slurry into ES coastal waters (Hatje et al. 2017, Magris et al. 2019). The plume of pollutant sediments from the dam collapse spread towards the area with the greatest density in the range of the franciscana (e.g., compare Fig. 2 above with Fig. 9 in Magris et al. 2019). The effect of the collapse of the dam on franciscanas in FMA Ia is still unknown and may contribute to a long-term population reduction.

Habitat degradation likely causes habitat loss and contributes to shrinking the habitat of the franciscana in ES. During aerial surveys conducted in 2011 franciscana groups were recorded as far south as Santa Cruz (19^{o}58') (Danilewicz et al. 2012), but in the present surveys, franciscanas were not detected that far south (Fig. 2). The closest sighting was about 20 km north of this location despite an increase in up to 15 times in sighting effort in the area and an expected increase in observer experience to detect franciscanas in the 2018 surveys when compared to 2011. It is worth noting that during this period a large shipyard (*Jurong Aracruz*) was built near Santa Cruz (Fig. 2) in response to the growing activities of the offshore oil exploration industry in the Brazilian pre-salt region. Construction of this shipyard increased ship traffic and potentially altered an array of features that typify the habitat of the franciscana (Pinedo et al. 1989, Bordino et al. 1999, Danilewicz et al. 2009, Amaral et al. 2018). Although this case may be viewed as merely speculative since a cause-consequence effect is difficult to be established, it serves as a potential example of the effect that habitat modification can have on franciscana populations. Erosion of habitat quality associated with shrinking available habitat would increase the exposure of individual dolphins to human impacts and thus impinge the conservation of the franciscana.

While the threats from habitat degradation are extensive and complex, mortality due to bycatch in gillnets is recognized as the major pressure on the long-term viability of franciscana populations (e.g. Kinas 2002, Ott et al. 2002, Secchi 2006). Incidental mortality of this species in gillnets and other types of fishing gear have been documented since 1940 in Uruguay (Van Erp 1969), and is currently reported for almost all areas where the franciscana habitat overlaps with gillnetting fishing grounds (Corcuera 1994, Crespo et al. 1994, Siciliano 1994, Secchi et al. 1997, Di Beneditto et al. 1998, Bertozzi and Zerbini 2002, Ott et al. 2002, Rosas et al. 2002, Cremer et al. 2013). Mortality due to bycatch is considered unsustainable and will likely drive the species to extinction if no management actions are effectively enforced (Kinas 2002, Kinas et al. 2002, Secchi 2006, Danilewicz et al. 2010b).

Data from the 1990's reports fishing communities along the ES coast captured franciscanas in various stages of maturity, including adult females and calves, and operated well within the preferred habitat of the species (Siciliano 1994). However, no statistically valid estimates of bycatch numbers had been computed at that time. New fisheries monitoring data have become available since the late 2010s. They show an apparent increase in fishing effort through most fishing communities of ES, and they also suggest mortality in gillnets continues to occur (Frizzera et al. 2012, Marcondes et al. 2018). Yet, quantitative estimates of bycatch mortality are needed to better understand the impact of fisheries on the small FMA Ia franciscana population.

Although monitoring population abundance and trends provides key information to plan effective management actions, it is remarkable difficult to detect declines in population abundance before the population has been severely depleted, especially for small populations (Gerrodette 1987, Wade and Gerrodette 1992, Taylor and Gerrodette 1993, Fujiwara 2001, Taylor et al. 2016). In this sense, an attempt is made here to assess what levels of bycatch mortality could be sustainable given the present estimate of population size. An internationally recognized assessment method, the potential biological removal (PBR) (Wade 1998, Taylor et al. 2000) can be calculated as a reference for sustainable bycatch. PBR is calculated as the product between the minimum population size (N_{min} = 369, the 20th percentile of the abundance estimated), 0.5 the maximum net population growth rate (*R*max = 0.04, default value used for cetaceans, Wade 1998) and a recovery factor (F_R) that allow to account for uncertainty in population status. F_R was defined equal 0.1 because of the proposed "Endangered" conservation status of the FMA Ia population (Wade 1998). Following PBR for the ES franciscana population would be computed as 0.74, suggesting that the mortality of one franciscana per year due to bycatch in gillnets could lead to depletion of this isolated population.

The Brazilian fishing regulation INI 12/2012 (MPA/MMA 2012) was established to regulate gillnet fisheries and reduce bycatch of the franciscana by banning fishing of motorized boats and industrial boats (i.e., >20 gross tonnage) within one and three nautical miles (nm) from the coast, respectively. These protected zones account for, respectively, 35% and 79% of the total sightings recorded off FMA Ia. These numbers suggest that if that full compliance of the INI 12/2012 along the ES coast would likely substantially reduce bycatch and result in increased protection to the species. Therefore, management actions should be directed to guarantee fully compliance by fishing communities.

Continued population monitoring is crucial to better understand the impacts of bycatch as well as other human-caused mortality on the long-term population viability of franciscanas inhabiting the ES coastal waters. It is important to note that PBR appropriately include all human-caused mortality, and that although PBR does not provide evidence of decline in population numbers, it flags populations that may be experiencing unsustainable mortality and aims to start reducing mortality before the population has been depleted (Wade 1998, Taylor et al. 2000). PBR, however, should not substitute proper population viability analysis (Gilpin and Soule 1986) that allow to incorporate factors known to affect especially small and threatened populations, such as environmental and demographic stochasticity.

Based on the estimated abundance of 595 (CV = 0.44) individuals and assuming an even sex ratio (Brownell 1984) and an even proportion of mature and immature animals in the population, it is expected that no more than 297 are mature individuals and no more than 148 are mature females. Under these circumstances, the FMA Ia population qualifies for listing as "Endangered" under the IUCN Red List criterion C2a(ii) because of the small size (less than 2,500 mature individuals) and because of an inferred decline in abundance as a consequence of bycatch and habitat degradation. While bycatch has not been estimated, increasing fishing effort in coastal waters of ES in recent years (Marcondes et al. 2018) suggests that mortality has probably also increased. In addition, habitat degradation due to expansion of human occupation along the coast of ES in the last few years has also increased (Pinheiro et al. 2019) so threats to this species continues in higher levels than in the past. The low abundance of franciscanas in FMA Ia highlights the higher risk of extinction of this population as it qualifies for a higher threat category than the species as a whole, which is currently listed as "Vulnerable" (Zerbini et al., 2017).

Conclusions

The information presented above suggests that the demographically isolated franciscana population of FMA Ia should be listened as "Endangered" under the IUCN Red List Categories and Criteria (IUCN 2012). In order to reduce threats to this population management actions are needed. An important one would be to reduce gillnet fishing effort or reduce the spatial overlap between franciscanas and gillnets. Although the current gillnet fishing regulations INI 12/2012 represents an important legal framework to reduce bycatch, it is necessary to enforce the fishing ban areas to effectively evaluate the conservation impact of these regulations. New data on abundance, distribution and bycatch mortality will allow to continue monitoring the ES population status and refine existing management actions or plan for future ones.

Distribution models could be used to assess the effectiveness of temporal and/or spatial area closure with an increase in survey effort and franciscana sighting data. In addition, levels of mortality due to chemical pollution, ship disturbance, noise and other human activities must be quantitatively evaluated. Habitat degradation is potentially shrinking available habitats for franciscanas in ES, increasing the exposure of individuals to threats and adding to the probability that mortality in fisheries is unsustainable. Clearly, additional conservation efforts are needed to minimize the risk of extinction of the smallest and northernmost franciscana population.

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References

Alonso, M. B., M. L. Feo, C. Corcellas, *et al.* 2012. Pyrethroids: A new threat to marine mammals? Environmental International 47: 99-106.

Amante, C. and B. W. Eakins. 2009. ETOPO-1 1 arc-minute global relief model: Procedures, data source and analysis. U.S. Department of Commerce, NOAA Technical Memorandum NESDIS NGDC-24. 19p.

Amaral, K. B. do, Danilewicz, D., Zerbini, A. et al. 2018. Reassessment of the franciscana Pontoporia blainvillei (Gervais & d'Orbigny, 1844) distribution and niche characteristics in Brazil. Journal of Experimental Marine Biology and Ecology 508:1-12.

Anonymous. 2015. Report of the VIII Workshop for the Research and Conservation of the Franciscana dolphin (*Pontoporia blainvillei*) in the southwestern Atlantic. UNEP/CMS, São Francisco do Sul, Brazil. 25p.

Barbato, B. H. A., E. R. Secchi, A. P. M. Di Beneditto, et al. 2013. Geographical variation in franciscana (*Pontoporia blainvillei*) external morphology. Journal of the Marine Biological Association of the United Kingdom 92:1645-1656.

Bertozzi, C. P. and A. N. Zerbini. 2002. Incidental mortality of Franciscana (*Pontoporia blainvillei*) in the artisanal fishery of Praia Grande, São Paulo State Brazil. Latin American Journal of Aquatic Mammals 1:153-160.

Bordino, P., G. Thompson and M. Iñíguez. 1999. Ecology and behaviour of the franciscana (*Pontoporia blainvillei*) in Bahía Anegada, Argentina. Journal of Cetacean Research and Management 1:213-222.

Brownell R. L. Jr. 1984. Review of reproduction in platanistid dolphins. Report of the International Whaling Commission 6, 149–158.

Buckland, S. T., K. P. Burnham and N. H. Augustin. 1997. Model selection: An integral part of inference. Biometrica 53:603-618.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of wildlife populations. Oxford University Press.

Committee on Taxonomy. 2018. List of marine mammal species and subspecies. Society for Marine Mammalogy. Available from www.marinemammalscience.org. Accessed 25 July 2019.

Corcuera, J. 1994. Mortality of *Pontoporia blainvillei* in Northern Buenos Aires Province: the threat of small fishing camps. Pages 291-294 *in* Gillnets and cetaceans: Incorporating the proceedings of the symposium and workshop on the mortality of cetaceans in passive fishing nets and traps, eds. Perrin, W. F., G. P. Donovan and J. Barlow. International Whaling Commission, Special Issue 15.

Cremer, M. J., C. M. Sartori, A. C. Holz, B. Schulze, N. Z. dos Santos, A. K. de M. Alves and R. L. Paitach. 2013. Franciscana strandings on the north coast of Santa Catarina State and insights into birth period. Biotemas 26:133-139.

Crespo, E. A., J. F. Corcuera and A. L. Cazorla. 1994. Interactions between marine mammals and fisheries in some coastal fishing areas of Argentina. Pages 269-282 *in* Gillnets and cetaceans: Incorporating the proceedings of the symposium and workshop on the mortality of cetaceans in passive fishing nets and traps, eds. Perrin, W. F., G. P. Donovan and J. Barlow. International Whaling Commission, Special Issue 15.

Crespo, E. A., G. Harris and R. González. 1998. Group size and distributional range of the franciscana, *Pontoporia blainvillei*. Marine Mammal Science 14:845-849.
Crespo, E. A. 2009. Franciscana dolphin *Pontoporia blainvi*llei. Pages 466-469 *in* Encyclopedia of marine mammals, 2nd ed, eds. Perrin, W. F., B. Würsig and J. G. M. Thewissen. Academic Press.

Crespo, E. A., S. N. Pedraza, M. F. Grandi, S. L. Dans and G. V. Garaffo. 2010. Abundance and distribution of endangered Franciscana dolphins in Argentine waters and conservation implication. Marine Mammal Science 26:17-35.
Cunha, H. A., B. V. Medeiros, L. A. Barbosa, M. J. Cremer, J. Marigo, J. Lailson-Brito, A. F.

Azevedo and A. M. Solé-Cava. 2014. Population structure of the endangered franciscana dolphin (*Pontoporia blainvillei*): Reassessing management units. PLOS ONE 9:e85633.

Danilewicz, D., E. R. Secchi, P. H. Ott, I. B. Moreno, M. Bassoi and M. Borges-Martins. 2009. Habitat use patterns of franciscana dolphins (*Pontoporia blainvillei*) off southern Brazil in relation to waters depth. Journal of the Marine Biological Association of the United Kingdom 89:943-949.

Danilewicz, D., I. B. Moreno, M. Borges-Martin, M. Muelbert, L. Oliveira, P. H. Ott, E. R. Secchi and M. Tavares. 2010a. Toninha, *Pontoporia blainvillei*. Pages 466-469 *in* Espécies da Fauna Ameaçada de Extinção: Recomendações para o manejo e políticas públicas, ed. Rambaldi, D. MMA.

Danilewicz, D., I. B. Moreno, P. H. Ott, M. Tavares, A. F. Azevedo, E. R. Secchi and A. Andriolo. 2010b. Abundance estimate for a threatened population of franciscana dolphins in southern coastal Brazil: Uncertainties and management implications. Journal of the Marine Biological Association of the United Kingdom 90:1659-1666.

Danilewicz, D., A. N. Zerbini, A. Andriolo, *et al.* 2012. Abundance and distribution of an isolated population of franciscana dolphins (*Pontoporia blainvillei*) in southeastern Brazil: Red alert for FMA I?. International Whaling Commission, Scientific Committee Paper SC/64/SM17.

De la Torre, A., M. B. Alonso, M. A. Martínez, *et al.* 2012. Dechlorane-related compounds in franciscana dolphin (*Pontoporia blainvillei*) from southeastern and southern coast of Brazil. Environmental Science & Technology 46:12364-12372.

Di Beneditto, A. P. M., R. M. A. Ramos and N. R. W. Lima. 1998. Fishing activity in northern Rio de Janeiro State (Brazil) and its relation with small cetaceans. Brazilian Archives of Biology and Technology 41: 296-302.

Frizzera, F. C., C. Tosi, H. T. Pinheiro and M. C. C. Marcondes. 2012. Captura acidental de toninha (*Pontoporia blainvillei*) na costa norte do Espírito Santo, Brasil. Bol. Mus. Biol. Mello Leitão (N. SÉR) 29:81-86.

Fujiwara, M. and H. Caswell. 2001. Demography of the endangered North Atlantic right whale. Nature 414:537-541.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68:1364-1372.

Gilpin, M. E. and M. E. Soulé. 1986. Minimum viable populations: The process of species extinctions. Pages 13-34 *in* Conservation biology: The science of scarcity and diversity, ed., M. E. Soulé. Sinauer Associated.

Hatje, V., R. M. A. Pedreira, C. E. De Rezende, et al. 2017. The environmental impacts of one of the largest tailing dam failures worldwide. Scientific Report 7:1–13.

ICMBio. 2011. Plano de ação nacional para a conservação do pequeno cetáceo – Toninha (*Pontoporia blainvillei*). 76p.

International Whaling Commission. 2005. Annex L - Report of the Sub-Committee on Small Cetaceans. Journal of Cetacean Research and Management 7:307-326.

International Whaling Commission. 2016. A conservation management plan for franciscana (*Pontoporia blainvillei*). IWC/66/CC11. 22p.

IUCN. 2012. IUCN Red List Categories and Criteria: Version 3.1., second edition. IUCN.

Kinas, P. G. 2002. The impact of incidental kills by gill nets on the franciscana dolphin (*Pontoporia blainvillei*) in southern Brazil. Bulletin of Marine Science 70:409-421.

Kinas, P. G., E. R. Secchi, R. Ramos, D. Danilewicz and E. A. Crespo. 2002. Report of the Working Group on Vital Parameters and Demography. Latin American Journal of Aquatic Mammals 1:43-46.

Laake, J., D. Borchers, L. Thomas, D. Miller and J. Bishop. 2018. mrds: Mark-recapture distance sampling. Available at https://cran.r-project.org/package5mrds.

Lailson-Brito, J., P. R. Dorneles, C. E. Azevedo-Silva, *et al.* 2011. Organochlorine concentrations in franciscana dolphins, *Pontoporia blainvillei*, from Brazilian waters. Chemospehere 84:882-887.

Lavandier, R., J. Arêas, N. Quinete, *et al.* 2016. PCB and PBDE levels in a highly threatened dolphin species from the southeastern Brazilian coast. Environmental Pollution 208:442-449.

Magris, R. A., M. Marta-Almeida, J. A. F. Monteiro and N. C. Ban. A modelling approach to assess the impact of land mining on marine biodiversity: Assessment in coastal catchments experiencing catastrophic events (SW Brazil). Science of Total Environment 659:828-840.

Manly, B.F.J. 2006. Randomization, Bootstrap and Monte Carlo Methods in Biology: Third edition. United States of America: Chapman & Hall/CRC.

Marcondes, M. C. C., M. Angeli, F. Fontes, J. T. Pallazo Jr., R. Campos, C. Daper and M. Cremer. 2018. Report on franciscana fisheries interaction. International Whaling Commission, Scientific Committee Paper SC/67b/SM/03.

Marsh, H. and D. F. Sinclair. 1989. Correcting for visibility bias in strip transect aerial surveys of aquatic fauna. Journal of Wildlife Management. 53:1017-1024.

Mendez, M., H. C. Rosenbaum, A. Subramaniam, C. Yackulic and P. Bordino. 2010. Isolation by environmental distance in mobile marine species: Molecular ecology of franciscana dolphins at their southern range. Molecular Ecology 19:2212-2228.

MMA. 2014. Lista nacional oficial de espécies da fauna ameaçada de extinção—Mamíferos, aves, répteis, anfíbios e invertebrados terrestres. In: Portaria MMA no. 444, de 17 de dezembro de 2014, Brasil. Available from http://www.icmbio.gov.br/cepsul/images/stories/legislacao/Portaria/2014/p_mma_444_2014_lista_esp%C3%A9cies_ame%C3%A7adas_extin%C3%A7%C3%A3o.pdf. Accessed 27 July 2017.

Moreno, I. B., C. C. A. Martins, A. Andriolo, M. H. Engel. 2003. Sightings of franciscana dolphins (*Pontoporia blainvillei*) off Espírito Santo, Brazil. Latin American Journal of Aquatic Mammals 2:131-132.

MPA/MMA. 2012. Instrução Normativa Interministerial MPA/MMA Nº 12, de 22 de agosto de 2012. Available from http://www.icmbio.gov.br/cepsul/images/stories/legislacao/Instrucao_normativa/2012/in_inter_mpa_mma_12_2012_redesemalhe_se_s.pdf. Accessed 27 July 2017.

Ott, P. H., E. R. Secchi and I. B. Moreno, *et al.* 2002. Report of the Working Group on Fishery Interactions. Latin American Journal of Aquatic Mammals 1:55-64.

Perrin, W. F., G. P. Donovan and J. Barlow eds. 1994. Gillnets and cetaceans: Incorporating the proceedings of the symposium and workshop on the mortality of cetaceans in passive fishing nets and traps. Report of the International Whaling Commission, Special Issue 15.

Pinedo, M. C., R. Praderi and R. L. Brownell Jr. 1989. Review of the biology and status of the franciscana *Pontoporia blainvillei* (Gervais & D'Orbigny, 1844). Pages 46-51 *in* Biology and conservation of the river dolphins, eds. Perrin, W. F., R. L. Brownell Jr., K. Zhou and L. Jiankang. IUCN.

Pinheiro, F. C. F., H. T. Pinheiro, J. B. Teixeira, A. S. Martins and M. J. Cremer. 2019. Opportunistic development and environmental disaster threat franciscana dolphins in Southeast of Brazil. Tropical Conservation Science 12:1-7.

R Core Team. 2018. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Read, A. J., P. Drinker and S. Northridge. 2006. Bycatch of marine mammals in US and global fisheries. Conservation Biology 20: 163-69.

Read, A. J. 2008. The looming crisis: Interactions between marine mammals and fisheries. Journal of Mammalogy 89:541-548.

Reeves, R. R., B. D. Smith, E. Crespo and N. G. Di Sciara. 2003. Dolphins, whales, and porpoises: 2002-2010 conservation action plan for the world’s cetaceans. IUCN Species Survival Commission.

Reeves, R. R., K. McClellan and T. B. Werner. 2013. Marine mammal bycatch in gillent and other entangling net fisheries, 1990 to 2011. Endangered Species Research 20:71-97.

Rosas, F. C. W., E. L. A. Monteiro-Filho and M. R. de Oliveira. 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 1:161-167.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd edition. Charles Griffin & Company Ltd.

Secchi E. R., A. N. Zerbini, M. Bassoi, L. Dalla Rosa, L. M. Moller and C. C. Rocha-Campos. 1997. Mortality of franciscanas, *Pontoporia blainvillei*, in coastal gillnets in southern Brazil: 1994-1995. Report International Whaling Commission. 47:653–658.

Secchi, E. R., J. Y. Wang, B. W. Murray, C. C. Rocha-Campos and B. N. White. 1998. Population differentiation in the franciscana (*Pontoporia blainvillei*) from two geographic locations of Brazil as determined from mitochondrial DNA control region sequences. Canadian Journal of Zoology 76: 1622-1627.

Secchi, E. R., P. H. Ott and D. S. Danilewicz. 2003a. Effects of fishing by-catch and conservation status of the Franciscana dolphin, *Pontoporia blainvillei*. Pages 174-191, *in* Marine mammals: Fisheries, tourism and management issues, eds. Gales, N., M. Hindell and R. Kirkwood. CSIRO Publishing.

Secchi, E. R., D. Danilewicz and P. H. Ott. 2003b. Applying the phylogeographic concept to identify franciscana dolphin stocks: Implications to meet management objectives. Journal of Cetacean Research and Management 5:61-68.

Secchi E. R. 2006. Modelling the population dynamics and viability analysis of franciscana (*Pontoporia blainvillei*) and Hector's dolphins (*Cephalorhynchus hectori*) under the effects of bycatch in fisheries, parameter uncertainty and stochasticity. Unpublished thesis, University of Otago.

Secchi E. R. 2010. Review on the threats and conservation status of franciscana, *Pontoporia blainvillei* (Cetacea, Pontoporiidae). Pages 323-339, *in* Biology, evolution and conservation of river dolphins within south America and Asia, eds. Ruiz-Garcia M. and J. M. Shostell. Nova Science Publishers Inc.

Siciliano S. 1994. Review of small cetacean and fishery interaction in coastal waters of Brazil. Pages 241-450 *in* Gillnets and cetaceans: Incorporating the proceedings of the symposium and workshop on the mortality of cetaceans in passive fishing nets and traps, eds. Perrin, W. F., G. P. Donovan and J. Barlow. International Whaling Commission, Special Issue 15.

Siciliano, S., A. P. Di Beneditto and R. Ramos. 2002. A toninha, *Pontoporia blainvillei* (Gervais & D'Orbigny, 1884) (Mammalia: Cetacea) nos Estados do Rio de Janeiro e Espírito Santo, costa sudeste do Brasil: caracterização dos hábitats e possíveis fatores de isolamento das populações. Boletim do Museu Nacional, Nova Série, Zoologia 146:1-15.

Slooten, E., J. Y. Wang, S. Z. Dungan, *et al.* 2013. Impacts of fisheries on the critically endangered humpback dolphin *Sousa chinensis* population in the eastern Taiwan Strait. Endangered Species Research 22:99-114.

Taylor, B. L. and T. Gerrodette. 1993.The use of statistical power in conservation biology: The vaquita and northern spotted owl. Conservation Biology 7:489-500.

Taylor, B. L., P. R. Wade, D. P. De Master and J. Barlow. 2000. Incorporating uncertainty into management models for marine mammals. Conservation Biology 14:1243-1252.

Taylor, B. L., L. Rojas-Bracho, J. Moore, et al. 2016. Extinction is imminent for Mexico's endemic porpoise unless fishery bycatch is eliminated. Conservation Letters XX:1-8.

Thomas, L., S. T. Buckland, E. Rexstad, *et al.* 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology 47:5–14.

Van Erp I. 1969. In quest of the La Plata dolphin. Pacific Discovery 22:18-24.

Wade, P. R. and T. Gerrodette. 1992. Estimates of dolphin abundance in the eastern tropical Pacific: Preliminary analysis of five years of data. Report of the International Whaling Commission 42:533-539.

Wade, P. R. 1998. Calculating limits to the allowable human-caused mortality of cetaceans and pinnipeds. Marine Mammal Science 14:1-37.

Williams, B. K., J. D. Nichols and M. J. Conroy. 2001. Analysis and management of animal populations: Modeling, estimation, and decision making. Academic Press.

Williams, R. and L. Thomas. 2009. Cost-effective abundance estimation of rare animals: Testing performance of small-boat surveys for killer whales in British Columbia. Biological Conservation 142:1542-1547.

Yogui, G. T., M. C. O. Santos, C. P. Bertozzi and R. C. Montone. 2010. Levels of persistent organic pollutants and residual pattern of DDTs in small cetaceans from the coast of São Paulo, Brazil. Marine Pollution Bulletin 60:1862-1867.

Zerbini, A. N., E. Secchi, E. Crespo, D. Danilewicz and R. Reeves. 2017. *Pontoporia blainvillei*. In: IUCN 2017. The IUCN Red List of Threatened Species. 2017. Available: www.iucnredlist.org. Accessed 30 January 2018.