Abundance and distribution of an isolated population of franciscana dolphins (*Pontoporia blainvillei*) in southeastern Brazil: red alert for FMA I?

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ABSTRACT

The franciscana (*Pontoporia blainvillei*) is endemic of the eastern coast of Brazil, Uruguay and Argentina and inhabits coastal waters from Brazil (18°25'S) to Argentina (41°10'S). The species is currently regarded as the most threatened small cetacean in South America due to high bycatch levels throughout its range. Recently, four management stocks (known as Franciscana Management Areas or FMAs) were defined: two in Brazil (FMA I-III), one in Brazil/Uruguay (FMA III) and one in Argentina (FMA IV). FMA I corresponds to the coasts of the Brazilian states of Rio de Janeiro (RJ) and Espirito Santo (ES) and represents one of the least known stocks. This population faces a number of conservation threats including bycatch in fisheries and habitat degradation, but the magnitude of these threats have not yet been well understood because of lack of information on population size. In December 2011 and January 2012 design-based aerial surveys were conducted to assess the distribution and to estimate abundance of franciscanas in FMA I in three coastal (coastline to 30m isobath). One of this strata corresponded to an area believed to represent a hiatus in the species distribution between RJ and ES. A total of 20 franciscana groups (46 individuals) were seen, including in the proposed hiatus. Average group size was 2.2 (SE = 0.305). Abundance corrected for perception and availability bias was estimated to be 1,998 (CV=0.48, 95% CI: 796-5,013) with the most supported detection probability model. Franciscanas were recorded from very coastal and turbid waters near the shore (just behind the surf zone) to clearer waters as far as 13km from the shore. The most recent (2001-2002) estimates of incidental mortality in FMA I correspond to 5.5% (2.2-13.8%) of the estimated population size presented here, possibly indicating high and unsustainable bycatch. It is strongly recommended that new aerial surveys with increased sampling effort be conducted in order to produce more robust population estimates and further assess the species distribution. It is also recommended that research to estimate bycatch is resumed in FMA I.

INTRODUCTION

The franciscana (*Pontoporia blainvillei*) is endemic of the eastern coast of Brazil, Uruguay and Argentina (e.g. Praderi et al., 1989) and inhabits coastal waters (usually shallower than 30m) from Itaúnas, Brazil (18°25'S) to Golfo San Matías, Argentina (41°10'S) (Siciliano, 1994; Crespo et al., 1998). High levels of incidental mortality in coastal fisheries have been recorded throughout its range since the 1940s and the species is currently regarded as the most threatened cetacean species in South America (Van Erp, 1969; Ott et al., 2002; Secchi et al., 2003a).

For management purposes, the franciscana distribution range was divided into four zones known as Franciscana Management Areas, or FMAs (see Secchi et al., 2003b): two in southern and southeastern Brazil (FMA I and II), one in southern Brazil and Uruguay (FMA III) and one in Argentina (FMA IV) (Fig. 1). Franciscanas inhabiting FMA I belong to a geographically isolated population (Siciliano et al., 2002). There is a well-known discontinuity in the distribution of the species between northern São Paulo (FMA II) and Rio de Janeiro (FMA I), which corresponds to a stretch of about 400 km of coastline without franciscana records (either from incidental catches, sightings or strandings). Moreover, the species occurrence is likely discontinuous within FMA I, where a gap in the distribution seems to occur in Espírito Santo State (ES, in Fig. 1). The isolation and possible fragmentation of this population inhabiting the northernmost portion of the species range, emphasize the concerns regarding the conservation status and long-term viability of this stock.

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Franciscanas have been incidentally caught in FMA I since at least the 1980s (Lodi & Capistrano, 1990), especially in the north of Rio de Janeiro State (RJ, in Fig. 1). Fishing-related mortality is only one of the threats faced by the species in this region. Increasing oil and gas exploration activities, domestic and industrial sewage, and increasing vessels traffic likely cause habitat degradation due to, among others, increased underwater noise and chemical pollution. Effects of these potential threats are yet to be evaluated. Despite all these potential conservation issues, management actions have never been proposed for the population in FMA I mainly because of a lack of knowledge on population size, distribution, and critical habitats. Robust abundance estimates for franciscanas in FMA I are required to determine the magnitude and impact of bycatch removal and to assess the population conservation status. In addition, it is unlikely that without the identification and description of the critical habitats, management advice can be provided and adequate conservation actions be implemented.

Conducting assessments of the conservation status of the franciscana has been a long-term recommendation of various bodies, including the government of the franciscana range states (ICMBio, 2011) and the IUCN (Reeves et al., 2003). In 2004, during the IWC Scientific Committee’s annual meeting in Sorrento, Italy, the sub-committee on Small Cetaceans (SM) reviewed the franciscana status (IWC, 2005). The committee expressed their concern in regards to the conservation of the species due to high levels of bycatch mortality and absence of reliable population estimates (IWC, 2005). The committee recommended that abundance surveys be conducted in FMA I and II, two of the four populations for which estimates were not available. In addition to estimates of abundance, the SM sub-committee recommended that hiatuses in the distribution of franciscana’s be evaluated so that the limits of distribution within FMA I are determined (IWC, 2005). Abundance estimates in FMA II were computed from aerial surveys conducted in 2008 and 2009 (Zerbini et al., 2010), but estimates for FMA I were still missing.

In 2011, a proposal to assess the status of the franciscana in FMA I was funded by the International Whaling Commission (IWC) Small Cetacean Conservation Fund with the following main goals:

1) Estimating population size;
2) Documenting distribution, core habitats and geographic limits of hiatuses in distribution;
3) Investigating the relationship of distribution and environmental parameters (e.g. water turbidity and bathymetry).

This document provides results from aerial surveys conducted in December 2011 and January 2012 and the first estimates of abundance for franciscanas in FMA I.

METHODS

Aerial surveys were carried from Rio das Ostras, Rio de Janeiro (22°31’S, 41°55’W) to Itaúnas, border of the State of Espírito Santo and Bahia States. The surveys occurred in two periods: 11-18 December 2011 and 5-11 January 2012. Three survey strata were proposed (Table 1, Fig. 2): (1) northern Rio de Janeiro coast (RJ stratum), (2) distributional gap in southern Espírito Santo (H stratum) and (3) northern Espírito Santo coast (ES stratum). A set of parallel transect lines were designed to sample these strata from the coastline to the 30m isobaths, the likely limit of the species (Pinedo et al. 1989; Secchi and Ott 2000) (Fig. 2). The H stratum has been identified as a gap in the distribution of franciscanas in southeastern Brazil due to the lack of records of stranded or incidentally killed dolphins (Siciliano et al., 2002).

Table 1 – Survey strata area and proposed survey effort for franciscana aerial surveys in southeastern Brazil.

Stratum	Area (km^2)	#Transects	Effort (km)
(1) Northern Rio de Janeiro (RJ stratum)	5,625	39	1,329
(2) Hiatus (H stratum)	4,969	12	274
(3) Northern Espírito Santo (ES stratum)	5,122	30	1,146
Total	15,716	81	2,750

Survey Design and Sampling Methods

Aerial surveys followed design-based line transect methods (Buckland et al., 2001), which assume that the density of animals in the survey area is, on average, equal to the density in the study area if transect placement provides uniform coverage probability. Stratum specific and total survey effort is summarized in Table 1. A set of 69 equally-spaced parallel transect lines were placed perpendicular to the coast line in the RJ and ES strata and 12 lines were placed in the H stratum (Fig 2). Higher survey effort per unit of area was applied to the regions where franciscanas were known to occur in order to maximize collection of sighting data, resulting in tracklines being spaced every 4.8km in the RJ and ES strata. Lower effort was allocated to the H stratum (16.3km trackline spacing) in an attempt to provide some survey coverage to investigate distribution in an area with a historical lack of records and therefore lower likelihood to observe franciscanas.

Visual surveys were made from a high-wing, twin-engine Aerocommander aircraft at an approximately constant altitude of 152m (500ft) and a speed of 170-200km/h (~90-110 knots). The aircraft had four observation positions (two on each side of the plane), with bubble and flat windows 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 collected environmental data (e.g. sea conditions, water transparency) at the beginning and end of each transect, or when conditions changed. The beginning and the end of the transects were informed to the observers by the pilot. All observers were independent as they did not communicate with each other during the flights. 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 at the end of each flight. When a sighting was detected, the species and the size of the group were recorded. The declination angle between the horizontal and the sighting was obtained using an inclinometer when the group passed a beam of the plane. Additional information such as sea state, presence of calves in the groups, and water visibility were also recorded along with each sighting.

Sighting data collection was standardized while surveying the proposed transects as well as during transiting between transects and from and to the survey area to airports. Additional transit lines were proposed in known or suspected areas of high density of franciscanas to increase sample size for the estimation of detection probability. All sightings recorded under such conditions were used for the estimation of the detection function but only sightings detected while flying the originally proposed survey design (Fig. 2) were used to compute the estimates of density and abundance.

Analytical Methods

Detection probability was estimated using Conventional (CDS) and the Multiple Covariate Distance Sampling (MCDS) methods (Buckland et al., 2001; Marques and Buckland, 2003). MCDS differs from CDS as it allows for the inclusion of environmental covariates in the estimation of detection probability. In this study, only sightings from observers located in the front (bubble) windows were used in estimating detection probability. Because of the small sample size of sightings collected in FMA I (n = 11, see below), perpendicular distance data was increased by pooling sightings from this study with those from a previous franciscana abundance estimate for FMA II (Zerbini et al., 2010) and those from aerial surveys conducted off the southeastern coast of Brazil in April 2012 (Danilewicz et al., unpublished data). Both of these studies used methods similar to the ones applied during sampling at FMA I (e.g. same aircraft, survey altitude, data collection procedures, observers). Pooling of sighting data increased the sample size for detection probability estimate to 48 sightings.

Half normal and hazard rate models without covariates and with group size (numeric), sea state category (factor covariate with two levels: “low beaufort” [0-2] and “high beaufort” [3-4]) and water transparency covariates (factor covariate with two levels: “clear” and “turbid”) were proposed to model perpendicular distance data. Exploratory analyses indicated that adequate fits were obtained by modeling grouped perpendicular distance data (grouping intervals: 0-60m, 60-120m, 120-180m, 180-240m, and 240m-300m). Only data collected by the front observers in the airplane (bubble windows) were considered in the analysis presented below. The most supported models were selected according to the Akaike Information Criterion (AIC).

Uncorrected (for visibility bias) density of franciscanas (D_u) was estimated using the Horvitz-Thompson estimator as follows (Marques and Buckland 2003):

$$\widehat{D_u} = \sum_{i=1}^{n} \frac{s_i}{\hat{p}(z_i)}$$

Where: n – number of sightings, s_i – cluster size for observation i, $p(z_i)$ – detection probability for vector of sighting-specific covariates z for each observation i (note that p is constant for CDS models).

Expected group size was estimated by dividing density of individuals (D_u) by density of groups (Innes *et al.*, 2002; Marques and Buckland, 2003). Variance was estimating using the analytical estimator of Innes *et al.* (2002) and Log-normal 95% confidence intervals were computed as recommended by Buckland *et al.* (2001).

Correcting for Visibility Bias and Group Size

Aerial surveys have been considered the most appropriate survey method to estimate population size of franciscanas (e.g. Secchi et al., 2001; Crespo et al., 2002), but most previous abundance surveys suffered from appropriate correction for visibility bias and for potential underestimation of group sizes from the air. In 2011, an experiment was conducted at Babitonga Bay (southern Brazil) to compute a correction factor that would account for these factors in aerial surveys of franciscanas (Zerbini et al., 2011). This study used simultaneous boat and aerial surveys to estimate abundance of franciscanas in a relatively small, but large density area. This correction factor was estimated by the ratio of the boat and the airplane estimates of density, assuming that the boat estimate corresponded to the 'true' density. This factor, estimated at 4.74 (CV=0.05), was applied to uncorrected density estimates to account for visibility and group size estimation bias. This correction is believed to be appropriate because the sampling procedures and survey conditions were similar to those observed in Babitonga Bay and the observers conducting the survey were the same.

The corrected density estimate (D_c) was computed by multiplying the uncorrected estimate (D_u) by the correction factor mentioned above. The variance of the corrected abundance was approximated by the Delta Method.

RESULTS

A total of 2,242.6 km were surveyed (Fig. 2). Realized effort was slightly lower than proposed effort because visibility conditions (e.g. rain or wind) resulted in effort being interrupted in some survey lines (Fig. 2).

Distribution

A total of 20 franciscana groups were seen during the survey (Fig. 2), with 15 sightings observed on-effort (11 from front observers and 4 from rear observers) and 5 off-effort. Total number of individuals seen was 46 and the average group size for all sightings combined was 2.2 (SE = 0.305, range=1-6, median=2). On-effort sightings were recorded only in Rio de Janeiro (RJ stratum), between Jurubatiba National Park (22^{o}14'S; 41^{o}35'W) and São João da Barra (21^{o}35'S; 41^{o}00'W) (Fig. 2). Off-effort sightings were observed in northern Espirito Santo (ES stratum) and in the Hiatus. Sightings in ES occurred in very coastal waters (less than 1km from the coastline) during transit lines and therefore were not used in the estimates of density/abundance presented below. Franciscanas were recorded from very coastal and turbid waters near the shore (behind the surf zone) to clearer waters 13km distant from the shore.

Abundance

Detection probability estimates for well supported models (AIC ≤ 2) are presented in Table 2. The model (#1 in Table 3) that received most support from the data was the half normal without covariates. The hazard rate model without covariates and half normal detection functions with covariates (group size and turbidity) were also among well-supported models, but ranked lower. Detection functions for models in Table 2 are illustrated in Fig. 3.

Table 2 – Best models (ΔAIC ≤ 2) for estimation of franciscana detection probability in FMA I.

Model #	Model Specification	npar	AIC	Delta AIC	AIC weight	*Average p*	CV(p)
1	hn	1	146.271	0.000	0.346	0.62	0.13
2	hr	2	147.701	1.430	0.169	0.67	0.15
3	hn + Group Size	2	147.895	1.625	0.153	0.61	0.14
4	hn + f(Turbidity)	2	147.956	1.685	0.148	0.62	0.14

hn – half normal model, hr – hazard rate model, f – factor covariate, npar = number of parameters AIC – Akaike Information Criterion, CV – Coefficient of Variation.

Only the 11 sightings recorded in the proposed survey tracklines (i.e. excluding transit lines) were used to compute an estimate of abundance of 1,998 franciscanas for FMA I (CV=0.48, 95% CI: 796-5,013) with the best detection probability model (Table 3). Estimates with other relatively well-supported models (Delta AIC ≤ 2) resulted in similar estimates (Table 3). Because no on-effort sightings were detected while surveying the H and ES strata, the estimated presented here corresponds to the RJ stratum alone.

Table 3 – Encounter rate, expected group size, density and abundance estimates of franciscanas in FMA I, southeastern Brazil (Model # corresponds to models in Table 2).

Model #	*er*	CV(*er*)	*E(S)*	CV(*E[S]*)	D_u	CV(D_u)	D_c	CV(D_c)	N_c	CV(N_c)	95% LCL	95% UCL
1	0.011	0.46	2.54	0.15	0.027	0.48	0.127	0.48	1998	0.48	796,	5013
2	0.011	0.46	2.54	0.15	0.024	0.49	0.114	0.49	1830	0.49	718	4663
3	0.011	0.46	2.47	0.16	0.026	0.48	0.123	0.48	1962	0.48	782	4924
4	0.011	0.46	2.57	0.16	0.027	0.49	0.127	0.49	1999	0.49	784	5092

er – encounter rate, CV – Coefficient of variation, *E(S)* – average cluster size, D_u – density uncorrected for visibility bias, D_c – corrected density, N_c – corrected abundance estimation, LCL – lower confidence limit, UCL – upper confidence limit. [1]Density is expressed in individuals/km^2.

DISCUSSION

Distribution

The present study reports on the first aerial surveys for franciscanas and contributes with new information about the distribution of this elusive species in FMA I. The distribution depicted here shows a somewhat different latitudinal pattern from what was described by previous studies. Former research on the occurrence of franciscanas in FMA I was based primarily on stranded or incidentally captured individuals (e.g. Siciliano et al., 2000; Di Beneditto and Ramos, 2001) and suggested that franciscanas occurred in two distinct regions within FMA I, the northern coast of Rio de Janeiro State and the northern coast of Espírito Santo State, with a hiatus between these two regions. During the present aerial surveys, two franciscana sightings were recorded inside the northern portion of the hiatus area, indicating that the species does occur in areas where it had not been previously recorded. Despite that, a large portion of the hiatus remains without records, which may still be indicative of a fragmented population. Therefore, the hiatus in franciscana distribution in Espirito Santo could now be considered to be between São Francisco de Itabapoana (21^{o}18’S) and Santa Cruz (19º58’S): an area of ~200km without sightings, strandings and incidental catches, historical or actual.

The presence of franciscanas in the hiatus combined with the relatively low survey effort allocated to this stratum indicate the need for further survey effort to confirm whether the species had not been previously observed there due to lack of appropriate survey effort. This is particularly important if the distribution further to the north is very coastal, as observed for the few sightings reported here.

There is currently no evidence that franciscanas occur in relatively deep waters in this area. In fact, no individual was seen further than 13km from the coast (19m deep), suggesting that as in FMA II, franciscanas may have more coastal habits than in other areas (e.g. Rio Grande do Sul, FMA III), where animals are sometimes recorded in waters 50m deep or more (Danilewicz et al., 2009). Incidental catch and sighting data also confirm this pattern for FMA I (Di Beneditto et al., 2001b; Di Beneditto, 2003). Since this was the first study and very limited information was available on distribution of franciscanas in FMA I, it was decided to design the transect lines following the 30m isobath. It seems that same distribution pattern does not occur in the species northern limit, indicating that shorter transects could be considered in future aerial surveys.

Fewer sightings than expected were observed in the northern coast of Rio de Janeiro, between Cabo de São Tome (22^{o}S) and São Francisco de Itabapoana (21^{o}18’S), an area with several historical records of incidental catches and sightings (Di Beneditto and Ramos, 2001). Whether the low occurrence of franciscanas in this area represents seasonal or random variation in habitat use, a decrease in density due to, for example, bycatch requires further investigation.

Density and Abundance

Point estimates of density recorded for FMA I is, to date, the lowest across all estimates along the franciscana range (Table 4). However, it should be stressed that methodological differences in collecting data in FMA III and IV as well as the small sample size of the present estimate still precludes definitive comparison and conclusions.

The abundance estimate provided here is the first for FMA I and suggests that only approximately 2,000 franciscanas inhabit this management area, between the coastline and the 30m isobaths. It is important to note, however, that this estimate is relatively imprecise (CV=0.48) due to the small sample of sightings collected. In addition, the estimate may be slightly underestimated as off-effort sightings of franciscanas were observed in the two other strata (H stratum and in the ES stratum), but no abundance estimate has been computed for them. Yet, even considering the various sources of uncertainty, the size of this population is likely small and of conservation concerns.

Table 4 – Density estimates for franciscanas throughout the species range.

Location	FMA	Year	Density (ind/km^2)	95% CI (Density)	Observations and source
Argentina coastal waters	IV	2003-2004	0.377	0.223-0.636	Aerial survey, northern stratum to depths of up to 30m, Crespo et al. (2010)
Rio Grande do Sul, southern Brazil	III	1996	0.651	0.516-0.836	Aerial survey, Secchi et al. (2001)
Rio Grande do Sul, southern Brazil	III	2004	0.510	0.278-0.944	Aerial survey, Danilewicz et al. (2010a)
Babitonga Bay, SC, southern Brazil	II	2001-2003	0.318	0.178-0.570	Boat survey, Cremer and Simões-Lopes (2008)
Santa Catarina to Sao Paulo, southern and southeastern Brazil	II	2008-2009	0.348	0.188-0.641	Aerial survey, Zerbini et al. (2010)
			0.362	0.189-0.692	
Rio de Janeiro and Espirito Santo	I	2011-2012	0.127	0.005-0.318	This study

Conservation Implications

Bycatch is currently the main conservation problem for the franciscana throughout its range (e.g. Secchi et al., 2003a and b, Danilewicz, 2007, Danilewicz et al., 2010b). The annual fishery-related mortality of the species in FMA I is not well understood. In two reviews on franciscana mortality, Ott et al. (2002) and Secchi et al. (2003) compiled the information for FMA I presented by Siciliano et al. (1994), Ramos et al. (1994), Di Beneditto et al. (1998) and Di Beneditto and Ramos (2000) and concluded that an average of 23 animals (min=13, max=32) were killed annually during the 1990's. Nevertheless, in a more recent study, where by-catch estimates were based on CPUE indexes, Di Beneditto (2003) computed an average annual mortality of 110 franciscanas only in Rio de Janeiro during 2001-2002 (confidence intervals not provided). The estimated incidental mortality of franciscanas in Rio de Janeiro (from Di Beneditto, 2003) in the early 2000s corresponds to 5.5% of the estimated stock size for FMA I; numbers that are largely considered unsustainable for small cetacean populations (Wade, 1998) and for the franciscana in particular (e.g. Secchi et al., 2001; Crespo et al., 2010). If we consider the lower and higher confidence limits for the present abundance estimation, this percentage ranges from 13.8 and 2.2% of the stock size. That is, even in best case scenarios for population size (e.g. the 95 upper percentile of the abundance estimation, ~5,000 animals), the Di Beneditto (2003) by-catch estimates are not sustainable.

It is important to emphasize that after the publication by Di Beneditto (2003) no systematic survey on the franciscana fishery interaction has been carried out and published for FMA I. This information (based on CPUE data) is vital to understand whether the Di Beneditto (2003) mortality estimates are still valid and what is its trend, as well as to characterize and assess the trend in the fishery effort in this management area.

Conclusions and Recommendations

Current evidence strongly suggests that FMA I is geographically isolated from the remainder of the range of the population (FMA II-FMA IV). The northern coast of São Paulo and southern coast of Rio de Janeiro have been identified as a hiatus in the distribution of franciscanas in southeastern Brazil likely due habitat unsuitability (Siciliano et al. 2002). Despite the existing observation effort (monitoring for strandings and bycatch, aerial surveys) franciscanas have not yet been recorded in this region (Siciliano et al., 2002; Zerbini et al., 2010). Geographic isolation *per se* should be a reason for a higher awareness towards FMA I. But other factors contribute to increased concern about the status of this population. It is likely that its distribution is not only fragmented but also restricted (e.g. dolphins don't go as far offshore as other stocks), density is low (lower than any other FMA), and fishing mortality is likely unsustainable. It is also likely that FMA I corresponds to the smallest population of franciscanas.

Give findings of this study it is strongly recommended that additional research effort should be put in to conduct the following additional research for the FMA I population:

1) New aerial surveys with increased sampling effort in order to:

   (i) produce more robust (lower CVs, estimates for the northern range of FMA I) population estimates;

(ii) further assess distribution (e.g. offshore limits, fragmentation);

(iii) evaluate potential habitats that could be protected (e.g. by one or more no-take zones, marine protected areas) to improve conservation.

2) Resume systematic and long-term by-catch monitoring in northern Rio de Janeiro and Espírito Santo, in order to produce more up-to-date mortality estimates.

3) Studies be conducted to assess areas within the range of the species where other human activities could pose a threat to the long-term viability of franciscanas in FMA I.

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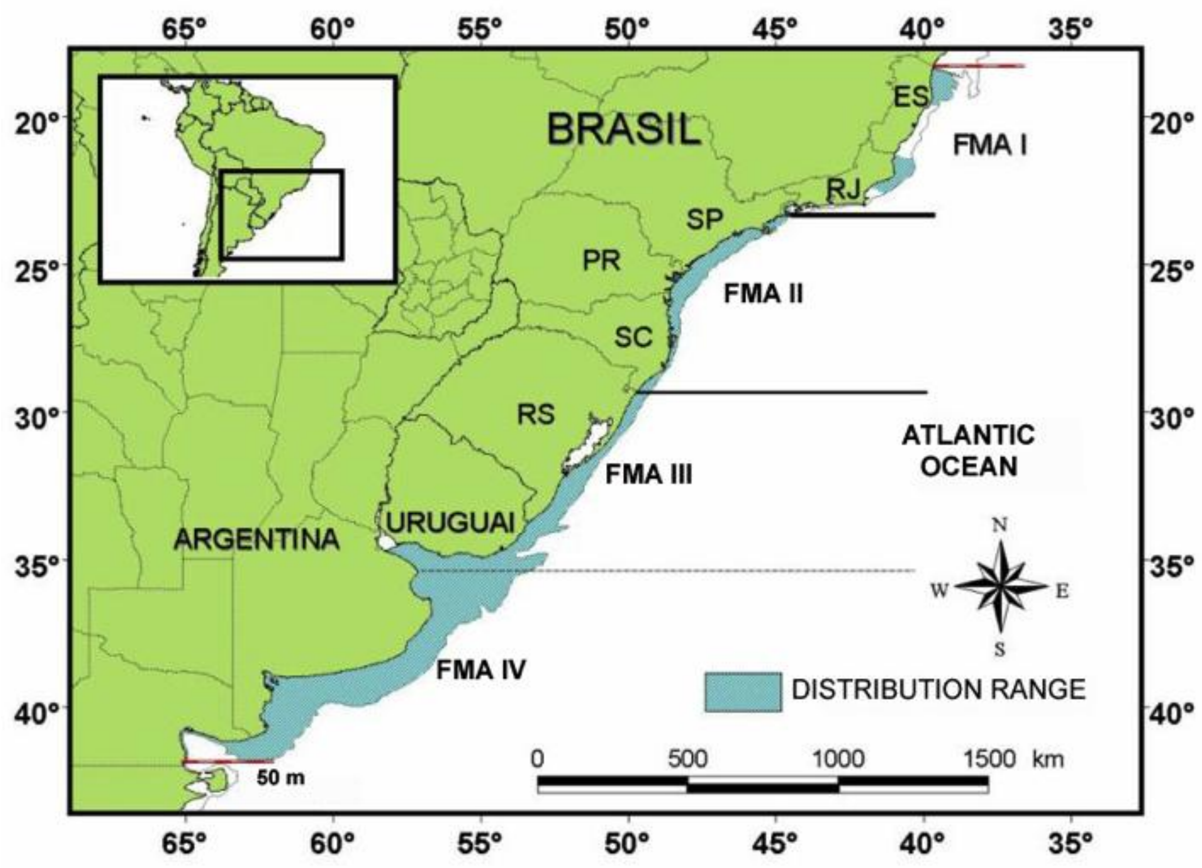


Fig. 1- Franciscana distribution range (following the 50m isobaths) showing the four Franciscana Management Areas (FMAs). FMA I, is located in the northern range of the species.

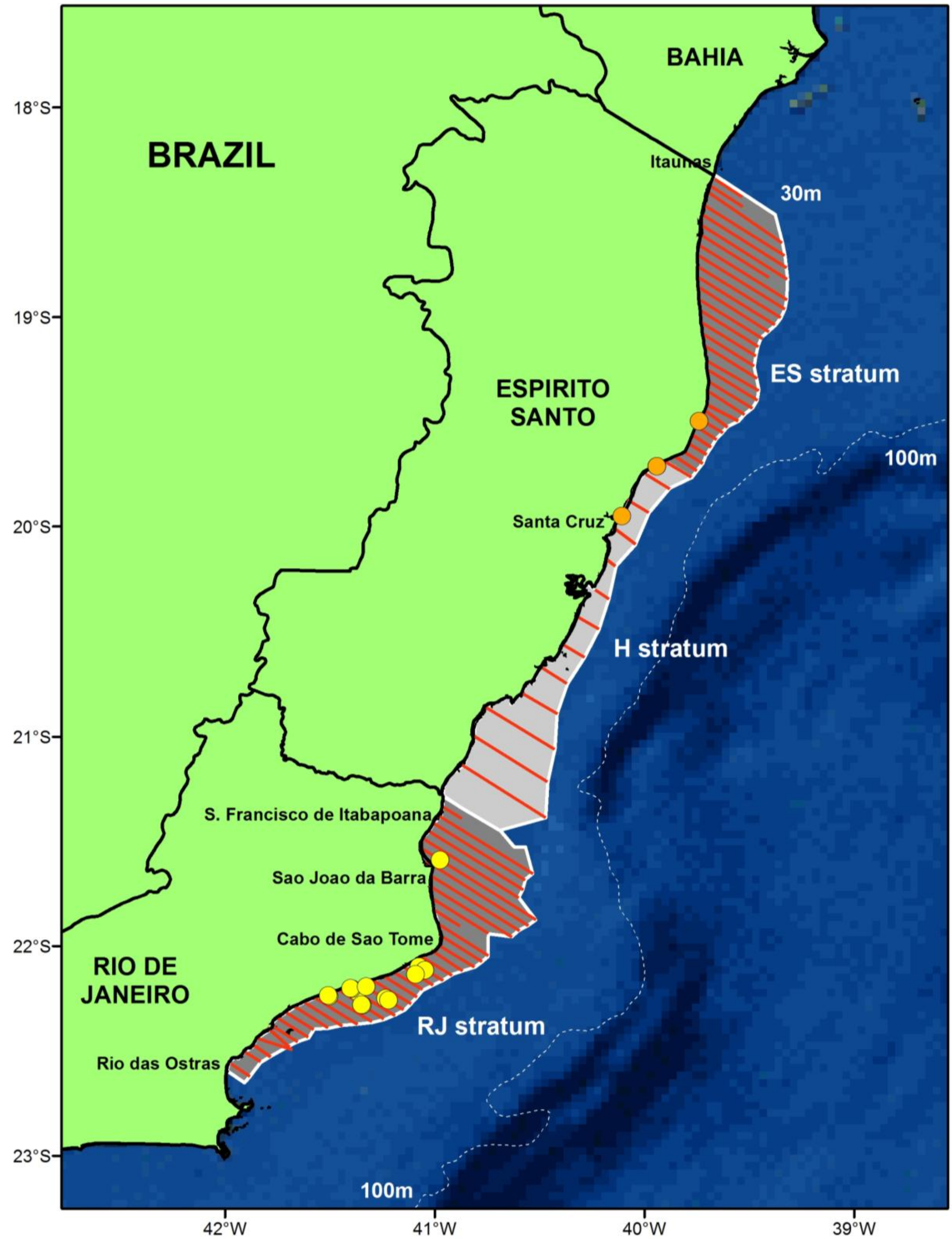
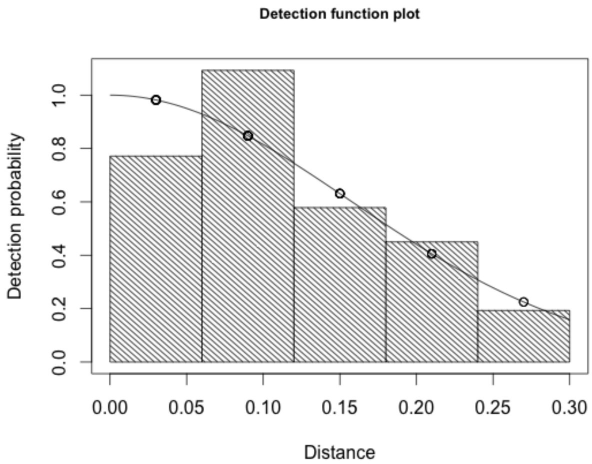
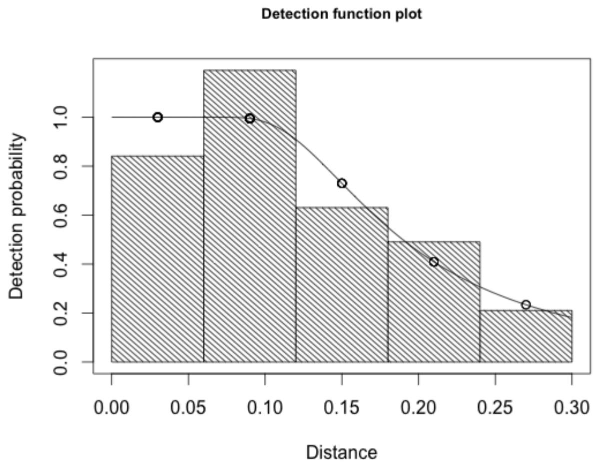


Fig. 2– Realized survey effort (red lines) and survey strata (RJ, H and ES) for franciscana aerial survey in FMA I in 2011/2012. Yellow and orange circles correspond to on- and off-effort sightings, respectively.



Model 1



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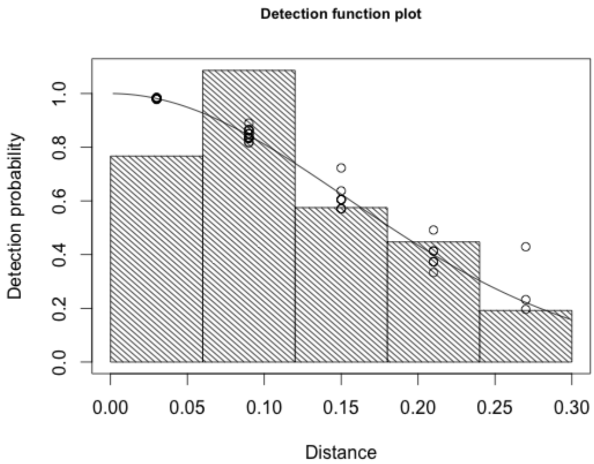
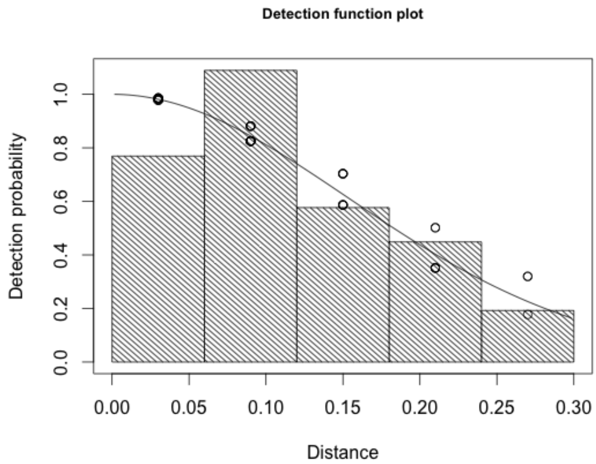


Model 3



Model 4

Fig. 3 – Detection functions for four well supported models used in the estimation of abundance of franciscanas in FMA I.