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Abundance and distribution of endangered Franciscana dolphins in Argentine waters and conservation implications

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ABSTRACT

This is the first study in Argentine waters on the abundance of the threatened Franciscana dolphin, *Pontoporia blainvillei*. During 2003–2004 we carried out 17 aerial surveys using line transect sampling methodology. We observed 101 Franciscanas in 71 sightings. In northern areas density was estimated at 0.106 individual/km^2. Density was lower in southern areas (0.055/km^2) and declined with depth beyond 30-m isobaths (0.05/km^2). A correction factor for submerged dolphins was applied to density and then extrapolated to the strip between the coastline and the 30-m isobath. Abundance in the northern area was estimated at 8,279 (4,904–13,960) individuals, while in the southern area it was estimated at 5,896 (1,928–17,999) individuals. Considering an annual mortality of about

500–800 individuals, about 3.5%–5.6% of the stock may be removed each year by the fishery and over the 2% recommended by the International Whaling Commission (IWC) and may not be sustainable by the population. Higher densities in coastal areas make Franciscanas more vulnerable to coastal fishing camps, which increased mortality in recent years. A remarkable finding was that while density decreases to the south, values of catch per unit effort (CPUE) increases, indicating different catchability of dolphins between areas.

Key words: Franciscana (*Pontoporia blainvillei*), abundance estimations, western South Atlantic, aerial surveys, conservation.

The Franciscana, *Pontoporia blainvillei*, is a small cetacean endemic to the western South Atlantic Ocean, ranging from Itaúnas (18°25′S, 30°42′W), Espírito Santo, Brazil,[1] to Golfo Nuevo (42°35′S, 64°48′W), Península Valdés, Argentina (Crespo *et al.* 1998). Due to the continued incidental mortality throughout most of its geographic distribution (Praderi *et al.* 1989), the Franciscana is perceived as the most threatened small cetacean in western South Atlantic Ocean (UNEP/CMS 2000, Secchi *et al.* 2001*a*, Crespo 2002). Preliminary estimates of catch per unit effort (CPUE) and annual mortalities showed a great variability among locations. Although its incidental mortality has been estimated in some areas (Pérez Macri and Crespo 1989, Monzón and Corcuera 1991, Corcuera *et al.* 1994, Crespo *et al.* 1994, Praderi 1994, Secchi *et al.* 1997, Kinas and Secchi 1998, Bordino *et al.* 2002), the real impact of these captures remains unknown mainly because of the lack of abundance estimates, the variability in mortality rates, and the uncertainties about stock discreteness.

Little was known until recently about the ecology and behavior of individuals in the wild. These approaches have been considered as research priorities for the Franciscana in several meetings and workshops carried out during the last two decades (Perrin *et al.* 1989, Crespo 1992, Pinedo 1994, Crespo 1998, Bordino *et al.* 1999, Secchi *et al.* 2001*a*). In the last few years, important progress was made in all these recommended fields. With regard to abundance estimates, one survey was carried out in the Rio Grande do Sul State coast, southern Brazil, a region where there are recent data on annual incidental mortality (Secchi *et al.* 1997, 2001*b*). Complementing morphological and parasitological information, advances in stock identification were gathered through genetic markers, formerly from Brazilian localities (Secchi *et al.* 1998). More recently, sampling sites from Uruguay and Argentina were incorporated[2] (Lázaro *et al.* 2004). According to ecological, morphological, and genetic information Secchi *et al.* (2001*a*, 2004*a*) proposed four different stocks or management units. On the other hand, some geneticists sustain the idea of isolation by distance (Lázaro *et al.* 2004). However, on the basis of genetic information, the International Whaling Commission (IWC) (2004) agreed that at least

[1]Moreira, L. M., and S. De P. Siciliano. 1991. Northward extension range for *Pontoporia blainvillei*. Ninth Biennial Conference on the Biology of Marine Mammals, Chicago, IL (unpublished). (Available from the first author.)

[2]Lázaro, M. 2000. Variación genética y estructura poblacional de la franciscana: Aporte de un estudio basado en ejemplares de la costa uruguaya. IV Workshop para a Coordenação da Pesquisa e Conservação da franciscana, Pontoporia blainvillei, no Atlântico Sul Ocidental. Porto Alegre, RS, Brazil (unpublished). (Available from the first author.)

three distinct stocks of Franciscana exist (Franciscana Management Unit: FMU I, FMU II, and FMU III–IV). Boundaries need to be reconfirmed as new information becomes available. With particular regard to boundaries between FMU III and IV, more information is required to define whether they should be considered one management area or two. In addition, this is the region where annual mortality is higher even though it seems to be highly variable from year to year (Secchi *et al.* 2004*b*).

Its distribution was traditionally thought to be restricted to coastal waters within the 30-m isobath (Pinedo *et al.* 1989), which makes it more vulnerable to anthropogenic activities. It has also been proposed that CPUE could be related to relative abundance (Corcuera 1994, Corcuera *et al.* 2000). Nevertheless, one thing that remains unknown to date is, how far from the coast the Franciscana is found.

In view of these conservation research needs, we studied the distribution and abundance of Franciscana in Argentine waters, in the southern part of the species' range where mortality rates may be threatening the stock (FMU IV by Secchi *et al.* 2001*a*, 2004*a*). Specific objectives included the study of patterns of density across regions, seasonal changes between summer and fall, and shallow *vs.* deeper waters. Density was then extrapolated beyond the surveyed area to waters with similar characteristics in order to obtain abundance estimates for the whole Argentine coast.

Materials and Methods

Study Areas and Aerial Survey Designs

The survey was conducted along the Argentine coast, where we defined two different areas of interest (Fig. 1) taking into account the available data about the Franciscana's distribution pattern, the intensity of fishing effort, and the occurrence of incidental mortality: (1) northern area (NA), corresponding to the northern coast of Buenos Aires province between Lavalle and Claromecó and (2) southern area (SA), corresponding to El Rincón, on the southern coast of Buenos Aires province and Golfo San Matías. The border between NA and SA was determined by a straight line at 61°W from the coastline to the 30-m isobath.

Four aerial surveys were designed: two for the NA (designs 1 and 2, Fig. 1) and two for the SA (designs 3 and 4, Fig. 1). The selection was based on the availability and cost of aircraft, conditions for safety and security, and fuel accessibility. Each survey design was planned in advance with 20 line transects between the shoreline and a distance of 27.8 km (15 nmi) from the coast.

Transect length was defined according to security restrictions of the private company owner of the rented aircraft. The basic plan was to follow transects in a zigzag pattern. Surveys were undertaken on a calm sea state (Beaufort 3 or less). This design has been previously and successfully tested in southern Brazil for the Franciscana dolphin (Secchi *et al.* 2001*b*) and for dusky and Commerson's dolphins in Patagonia[3] (Schiavini *et al.* 1999).

[3]Data from Pedraza, S. N., A. C. M. Schiavini, E. A. Crespo, S. L. Dans and M. A. Coscarella. Abundance of Commerson's dolphins (*Cephalorhynchus commersoii*) in the coasts of Patagonia (Argentina) (unpublished).

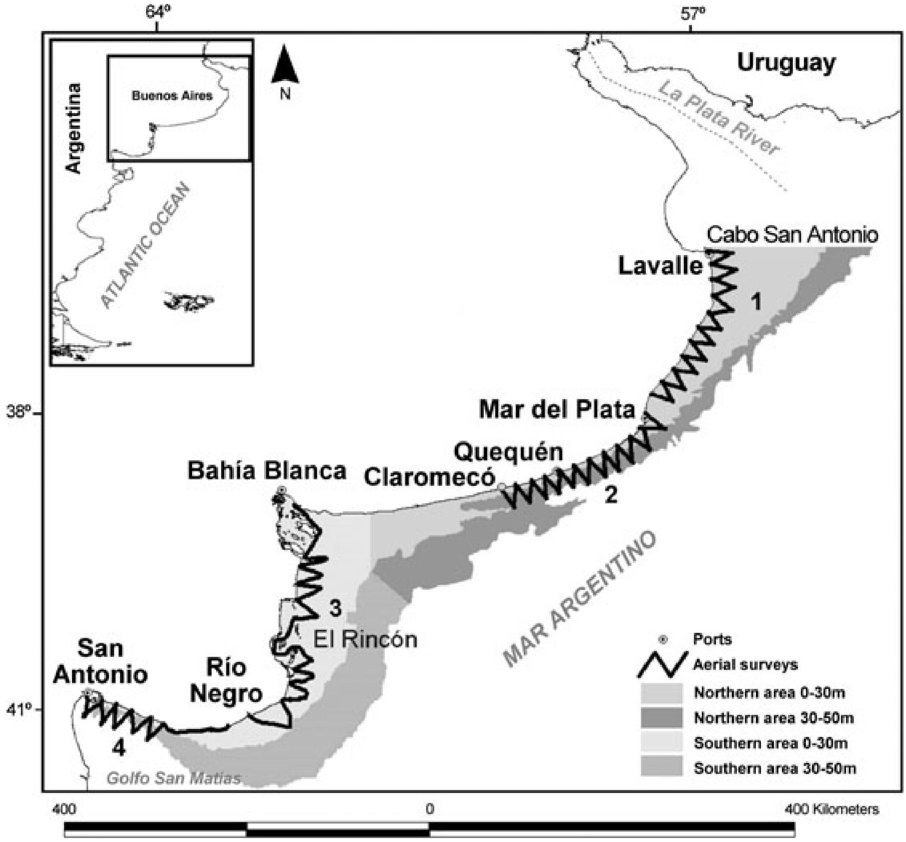

Figure 1. Study area and survey designs for Franciscana abundance estimates, along the Argentine coast. Northern area: survey 1 (Lavalle to Mar del Plata) and survey 2 (Mar del Plata to Claromecó). Southern area: survey 3 (Bahía Blanca to the mouth of Río Negro River) and survey 4 (northern coast of Golfo San Matías). The line dividing the 0- to 30-m strata from the 30- to 50-m strata corresponds to the 30-m isobath and the line limiting the 30- to 50-m strata corresponds to the 50-m isobath.

The surveys were carried out using a high-wing, twin-engine Cessna 337 Super-Skymaster aircraft. Four people traveled on each flight: the pilot, one recorder, and one observer on each side of the plane. Declination angles between the horizon and the animals detected were recorded by means of a clinometer. Those angles were converted into distances by trigonometric calculations. Average speed of the aircraft remained fairly constant around 166 km/h (90 kn) at a height of about 152 m (500 ft).

We surveyed the NA with fifteen flights (seven for survey design 1 and eight for survey design 2). On the other hand, the SA was surveyed only once with two flights, one for each of design 3 and 4. A total of 60 h was spent flying with an estimated 3.5 h per flight. The NA was surveyed in February and May of 2003 (summer and autumn, respectively) and February 2004, while the SA was only surveyed in February 2003. Thus, seasonal variations in density could only be tested in the NA.

Detection Probability (g_0)

Considering the chance of missing submerged dolphins, the probability of detecting a Franciscana was estimated based on the equation used by Barlow *et al.* (1988) in abundance estimation of harbor porpoises (*Phocoena phocoena*). This equation was previously used for the abundance estimation of Franciscanas at Rio Grande do Sul (Secchi *et al.* 2001*b*):

$$g_0 = \Pr(\text{dolphin is visible} \mid \text{dolphin is on transect line}) = \frac{s + t}{s + d},$$

where s is the average time of a Franciscana being at the surface, d is the average time of a Franciscana being submerged, and t is the time window during which the Franciscana is within the visual range of an observer. Values of s and d were obtained in free-living behavioral studies in the wild during the summer season (Bordino *et al.* 1999, Bordino 2004, Bordino[4]), while t was measured directly on board the aircraft from seabirds, carcasses, or any other floating objects. For completeness we define $g_0 = 1$ if $t > d$. The variance of g_0 was estimated by the delta method (Seber 1982) given by the following equation:

$$\mathrm{Var}(g_0) = \mathrm{Var}(d)\left[\frac{-s - t}{(s + d)^2}\right]^2 + \mathrm{Var}(t)\left[\frac{1}{\left(s + d\right)}\right]^2 + \mathrm{Var}(s)\left[\frac{d - t}{(s + d)^2}\right]^2.$$

Parameters s and d were re-estimated by Bordino (2004) and t was estimated by the authors on board the aircraft. Even though the values of s and d are correlated, the information for each was taken independently in different events. Given that there was no chance of estimating the covariance, it was assumed to be 0 for the calculation of $\mathrm{Var}(g_0)$ as in other previous articles (Secchi *et al.* 2001*b*).

Density Estimates

Franciscana density ($D = D_u$ = uncorrected density) was estimated using the standard distance sampling methods applied to clusters of animals (Buckland *et al.* 1993, 2001). Data were analyzed using the program DISTANCE 4.1 Release 2 (Thomas *et al.* 2004). Essentially, the program fits a detection function to the distribution of perpendicular distances, and this function is used to estimate the effective strip half-width (*ESW*). Then, the density is given in the following equation:

$$D = \frac{n \times Es}{2l \times ESW},$$

where n is the number of sightings on effort, l is the total search effort, and Es is the mean cluster size. The quantity n/l is referred to as the encounter rate that is the number of sightings per km surveyed. A blind strip was left on each side below the plane because the flat windows in the aircraft did not permit the detection of animals at angles closer to the transect line.

[4]Personal communication from P. Bordino, Fundación Aquamarina-CECIM, M. Díaz Velez 315–1° C, (1636) La Lucilla, Buenos Aires, Argentina, February 2005.

In order to study the detection function, the following models were initially considered: half-normal with cosines, half-normal with Hermite polynomials, hazard rate with cosines, and uniform with cosines. For each model the number of adjustment terms required was selected using the likelihood ratio test ($\alpha = 0.05$) and model selection was made using the Akaike information criterion (AIC) (Buckland *et al.* 2001).

Only the two survey designs included in the NA were tested for homogeneity, because data from the SA were not enough for such analysis, considering each design as a different stratum. Homogeneity was also tested among depth categories. Survey design 2 (from Mar del Plata to Claromecó, Fig. 1) allowed testing differences in density between the following two strata: (1) from the coast to the 30-m isobath and (2) from the 30-m to the 50-m isobaths. Temporal patterns in density were also analyzed.

The variance estimate of pooled and uncorrected ($g_0 = 0$) densities D_u was obtained with DISTANCE 4.1 Release 2 (Thomas *et al.* 2004). For corrected densities $\hat{D} = \hat{D}_u \hat{g}_0^{-1}$ variance estimates were calculated with the delta method (Seber 1982) given the following equation:

$$\mathrm{Var}(\hat{D}) = \hat{g}_0^{-2} \cdot \left(\mathrm{Var}(\hat{D}_u) + \hat{D}^2 \cdot \mathrm{Var}(\hat{g}_0)\right).$$

Confidence intervals for the corrected density were calculated as $(\hat{D}/C\,;\,\hat{D} * C)$ according to Buckland *et al.* (2001), where $C = e^{(z_{\frac{\alpha}{2}}\sqrt{\ln(1+(CV(D))^2)})}$ where $z_{\frac{\alpha}{2}} = z_{0.025} = 1.96$ for a 95% confidence interval.

Extrapolation of Survey Results to the Whole Area

In order to analyze mortality estimates in gill-net fisheries with respect to abundance estimation, the results obtained for density in the area surveyed were extrapolated to the whole area where Franciscana is known to inhabit Argentine waters from Lavalle to San Antonio Oeste in the northern coast of Golfo San Matías (FMU IV according to Secchi *et al.* 2004*a*) and from the coast to the 30-m isobath. An exception was made for the La Plata River (border between Argentina and Uruguay), which was not surveyed due to the lack of fuel availability.

Two criteria have been suggested previously as offshore borders to the Franciscana distribution (Pinedo *et al.* 1989): (1) the 30-m isobath and (2) the 55.5 km (30 nmi) distance from the coast. In this article we considered that the 30-m isobath best fits the distribution pattern of the species in the area based on the depth distribution of aerial sightings of Franciscanas in the surveys. However, Franciscanas were sighted in the aerial survey design 2, which was flown on deeper waters, allowing the estimation of density for the stratum between the 30- and 50-m isobaths. Nevertheless, this density was not extrapolated to waters between those isobaths due to the low proportion between the surface surveyed and the surface of the stratum.

Therefore, density was extrapolated to nonsurveyed areas between 0 and 30 m, with powerful criteria using GIS software by integrating the digitalized bathymetry. Given these criteria the total surface to which extrapolation should be carried out was as follows: NA from the shoreline to 30-m isobath, 21,961.04 km^2; SA from the shoreline to 30-m isobath, 29,927.05 km^2 (Fig. 1).

Table 1. Detail of flights carried out by area and number of sightings and Franciscanas.

Area	Surveys	Date	Sightings	Individuals	Distance (km)
S	Golfo San Matías	9 February 2003	2[a]	5[a]	298.65
S	El Rincón	10 February 2003	4	8	564.91
N	MDP–Claromecó[b]	11 February 2003	2	4	212.2
N	MDP–Claromecó[b]	13 February 2003[c]	1	1	209.07
N	MDP–Claromecó	13 February 2003[d]	1	1	527.11
N	MDP–Lavalle	18 February 2003[c]	8	9	508.52
N	MDP–Lavalle	18 February 2003[d]	1	1	333.51
N	MDP–Claromecó	29 April 2003	9	14	469.43
N	MDP–Lavalle	30 April 2003	6	9	496.3
N	MDP–Lavalle	1 May 2003	6	8	512.92
N	MDP–Claromecó	2 May 2003	6	9	483.33
N	MDP–Claromecó	3 May 2003	9	11	540.61
N	MDP–Lavalle[b]	4 May 2003	–	–	71.7
N	MDP–Lavalle[b]	12 February 2004	2	6	245.05
N	MDP–Claromecó[b]	14 February 2004	2	2	185.16
N	MDP–Lavalle	16 February 2004	7	10	487.6
N	MDP–Claromecó	18 February 2004	7	8	488.36

[a] Recorded doubtful identification.
[b] Interrupted flight.
[c] Morning.
[d] Afternoon.

Results

Detection Probability

Values of s, d, and t were estimated respectively to be 1.2 ± 0.4 s, 27.95 ± 4.41 s, and 7.0 ± 1.44 s. The time window t corresponds to a distance of about 292 m. The estimates for g_0 resulted in a correction factor of 0.281 ± 0.048.

Abundance Estimation

A total of 101 Franciscanas were observed in 71 sightings (Table 1). The size of the group, computed by simple average, ranged between one and five individuals with an average of 1.43 individuals per group (SD = 0.85). Solitary individuals represented 73.2% of the total individuals sighted, while the remaining individuals were in groups of different sizes (Fig. 2). This figure was obtained from a total of 6,634.43 km flown under favorable conditions and over 300 transects distributed as follows: from Lavalle to Mar del Plata (survey design 1) the area was covered with 122 transects (2,655.60 km), from Mar del Plata to Claromecó (survey design 2) the area was covered with 146 transects (3,115.27 km), El Rincón (survey design 3) was covered with 22 transects (564.91 km), and the northern coast of Golfo San Matías (survey design 4) was covered with 10 transects (298.65 km). The total surface area flown was 17,305.95 km^2, which represents 33% of the total surface to which density was extrapolated.

The distance of $x = 0$ from the transect line was considered to occur at a perpendicular distance of 88 m (clinometers angle of 60°), and all other distances rescaled

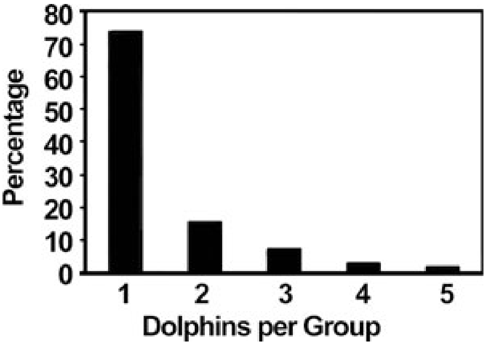

Figure 2. Franciscanas group size.

accordingly. The rescaled perpendicular distances were left-truncated at a distance of 25 m in order to correct for the peak of observations away from zero distance as a consequence of observation bias. The detection function was then extrapolated and fitted to these truncated data back to the track line. It is suspected that some dolphins could have been missed at 25 m beyond the 88-m blind spot under the plane as a consequence of improper observation by some of the observers. Data were also right-truncated at $w = 200$ m, therefore leaving a strip width of 175 m. In this way, the required shoulder close to zero distance could be fitted. In view of the minimum AIC, the uniform model with an expansion series of cosines of order one was selected to model the detection function (Fig. 3).

Franciscana sightings were analyzed as clusters on the basis of the high proportion of herds of different size sighted from the aircraft, almost 30%. With regard to parameter estimation, the encounter rate, the detection probability, the expected cluster size and density were either analyzed by stratum or for all data combined.

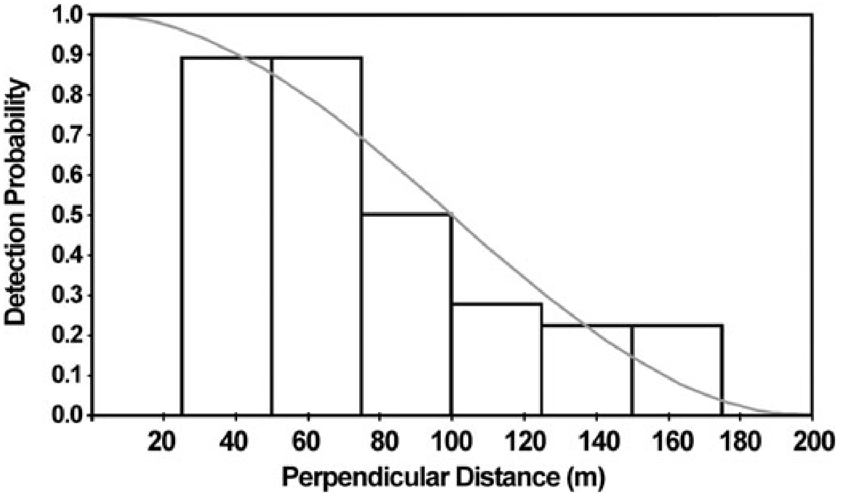

Figure 3. Detection probability function of Franciscana sightings.

Table 2. Analysis by stratum of the two northern survey designs.

		Estimate	% CV	df	95% CI
	n/l	0.010	25.33	117	0.006–0.016
Survey design 1	E(S)	1.360	11.92	24.00	1.064–1.738
MDP—Lavalle	DS	0.064	28.41	139.78	0.037–0.111
	D	0.087	30.81	163.77	0.048–0.157
	N	580	30.82	163.77	320–1,051
	n/l	0.009	19.16	145.00	0.006–0.013
Survey design 2	E(S)	1.38	8.37	28.00	1.162–1.637
MDP–Claromecó	DS	0.062	23.10	148.38	0.039–0.097
	D	0.085	24.57	174.01	0.053–0.137
	N	570	24.57	174.01	353–919

n/l = encounter rate (clusters/km); E(S) = estimate of expected value of cluster size (number of dolphins); DS = estimate of density of clusters (dolphins/km^2); *D* = estimate of density of animals (dolphins/km^2); N = estimate of number of animals in specified area (number of dolphins).

Abundance Estimation for the Northern Area

We found no differences between survey designs 1 and 2, either in the encounter rate, the detection probability, or the expected cluster size (Table 2). The detection function in this analysis was uniform with an expansion series of cosines of order one. Therefore, we treat the NA as one stratum.

Regarding the existence of a seasonal pattern in density, the summer estimate was found to be lower (0.065 individual/km^2 for 2003 and 0.049 individual/km^2 for 2004) in comparison with that for autumn (0.106 individual/km^2). The encounter rate was also lower in summer (0.005–0.007 cluster/km) than in autumn (0.012 cluster/km) flights. Coefficients of variation (CV) as well as confidence intervals of all parameters were larger in summer than in autumn. However, the wide confidence intervals indicate that the difference is not statistically significant (Table 3). The pooled estimate for density of clusters was 0.086 individual/km^2 (Table 3). In the absence of potential seasonal differences that could explain a lower density in summer, and on the base of better quality of the autumn flights, the density in autumn (0.106 individual/km^2) was considered a better figure for estimating Franciscanas abundance. The lower CV for all parameters during autumn surveys also supported this view. Autumn flights were performed in more homogeneous meteorological conditions with regard to wind and values of sea state, allowing sighting a higher number of Franciscanas.

The most important components of variance were related to encounter rate, model selection and cluster size, of which the former was always over 70% in autumn and reaching more than 90% in summer seasons. Model selection was adequate for the data collected (3.5%–18%) and cluster size contribution was very small most of the time (2.1%–1.2%).

Regarding differences with respect to depth, 60% of survey design 2 (Mar del Plata–Claromecó) was carried out in deeper waters. On the basis of the Franciscanas sighted beyond the 30-m isobath, this design allowed testing for differences in density between two depth strata. Results indicate that density is statistically lower when approaching higher depths. For the first stratum density was 0.107, while

Table 3. Parameter estimation for summer and autumn flights.

	Parameter	Estimate	SE	% CV	95% CI
Summer 2003	*ESW*	75.318	6.863	9.11	62.761–90.388
	n/*l*	0.007	0.003	37.72	0.003–0.015
	DS	0.047	0.018	38.81	0.023–0.100
	E(S)	1.370	0.096	7.03	1.190–1.578
	D	0.065	0.026	39.44	0.031–0.138
	N	870	343.13	39.44	409–1,850
Autumn 2003	*ESW*	75.318	6.863	9.11	62.761–90.388
	n/*l*	0.012	0.002	17.56	0.008–0.016
	DS	0.077	0.015	19.79	0.053–0.114
	E(S)	1.370	0.096	7.03	1.190–1.578
	D	0.106	0.022	21.00	0.070–0.159
	N	1,416	297.36	21.00	940–2,132
Summer 2004	*ESW*	75.318	6.863	9.11	62.761–90.388
	n/*l*	0.005	0.003	47.49	0.002–0.013
	DS	0.036	0.017	48.36	0.014–0.090
	E(S)	1.370	0.096	7.03	1.190–1.578
	D	0.049	0.024	48.86	0.019–0.125
	N	651	318.11	48.86	255–1,665
Pooled	DS	0.062	0.008	21.24	0.032–0.122
	E(S)	1.370	0.096	7.03	1.190–1.578
	D	0.086	0.010	22.37	0.045–0.161
	N	1,144	133	22.37	606–2,157

ESW = effective strip width (m); *n*/*l* = encounter rate (clusters/km); DS = estimate of density of clusters (dolphins/km^2); E(S) = estimate of expected value of cluster size (number of dolphins); *D* = estimate of density of animals (dolphins/km^2); N = estimate of number of animals in specified area (number of dolphins).

Table 4. Parameter estimation for depth strata in northern area, MDP–Claromecó.

	Parameter	Estimate	% CV	95% CI
Stratum 1	*n*/*l*	0.016	23.04	0.001–0.023
Coast to 30-m isobath	DS	0.077	19.79	0.052–0.114
	D	0.107	32.53	0.057–0.201
Stratum 2	*n*/*l*	0.008	25.43	0.005–0.013
30-m to 50-m isobaths	DS	0.034	35.50	0.017–0.067
	D	0.050	37.25	0.024–0.102

n/*l* = encounter rate (clusters/km); DS = estimate of density of clusters (clusters/km^2); *D* = estimate of density of animals (dolphins/km^2).

beyond the 30-m isobath density falls to 0.05. Encounter rate also falls in the second stratum to half of the first one (Table 4).

Abundance Estimation for the Southern Area

The estimation of density (D_u = 0.055 dolphin/km^2; CI = 0.018–0.169; % CV = 59) for this area is weak compared to the northern coast because the SA was

Table 5. Corrected density and abundance for northern and southern areas.

	Area (km^2)	D_u	$\hat{D}$	Estimated abundance	95% CI	
Northern area (0–30 m)	21,961.04	0.106	0.377	8,279	4,904	13,960
Southern area	29,927.05	0.055	0.197	5,896	1,928	17,999

D_u = density uncorrected; $\hat{D}$ = density corrected.

surveyed with only two flights. It was not possible to obtain a detection function for the SA alone due to the lack of data and the low goodness of fit to data. Therefore, the detection function obtained in the NA was used to estimate density in the SA. The sighting frequencies were also better fitted to the uniform model with cosines.

The component percentage of variance of density in the SA was mostly explained as in the north, by the encounter rate (96.3%), while the detection probability function explained 2.3% and the cluster size 1.5%. Density and the encounter rate (0.006 cluster/km) were little more than half of the pooled values obtained in the NA.

Correction for Density and Population Size Estimates

Uncorrected density estimates of the northern and southern areas were corrected applying the correction factor (CF = 0.281 ± 0.048) for submerged animals (Table 5). Estimates of abundance for the NA are based on the autumn density for the stratum between the shoreline and the 30-m isobath. Abundance was estimated for the NA as 8,279 individuals with confidence intervals shown in Table 5. The abundance in the SA was estimated as 5,896 dolphins with very wide confidence intervals (Table 5). If the individuals of the NA and SA were to be added, the total population for the stratum between the coast and the 30-m isobath for the Argentine coast could be estimated to be 14,175 individuals.

An abundance of 470 additional Franciscanas was estimated in deeper waters in survey design 2 (30- to 50-m isobaths). The density estimated for this stratum was not extrapolated to nonsurveyed areas (shown in dark gray in Fig. 1). A rough estimation of the corrected density suggests that a few thousand Franciscanas could inhabit 37,000 km^2 of deeper waters (D_u = 0.05 dolphin/km^2; CI = 0.024–0.102; $\hat{D}$ = 0.178 dolphin/km^2).

Discussion

Abundance Estimate

This is the first estimation of absolute density of Franciscanas in Argentine waters conducted for this threatened dolphin. New information was also gained regarding distribution at sea. The Rio Grande do Sul survey is the only one that allows some comparison between density results. At Rio Grande, the density was estimated at 0.657 individual/km^2 (Secchi *et al.* 2001*b*), while in Argentina it was 0.377 individual/km^2. In both cases the comparison is between corrected values of density for submerged animals. The density estimated along most of the coast of Buenos Aires province seems to be much lower than in Southern Brazil.

Rio Grande surveys were constrained by the single-engine aircraft, which did not allow flying beyond 9.3 km (5 nmi) from the coast. Therefore, the flights were restricted to a very shallow and coastal area where density may be substantially higher. The survey area in this case is also characterized by the continental runoffs of the Lagoa dos Patos. On the other hand, Buenos Aires surveys were flown with a twin-engine aircraft that allowed flying a maximum distance of 27.8 km (15 nmi).

Buenos Aires surveys required a greater effort. Rio Grande flights lasted an hour and covered 185 km, whereas Buenos Aires flights lasted for 3.5 h and averaged 500 km. Although long flights could have resulted in a lower encounter rate and consequently a lower estimate of density because of observer fatigue, there was no difference in the number of sightings between the first and the second half of the flight. Thus, we concluded that the observer attention was not affected by time onboard the aircraft. Buenos Aires flights were conducted in more open areas with lower effects of runoffs from continental waters, at least in survey design 2 for Mar del Plata–Claromecó. The survey design for Mar del Plata–Lavalle is more similar to Rio Grande waters due to the continental runoffs of La Plata River.

One important point to be clarified in the future is the offshore border of Franciscana distribution. Corcuera *et al.* (1994) showed a clear decline in Franciscana absolute catches in the fishing area that corresponds to the survey design 2 (Mar del Plata–Claromecó). That fishery operated at that time (late 1980s–early 1990s) as far as 37–46 km offshore, slightly beyond the survey area reported in this article. Nevertheless, the distribution of catches by depth and distance to the coast were not weighted by fishing effort. In the present work Franciscana sightings showed no differences with regard to distance to the coast in the Mar del Plata–Lavalle survey but decreased in the Mar del Plata–Claromecó survey as a consequence of having flown over areas of greater depths where density falls.

Another factor that could have resulted in slightly lower encounter rates and density estimates at Buenos Aires was the fraction of animals that reacted to the passing aircraft. The twin-engine aircraft used for Buenos Aires surveys was noisier than the single-engine plane used in Rio Grande surveys. Most sightings were of animals at the surface, though a small percentage corresponded to submerged animals swimming underwater (11.5%). At Buenos Aires a fraction (25%) of Franciscanas showed a sudden change from swimming to diving to deeper waters. This diving reaction was not seen in Rio Grande surveys. We observed this behavior previously only with Commerson's dolphins in northern Patagonia using the same twin-engine aircraft for aerial surveys. While aircraft noise could have resulted in some animals being missed, most of the animals that were swimming at the surface did not show any reaction to the passing aircraft so it is likely that the number missed was small.

Our study provides an estimate of the minimum number of animals present in the area surveyed. The low encounter rate for Franciscanas reflects the difficulty of sighting a small size dolphin that is seen alone or in small herds most of the time and that spends most of the time underwater. The substantial variation in the encounter rate also decreases the precision of the estimate. A slight underestimation of the detection function (leading to an overestimation of density) could be expected given the low number of observations in the interval 0–25 m.

With regard to the lower densities observed in summer in comparison to autumn, there could be two main explanations acting together or alone. One could be a real decrease in density during summer months, which has not been demonstrated in any study to date. All the evidence supports the hypothesis that Franciscanas do not disperse much from their location, suggesting a clear residence pattern throughout the year. Satellite-tagged animals in Bahía Samborombón and Bahía Anegada between 2007 and 2008 remained in the area for about 6 months during late summer and autumn,[5,6] (Méndez *et al.* 2007). The second explanation could be that autumn surveys are of better quality. Autumn is the season of the year in which wind speeds are lower. In fact, autumn surveys were uniformly done at sea states of Beaufort 2. Sea states during summer surveys were more heterogeneous, with transects conducted in states ranging from 0 to 4. The fact that summer densities may be lower than autumn ones may have important implications for conservation because the fisheries that cause the higher mortalities operate mainly during the summertime.

Conservation Considerations

Currently, it is known that the Franciscana is caught in gill nets throughout its distribution range (see Secchi *et al.* 2001*a*). In particular, Buenos Aires province and Rio Grande do Sul seem to be the regions with the highest mortalities[7] (Corcuera *et al.* 1994, Secchi *et al.* 1997, Bordino *et al.* 2002). Mortality in Argentine waters has been estimated at different periods starting in the mid-1980s, when the number of individuals caught per year was around 350 Franciscanas (Pérez Macri and Crespo 1989). Later studies estimated similar or higher levels of mortality, even though the fisheries in Buenos Aires province reduced its fleet size, fishing effort, and changed its location, mainly due to economic reasons. While large fisheries for sharks, like the one operating at Puerto Quequén in southern Buenos Aires province (Corcuera *et al.* 1994), declined, small fishing camps started to operate closer to the coast in summertime by small groups of fishermen fishing for bony fishes, with small rubber boats (Corcuera 1994, Bordino[8]). Most of these estimates of mortality include large extrapolations to the whole fleet in order to estimate gross numbers of dolphins killed. On this basis, 500 animals killed per year was the common figure during the last decade (Secchi *et al.* 2003). This represents around 3.5%–4% of the stock between the coastline and the 30-m isobath that may be removed each year by the fishery only in Argentine waters (mean bycatch divided by mean abundance). Bordino and Albareda[9] estimated a gross mortality of 800 individuals per year, which in turn increases the potential removal up to 5.6% of the total population or even worse, 9.7% of the northern stock each year.

[5]Bordino, P., R. S. Wells and M. A. Stamper. 2007. Site fidelity of Franciscana dolphins *Pontoporia blainvillei* off Argentina. 17th Biennial Conference on the Biology of Marine Mammals, Cape Town, South Africa (unpublished). (Available from the first author.)

[6]Bordino, P., R. S. Wells and M. A. Stamper. 2008. Satellite tracking of Franciscana dolphins (*Pontoporia blainvillei*) in Argentina: Preliminary information on ranging, diving and social patterns. 13° Reunión de Trabajo de Especialistas en Mamíferos Acuáticos de América del Sur, Montevideo, Uruguay (unpublished). (Available from the first author.)

[7]Cappozzo, H. L., F. Monzón, J. Pérez and J. Corcuera. 1999. Mortality of La Plata River dolphin, *Pontoporia blainvillei*, in southern Buenos Aires Province, Argentina (1998): Big changes that change nothing. 13th Annual Conference of the European Cetacean Society, Valencia, Spain (unpublished). (Available from the first author.)

[8]Personal communication from P. Bordino, Fundación Aquamarina-CECIM, M. Díaz Velez 315–1° C, (1636) La Lucilla, Buenos Aires, Argentina, August 2008.

[9]Bordino, P., and D. Albareda. 2005. Incidental mortality of Franciscana dolphin (*Pontoporia blainvillei*) in costal gillnet fisheries in Buenos Aires, Argentina. V Taller para la Coordinación de la Investigación y Conservación del delfín franciscana (*Pontoporia blainvillei*) en el Atlántico Sudoccidental. Mar del Plata, Argentina (unpublished). (Available from the first author.)

The International Whaling Commission Scientific Committee has noted that incidental mortality rates of 1% of the population size may be a matter of concern to the status of a given population (Donovan and Bjørge 1995) and incidental catches of 2% may not be sustainable (Secchi *et al.* 2001*b*). Wade (1998) introduced the concept of keeping populations at levels above the maximum net productivity level, which as defined by U.S. laws lies between 50% and 70% of carrying capacity. This concept is based on abundance, bycatch, and population growth rates and is known as the potential biological removal (Wade 1998). It is generally accepted that bycatch rate would not exceed 0.5 of $R_{\max}$ (maximum rate of increase). Secchi and Fletcher (2004) estimated the rate of increase for Franciscana stocks to vary between 2% and 3.5%. In any case, the removal is well over the maximum rate of increase.

Several studies quantified the annual mortalities as well as CPUE along the Argentine coast, suggesting that the variability in CPUE could be explained by variability in density, unknown at that time (Corcuera *et al.* 2000). The present study shows that there is no relation between areas of high or low density and CPUE values for those areas. In other words, high mortality is not found where density is higher and *vice versa* (Table 6). For example, CPUE shows the lowest values in the Rio Grande do Sul state in Brazil, where density is double compared to Argentine waters. Those CPUE values are one order of magnitude lower. In southern Buenos Aires province, density falls to one-half with respect to the north. Surprisingly, CPUE is double than in the north. On a large spatial scale, density declines to the south of the distribution range while CPUE increases. This means there is a different catchability of Franciscanas through its distribution range, which in turn reflects either differences in fishing gear or the spatial pattern of dolphin distribution. For example, if dolphins tend to be more aggregated and at the same time overlap with fishing areas, a clumped distribution pattern could be associated with predation for sciaenid fish in nursery areas. Such spatial pattern is worth further exploration in order to define management actions related to fisheries and the conservation of local populations.

On the other hand, higher annual mortalities were detected in two distinct areas: the northernmost marine coastal area of Buenos Aires province (Cabo San Antonio) and the southernmost marine coastal area of Buenos Aires province (El Rincón), where mortalities were estimated to be more than 54 dolphins per year (Corcuera *et al.* 2000). The latter would occur over lower densities, representing therefore higher proportions of dolphins extracted each year.

Mortality and abundance estimates need to be monitored continuously in order to provide the authorities with some of the priority information needed to design the best management options. Bycatch estimates in Argentina, as in many other countries, suffer from lack of continuity, seem to be highly variable from year to year and show rapid changes in response to meteorological and economic conditions. Mortality rates also depend on individual behavior of fishermen (Corcuera 1994). More refinement is needed on incidental mortality rate estimates. Time trends in abundance of dolphins or commercial fish stocks may influence the results. For example, as dolphin density declines, the encounter rate with commercial fisheries may decline. Thus, bycatch rates will be a function of effort by the fleet and dolphin population size. Another possibility is the case where dolphins are attracted to locations commonly used by fisheries, so the encounter rate may remain high and bycatch rates constant although population size is declining.

The conservation strategy for the Franciscana depends on political decisions as well as on biological information, testing pingers to reduce mortality and experimental

Table 6. Comparison of CPUE and density values estimated by areas.

Locality	Latitude range	CPUE	CPUE data source	Corrected density	Density data source
Tramandaí–Torres (Brazil)	29°15′–29°58″	0.054–0.088	Ott *et al.* (2002)	0.5	Danilewicz[a]
Rio Grande (Brazil)	32°05′	0.0066	Ott *et al.* (2002)	0.657	Secchi *et al.* (2001*b*)
Uruguay	33°45′–34°55′	0.0064	Ott *et al.* (2002)	0.657	Secchi *et al.* (2001*b*)
Buenos Aires North (Argentina)	35°00′–38°08′	0.22–0.43	Corcuera (1994)	0.377	This paper
Buenos Aires North (Argentina)	36°30′	0.31–0.77	Bordino[b]	0.377	This paper
Buenos Aires South (Argentina)	38°08′–40°30′	0.0734	Ott *et al.* (2002)	0.178/0.377	This paper
Buenos Aires South (Argentina)	39°–41°	0.65	Corcuera (1994)	0.178	This paper

[a] Danilewicz, D., I. Moreno, P. Ott, M. Tavares, A. Azevedo, E. Secchi and A. Andriolo. 2005. A new abundance estimation for Franciscana dolphins in Rio Grande do Sul, Southern Brazil. V Taller para la Coordinación de la Investigación y Conservación del delfin Franciscana (*Pontoporia blainvillei*) en el Atlántico Sudoccidental. Mar del Plata, Argentina (unpublished). (Available from the first author.)

[b] Bordino, P., and D. Albareda. 2005. Incidental mortality of Franciscana dolphin *Pontoporia blainvillei* in costal gill-net fisheries in Buenos Aires, Argentina. V Taller para la Coordinación de la Investigación y Conservación del delfín Franciscana (*Pontoporia blainvillei*) en el Atlántico Sudoccidental. Mar del Plata, Argentina (unpublished). (Available from the first author.)

CPUE measured as dolphins caught per day per 1,000 m of net; density measured as dolphins/km^2.

trials to replace gill nets with less harmful fishing gears and educational programs directed to fishing communities. Up-to-date bycatch species are not considered in fishing monitoring programs in the region. In spite of this, there are practical decisions that could make mortality rates lower like relocating slightly offshore the most coastal fisheries, especially those with the highest values of CPUE, or banning fishing activities in nursing areas for Sciaenid fishes, the most important group of Franciscana's prey. Biological information is matter of ongoing research (ecological parameters, genetic studies, abundance, mortality rates estimations, *etc*.) together with experimental trials that include pinger trials and the evaluation of alternative fishing gear, which minimizes the bycatch without reducing the economic potential of the fishery, longlines in this case.

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