



# NOTES

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## ABUNDANCE OF DUSKY DOLPHINS (*LAGENORHYNCHUS OBSCURUS*) OFF NORTH AND CENTRAL PATAGONIA, ARGENTINA, IN SPRING AND A COMPARISON WITH INCIDENTAL CATCH IN FISHERIES

The dusky dolphin (*Lagenorhynchus obscurus*) inhabits the temperate waters of the continental shelf and slope off Peru, Chile, Argentina, New Zealand, southwestern Africa, and several offshore island groups (Van Waerebeek 1992). The biology and ecology of this species in Argentine waters has been described by Würsig and Würsig (1980), Dans *et al.* (1993, 1997a), and Crespo *et al.* (1997a).

The South Atlantic Ocean off Argentina covers about 4,000 km of coastline from the Province of Buenos Aires to Tierra del Fuego (Cape Horn). Offshore fishing is expanding in these waters. Several previous reports have expressed concern about the potential effect of the fisheries on top predators such as dolphins (Goodall *et al.* 1994; Crespo *et al.* 1994a,b, 1997a).

From 1993 to 1996 the Patagonian Coastal Zone Management Plan (a GEF/UNDP project)<sup>1</sup> gathered information on the distribution and abundance of several delphinids inhabiting the southwestern South Atlantic. This paper presents the first reliable estimation of abundance for dusky dolphins in this area, based on several surveys, as well as a comparison of the abundance estimation with incidental mortality levels due to offshore fisheries over the Patagonian shelf (Crespo *et al.* 1997a).

Our study area covered the waters off the Patagonian coast from San Antonio Oeste (40°44'S) to Cabo Guardián, south of Puerto Deseado (48°10'S). This large area was selected because the objective of the surveys was to assess abundance for three species: short-beaked common dolphin (*Delphinus delphis*), dusky dolphin, and Commerson's dolphin (*Cephalorhynchus commersonii*). Another objective of the program was to assess interactions between fisheries and marine mammals, since this area is under relatively intense coastal and offshore fishing activity. The waters from Península Valdés to Isla Rasa (Fig. 1) were particularly important because they include large concentrations of anchovies (*Engraulis anchoita*) (Cousseau *et al.* 1981), a significant food item of the dusky

<sup>1</sup> Global Environmental Fund/United Nations Development Programme

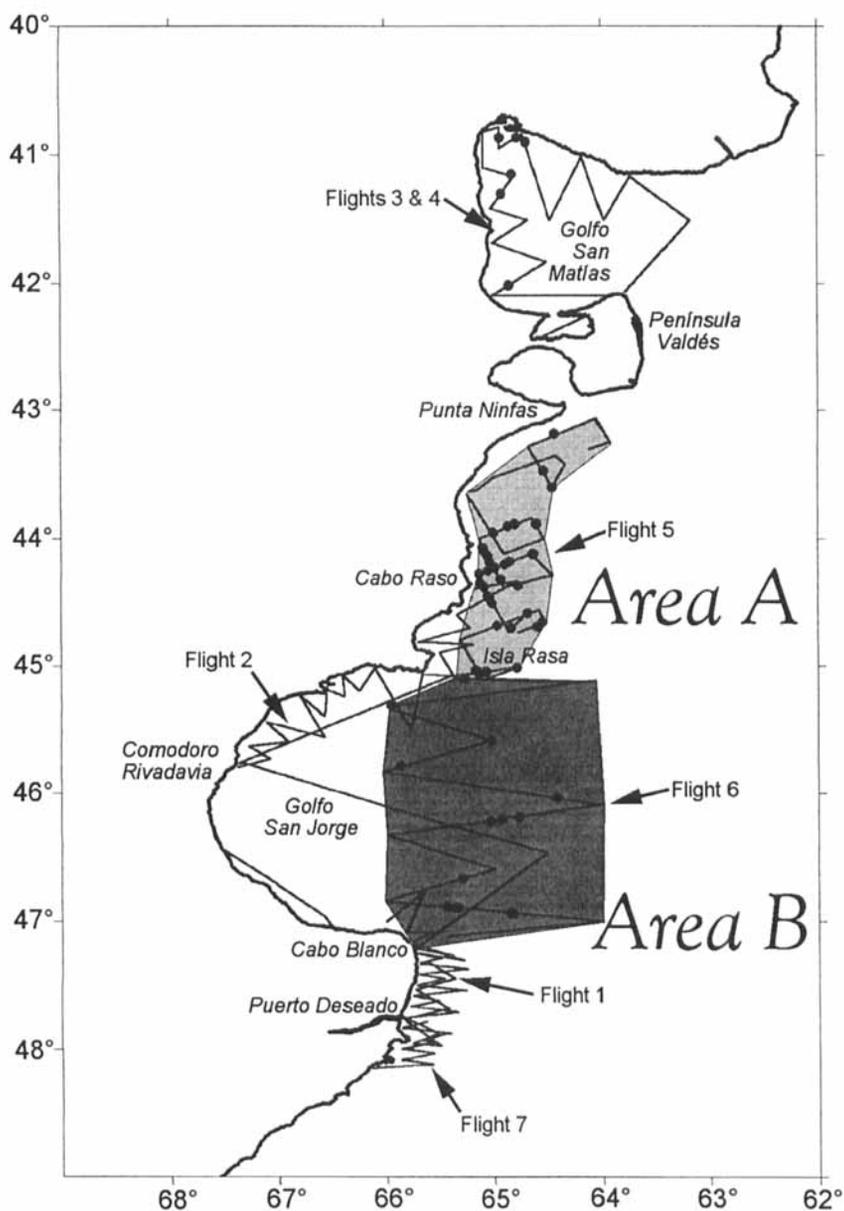


Figure 1. Line transects surveyed in southwestern South Atlantic Ocean off Patagonia, Argentina.

dolphin (Dans *et al.* 1993, Koen Alonso *et al.* 1998). The continental-shelf area between Península Valdés and Golfo San Jorge supports important fisheries for hake (*Merluccius hubbsi*) and shrimp (*Pleoticus muelleri*) (Crespo *et al.* 1994a,b, 1997a).

Our surveys followed line transect methods (Burnham *et al.* 1980, Buckland

*et al.* 1993). We planned them on the basis of previous sightings for the three species (Goodall *et al.* 1988, Crespo *et al.* 1997b, our own data), as well as information on their prey species (Cousseau *et al.* 1981, Otero *et al.* 1982, Dans *et al.* 1993, Crespo *et al.* 1997a, Koen Alonso *et al.* 1998).

The survey lines followed a systematic saw-tooth pattern, with the location of the first line chosen at random. One survey was flown using a boxlike design; the original idea was to explore the possibility of a differential distribution of sightings in relation to distance from the coast, using an alternative to the saw-tooth design, but this flight pattern was difficult for the pilots to follow. Therefore, we combined all data in the final analysis.

We used a high-wing twin-engine CASA-212 airplane operated by the Prefectura Naval Argentina. This plane is normally deployed in extensive fishing patrol activities and is rather fast for cetacean surveys, but it was the only high-wing twin-engine plane available in Patagonia for extended offshore flights. One flight was at 600 ft; the others at 500 ft. Speed was kept at the aircraft's lower limit, 120 kn. Cut-points for the transects were entered in the GPS system of the plane before the flight, so the flight was essentially automatic. However, it was necessary to correct the transects actually flown from the survey notes.

One observer covered each of the two bubble windows of the aircraft, allowing direct sight of the line. A third person was located between and slightly behind the pilots, to give the side observers advance warning of the presence of animals. This observer recorded all cetacean observations on forms and on audiotape. Two additional persons helped the primary observers and took photographs. To reduce fatigue, the positions were rotated approximately every 30 min during searching effort.

The basic data recorded for each sighting were GPS position, angle of declination, group size, identification to the lowest possible taxonomic level, Beaufort sea state, and sun position relative to the aircraft (for each leg). In cases of difficult species identification, the plane left the line and circled the group to allow identification and photographs.

The data were analyzed using the program DISTANCE 2.2 (Laake *et al.* 1996), which estimates  $f(0)$ , the probability density function evaluated at distance equal to zero. Three detection models were compared in the analysis: Half Normal with Hermite Polynomials Expansion Series, Fourier Series, and Hazard Rate, models frequently used in cetacean surveys (Buckland 1985, Leatherwood *et al.* 1988, Hiby and Hammond 1989, Forney *et al.* 1995). The final selection of the model was based on Akaike's Information Criterion (AIC) (Buckland *et al.* 1993), the fit of the model to the data (Chi-square test), the coefficient of variation of the pooled estimated density, and the percentage contribution of the detection probability to the overall variance.

We did not explore the uncertainty related to model selection by bootstrap analysis. Executing bootstrap over small units such as the transects flown over one day (each flight) may violate the assumption of independence between samples from which the resampling is done. In addition, the large number of transects with few or no sightings caused problems with the resampling, lead-

Table 1. Flight surveys carried out in southwestern South Atlantic.

Flight	Date	Area surveyed (nmi <sup>2</sup> )	Effort (nmi)	No. of sightings
1	17 Nov	Comodoro Rivadavia to Puerto Deseado	137	—
2	27 Nov	Cabo Raso to Comodoro Rivadavia	460	—
3	09 May	Golfo San Matías	411	4
4	31 Aug	Golfo San Matías	411	2
5	08 Nov	Punta Ninfas to Isla Rasa	486.5	38
6	27 Nov	off Golfo San Jorge	615	20
7	12 Dec	Cabo Blanco to Puerto Deseado	405	—

ing to collapse of DISTANCE during running. Therefore, the confidence intervals we present correspond to the output of DISTANCE, which follows the formula in Buckland *et al.* (1993:88–89), where the interval takes the shape of  $(fD/C; fD \cdot C)$ , with

$$C = \exp \left[ Z_{\alpha} \sqrt{\ln + \left( 1 \frac{\text{var } \hat{D}}{\hat{D}^2} \right)} \right]$$

We made seven flights, from San Antonio Oeste to Cabo Guardián, south of Puerto Deseado (Fig. 1, Table 1). Only flights 3–6 yielded sightings of dusky dolphins; we pooled all the observations to estimate  $f(0)$ . Environmental conditions such as sea state and sun position have been shown to influence sighting rates. Due to the low number of observations recorded in this study, it was not possible to evaluate these influences quantitatively. Flights were made during Beaufort conditions 0–2, but during the first three transects of Flight 3 Beaufort conditions rose to 3. During flight 4 the primary observers had to remain in their positions during the four hours of the flight. The other participants were untrained or were too airsick to observe from the windows. The fatigue of the primary observers may have affected the quality of the data acquired during this flight. Therefore, we excluded flights 3 and 4 for subsequent analysis.

For the density estimation, we analyzed only two areas with enough sightings to allow a reliable estimation. We based our decision on the extended latitudinal range covered by the surveys and our interest in the evaluation of the geographical variability in density. The two areas defined were (A) an area of 3,630 nm<sup>2</sup>, from Punta Ninfas to Isla Rasa and (B) an area of 9,408 nm<sup>2</sup> off Golfo San Jorge (Fig. 1), for a global coverage of 13,038 nm<sup>2</sup>. Each of the two areas included all the transects of flights 5 and 6, as well as transects (or part of transects) flown in flights 1, 2, or 7 and falling into these areas (Fig. 1). While transiting to the survey areas, the plane had to travel at increased speed and altitude in order to save fuel. For that reason, these transects and their sightings were excluded for the analysis. Areas A and B were surveyed with an overall effort of 560.3 nm and 865.4 nm, respectively, totaling 1,425.7

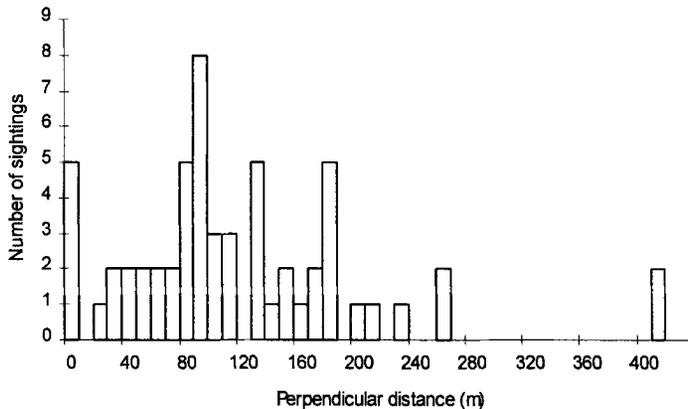


Figure 2. Frequency distribution of perpendicular distance raw data to sightings for dusky dolphin surveys. Cut-points every 10 m.

nm. We estimated encounter rate, expected cluster size, and density for each stratum (area). The overall density estimate was weighted by the area of each stratum.

During the exploratory analysis of the distance data, the distance frequency distribution histogram with cut-points every 10 m revealed a noticeable peak of sightings at about 80–100 m from the centerline, and a minor peak at about 160–180 m (Fig. 2). The frequency distribution of angles recorded for each flight was analyzed (regardless of the heights flown). This revealed a high relative frequency of readings every  $10^\circ$ . To correct heaping due to angle rounding, the cutpoints selected corresponded to distances related to clinometer readings of 0, 15, 25, 35, 45, and 55 degrees, averaging the distance determined for the two heights flown (500 and 600 ft). These cut-points were 0, 16, 44, 77, 116, 165 and 263 m. The interval from 0 to 44 m was pooled to avoid a “valley” in the frequency distribution. The right truncation at 263 m excluded two observations at 410 m.

Even with the analysis using four unequal intervals, there was a noticeable peak in the interval 77–116 m. The fit of a monotonically decreasing function would result in an underestimate of density due to a substantial portion of animals missed close to the centerline. For that reason we explored left truncation and rescaling of the data (with the left truncation point treated as zero distance; see details in Buckland *et al.* 1993). This procedure replaced the assumption of  $g(0) = 1$  with  $g(\text{left}) = 1$ . The left truncation points selected are presented in Table 2.

From the different grouping and truncation options presented in Table 2 we concluded that the fit for the four options is good, although the fit for the 80-m option is better. The truncation at 60 m yields larger density estimates than the others, suggesting a possible overestimation of density. The 60-m and 80-m options provide the density estimates with the lowest contribution to the overall variance due to the detection probability (Fourier Series). When comparing models for each grouping option, the Hazard Rate model yields

Table 2. Pooled density estimates and associated measures for three models considered, using different grouping and left-truncate options.

	Model	AIC	Chi-p	$\hat{D}$	CV ( $\hat{D}$ )	Component percentage of Var ( $\hat{D}$ ) due to detection probability (Area A; Area B)
No left truncation	Half-normal	183.95	0.33	0.46617	25.45	16.8; 15.2
5 unequal intervals	Fourier	184.22	0.3	0.48116	24.72	13.6; 12.3
right limit = 263 m	Hazard rate	184.69	0.36	0.43101	25.55	17.2; 15.6
Left truncated to 77 m	Half-normal	96.79	0.3	0.52969	27.02	14.6; 14.6
4 unequal intervals	Fourier	99.19	0.2	0.49013	29.14	22.9; 22.9
right limit = 333 m	Hazard rate	99.7	0.15	0.55903	31.57	31.1; 31.1
Left truncated to 60 m	Half-normal	122.98	0.33	0.66073	27	13.9; 15.1
rescaled 5 equal intervals	Fourier	123.1	0.25	0.61959	25.38	6.9; 7.6
right limit = 200 m	Hazard rate	124.21	0.16	0.79206	38.58	48.5; 51.0
Left truncated to 80 m	Half-normal	103.94	0.64	0.54788	27.39	14.9; 15.8
rescaled 5 equal intervals	Fourier	104.22	0.54	0.50835	25.31	6.2; 6.6
right limit = 200 m	Hazard rate	105.89	0.4	0.57961	33.09	34.0; 35.5

AIC = value of the Akaike's Information Criteria. Chi-p = probability of Chi-square test statistic.

$\hat{D}$  = estimated density. CV ( $\hat{D}$ ) = coefficient of variation.

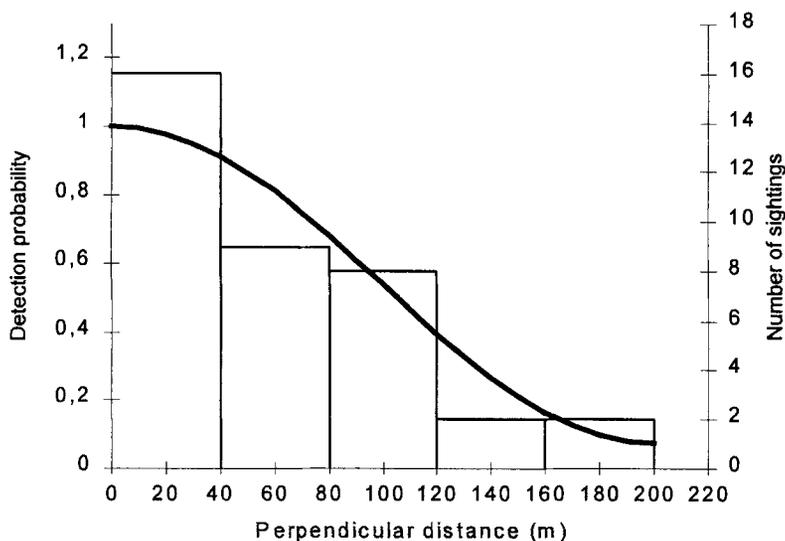


Figure 3. Frequency distribution of perpendicular distances to sightings for dusky dolphin surveys. Data rescaled to left-truncation point of 80 m. Continuous curve represents probability detection function based on fit of Fourier Series to perpendicular-distance data.

the largest CV. The AIC criterion would force the selection of the Half Normal model only for the 77-m option. For these reasons, we chose the left truncation option of 80 m, with a right limit of 200 m and five equal intervals, adjusting a Fourier Series (Fig. 3).

The peaks in our distance frequency histogram violate one of the assumptions of line transect methods, which is the need for the presence of a shoulder departing from the line for some distance and that the frequency of sightings should fall monotonically from the survey line. These peaks may be caused by: (1) movement of the animals in response to the airplane, (2) rounding error in the record of angles, or (3) searching methods, *e.g.*, observers spending more time searching in a comfortable position (viewing angle), causing them to focus attention on the line. The flight speed precludes further consideration of the first cause. The fact that there are no peaks close to the line (at zero distance, for example), suggests that rounding could not be a main factor affecting the distribution of the data. The peaks away from zero distance suggest that searching methods were a main factor in the observed distribution. The left truncation and rescaling of the data diminished this problem. However, the histogram could reflect chance variation due to the fairly small sample.

When comparing our results with those of other surveys for small cetaceans (Leatherwood *et al.* 1978, 1988; Gunnlaugsson and Sigurjónsson 1988; Forney *et al.* 1995; Polacheck 1995), the frequency distribution of dusky dolphin sightings falls more abruptly with distance. The steep histogram may be explained by the high flight speed in relation to the flight altitude, which may

have reduced the effective searching range. However, narrow strip widths have been reported from some ship surveys of harbor porpoises (Bjørge and Øien 1995, Palka 1995).

The estimated cluster size averaged from 1.69 to 3.42 individuals (Table 3). Most of the groups (95%) were of 10 individuals or fewer, with the exception of three herds (two of 15 and one of more than 50 animals). The latter were not considered in the analysis because they were recorded off the survey effort. The mean cluster size was different for areas A and B (Mann-Whitney test,  $P = 0.01$ ). Our group-size estimation may be low due to missing submerged animals because of high speed and searching methods. Larger groups were recorded off survey, when the plane circled these groups. Crespo *et al.* (1997b) reviewed the available information on distribution and group size (including this survey) and concluded that our group-size estimation is considerably lower than previously published (6–15 individuals).

The encounter rate was not significantly different between areas A and B (Mann-Whitney test,  $P = 0.16$ ). The estimated density was not corrected for submerged animals in view of the lack of data on surfacing rates. The density estimated for the two areas was different (Table 3); the 95% confidence intervals for estimated density do not overlap. The spatial distribution of sightings was very uneven, especially in the area from Punta Ninfas to Isla Rasa. This variation is reflected in the large proportion of the variance of density explained by the encounter rate for the two areas: 63.4% for Area A and 56.3% for Area B (the detection probability contributed 6.2% of the variance for Area A and 6.6% for Area B, and cluster size contributed 30.4% for Area A and 37.0% for Area B).

The low cluster size and encounter rate (Table 3) and the steep distribution of distance suggest that our abundance estimation should be taken as a lower limit of density, probably due to high flight speed, searching methods, and overlooking submerged animals.

It is noteworthy that three flights (1, 2, and 7) with no sightings of dusky dolphins and flights 5 and 6 (with 58 sightings) covered the same region and time of the year, with one year's difference. This suggests that the spatial distribution of animals could be highly variable in time, or that our survey design was inefficient in surveying the spatial distribution of animals.

Forney *et al.* (1995) presented density estimations for Pacific white-sided dolphins (*L. obliquidens*) in California waters. The density of individuals estimated for dusky dolphins for both of our areas (1.259 ind/nm<sup>2</sup> and 0.219 ind/nm<sup>2</sup>) are comparable with densities estimated for the Pacific white-sided dolphin (0.21–2.74 ind/nm<sup>2</sup>; data recalculated from Forney *et al.* 1995). Given the extended effort deployed for the Pacific white-sided dolphin when compared with the effort deployed in this survey (5,035 nm *vs.* 1,425.7 nm), the results achieved in our surveys seem plausible.

Kasamatsu and Joyce (1995) gave abundance estimations for hourglass dolphins (*L. cruciger*) in antarctic waters from ship-based surveys. Although they did not present density estimates, the ranges of encounter rates (0.001–0.016 sightings/nm), their coefficient of variation (33%–97%) and the coefficient of

Table 3. Estimation summary for dusky dolphin surveys.

Stratum	Area	<i>n</i>	ER	$\bar{f}$ (%CV)	$\hat{D}$ (%CV)	95% CI $\hat{D}$	$\hat{N}$	95% CI
Area A: Punta Ninfas to Isla Rasa	3,630	24	0.04	3.42 (18.13)	1.259 (32.88)	0.663; 2.390	4,570	2,408; 8,674
Area B: Golfo San Jorge	9,408	13	0.02	1.69 (19.37)	0.219 (31.84)	0.116; 0.411	2,058	1,096; 3,864
Pooled estimate weighted by area	13,038	37	—	—	0.508 (25.31)	0.310; 0.834	6,628	4,039; 10,877

Area = surveyed in nmi<sup>2</sup>.

*n* = number of groups sighted out to perpendicular distance of 200 m.

ER = encounter rate (sightings/nmi).

$\bar{f}$  = mean group size.

$\hat{D}$  = estimated density (individuals/nm<sup>2</sup>)

$\hat{N}$  = estimated number of animals.

%CV = percentage coefficient of variation for  $\hat{D}$  and  $\hat{N}$ .

95% CI = Confidence Interval.

variation of the uncorrected abundance estimation (37%–109%) are equivalent or higher than those we estimated for dusky dolphins.

Although the abundance estimation for dusky dolphins is preliminary and can be considered as a lower limit, it can be compared to the available mortality rates associated with offshore fisheries. Dans *et al.* (1997b) presented incidental mortality values for dusky dolphins associated with fishing for hake and shrimp in central Patagonian waters. These values were obtained in an area that includes our Areas A and B (from 42°S to 46°S and to the 100-m isobath). They estimated catch at 70–215 dusky dolphins in 1994. The lowest mortality estimate compared with the upper limit of the 95% CI pooled abundance (70 *vs.* 10,877 animals estimated), and the upper limit of the mortality estimate with the lower limit of the 95% CI pooled abundance (215 animals *vs.* 4,039 animals estimated), implies a crude mortality rate of between 0.6% and 5.3%.

However, the spatial range for which the mortality rate was estimated involves a larger area than the one surveyed here. Consequently, the actual mortality rate would be reduced. It was noted that dusky dolphins are affected differentially by different fishing types, such as mid-water trawling for shrimp, bottom trawling, *etc.* (Crespo *et al.* 1997a). As fishing type and effort change dramatically year to year, the mortality rate may change accordingly.

The present surveys covered only part of the habitat of the dusky dolphin in the southwestern South Atlantic. A recent review of the distribution of dusky dolphins (Crespo *et al.* 1997b) revealed that they inhabit the entire Patagonian shelf, from the coast to 200 nm offshore. Our surveys were carried out where dusky dolphins are most common in these waters (38°–47°S) but due to logistic constraints were mostly coastal.

Further attention should be paid to the spatial distribution of the animals; they seem to be highly concentrated in some areas, as was revealed by the difference in the number of sightings between flights 1,2,7 and flights 5 and 6. The high relative encounter rate in area A may be explained by the presence of important prey items such as anchovies and juvenile hake (Angelescu and Anganuzzi 1981, Cousseau *et al.* 1981, Koen Alonso *et al.* 1998).

The high levels of mortality for this species show the need for more precision in abundance estimates. Further steps to increase the precision of the estimates includes improving searching methods and stratification of the surveys.

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## PRELIMINARY RESULTS OF A PHOTOIDENTIFICATION STUDY OF THE MARINE TUCUXI, *SOTALIA FLUVIATILIS*, IN SOUTHERN BRAZIL

A number of small-cetacean species have been studied using photoidentification since the early 1970s. This method has been applied especially to the bottlenose dolphin, *Tursiops truncatus*, and the killer whale, *Orcinus orca*, but also to other species, providing important information on their behavior and biology (Würsig and Würsig 1977, Balcomb *et al.* 1982, Bigg 1982; see also a review for small cetaceans by Würsig and Jefferson 1990). Recently, photoidentification has been used to study the riverine tucuxi, *Sotalia fluviatilis*, in the Colombian Amazon (Trujillo Gonzalez 1994). The marine form of *S. fluviatilis* occurs apparently continuously along the Atlantic coast of Central and South America (Borobia *et al.* 1991, da Silva and Best 1996). Since 1991 a population has been studied in North Bay, Santa Catarina State, southern Brazil (Fig. 1). As a part of this long-term research on the ecology, behavior, and conservation of this population, systematic boat surveys began in 1993 for conducting photoidentification and behavioral ecology studies (Flores 1994). The main purposes of this paper are to examine the feasibility of using photoidentification techniques on marine *S. fluviatilis* and to present preliminary information on residence and ranging pattern of this species in North Bay.

From May 1993 to November 1994, 37 boat surveys were conducted in the study area, 32 of which (14 in 1993 and 18 in 1994) used photoidentification techniques (Table 1). Two types of surveys were conducted, always without following a regular course: (1) focal-group sampling, when the same animals were observed and photographed until the end of the survey and (2) "random surveys," when the group was left once it was concluded that most individuals were photographed and the survey resumed. The study area was divided into 18 zones using topographic references easily identifiable from the boat (Fig. 2). All zones were surveyed.

Surveys were made using a 3.0-m inflatable boat powered by a 15-hp outboard engine, with two to three persons in the boat; the same person took the photographs in all surveys. Once a group of tucuxis was found, approaches were made at lower speed or with the engine off by paddling or drifting, approaching within 10 m of the dolphins. Tucuxis were followed, observed,