Nest Density and Population Size of Magellanic Penguins (*Spheniscus magellanicus*) at Cabo Dos Bahias, Argentina

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Little is known about colony size of Magellanic Penguins along the Atlantic and Pacific coast of South America where they breed. However, interest in the commercial harvest of penguins for leather, oil, and protein (Carrara 1952) requires accurate colony estimates. Some information on colony size is available for the Argentine coast (Carrara 1952, Scolaro et al. 1980, Badano et al. 1982, Boswall and MacIver 1974, Daciuk 1976, Scolaro and Arias de Reyna 1984). We estimated colony size, nest density and the maximum number of penguins at Cabo Dos Bahias (44°54'30'S, 65°32'24'W; Fig. 1) and compared these numbers with Badano et al.'s (1982) survey. We surveyed the colony in March 1982 at the end of the breeding season less than a year after Badano et al.'s census (1982). We expected the numbers of nests and reproductive individuals to change little from one year to the next because nest depressions and burrows remain for several years in a desert and adults are long-lived. To test these assumptions we resampled the colony in January 1984 and quantified the differences in the number of nests over this two-year period. The edge of the colony was defined as the area where for 30 m there were no nests.

The colony at Cabo Dos Bahias has two distinct zones: the central zone which has most of nesting penguins and the peripheral zone where fewer penguins nest (Fig. 1). We divided the peripheral zone into 16 strips 50-m wide. Eleven people walked each strip, counted every nest, and examined its contents. We counted all the penguins breeding in small valleys near the sea and next to a small bay on the north side of the colony. We also counted and examined the contents of the nests in part of the central area where the density appeared to be highly variable.

The density of this colony was mapped. Soil in different areas was analyzed using Bouyoucos' (1927) method, and vegetational types were determined. The area occupied by penguins was determined by calculating the area of the colony and subtracting the portion of rock outcrops without nests.

The central zone (except those portions where nests were directly counted) was divided into 17 areas of constant slope. These were then subdivided into 325 plots of 10 m × 10 m. The number of plots sampled was determined after a preliminary sampling of 15 plots chosen randomly. The number of nests in these plots varied from 6–40. Using a *t*-test ($\bar{x}$ = 19.2; SD = 9.3), we determined that 78 plots from the area not directly counted needed to be sampled for 95% confidence, and we chose these 78 plots randomly (Fig. 2). In each plot, we counted the number of nests, determined whether they were active, recorded the type of nest (burrow or nest scrape), and whether it was covered by vegetation. We recorded date and time, and identified the vegetational cover. We considered a nest active when it contained an adult or chick, had guano at its entrance, or pieces of grass and feathers in the nest.

Density from the 78 sample plots was poststratified into five density strata to reduce the observed variance and improve the precision of the estimators (Holt and Smith 1979). Mean density and variance were calculated for each of the 5 density strata using Satterthwaite's (1946) method.

The total area with nests was estimated at 185,513 ± 1,752 m²; of this 2,799 m² was rocky ground where penguins do not nest, so that only 182,714 m² of land had nests (Table 1 and Fig. 2). The calculated error for the colony area was 0.9% and was so low that it was not taken into account for estimating densities. The peripheral zone is 43.7% of the total area and the central zone 54.8% of the colony; the remaining area of 1.5% is rocky outcrop. The number of nests for each density stratum was estimated by multiplying the mean density of sample plots times area. To these figures, we added our direct counts (Table 1). Estimate of total number of nests was 14,088 ± 702, with a mean density of 7.56/100 m².

We corrected our estimates of adults in each plot because the number of adults present in the colony

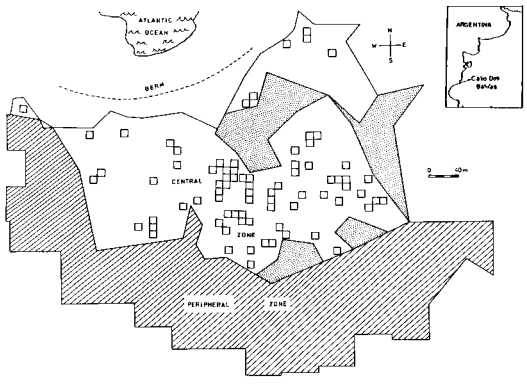

Fig. 1. Location and map of the Magellanic penguin colony at Cabo Dos Bahias, Argentina, showing central (higher density) and peripheral (lower density) zones. The locations of the 78 sample plots are indicated as squares.

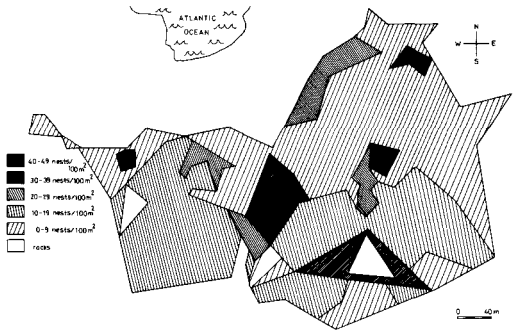

Fig. 2. Magellanic Penguin nest density and rock outcrops at Cabo Dos Bahias, Argentina.

depends on the time of day (Fig. 3). The percentage of birds that occupied nests was significantly higher on cloudy days ($\bar{x} = 72$, SD = 1.00, $n = 3$) than on less overcast days ($\bar{x} = 37$, SD = 15.10, $n = 25$, t-test = 3.59, df 26, $P < 0.001$).

Early in the day, birds tend to leave the colony for foraging; from about 1730–2100 h, a large number of adults arrives from the sea (Fig. 3). At 2100 h, mean occupation was 85.3%. We calculated adult numbers as if we had sampled at maximum occupation (Tables 1 and 2). The maximum number of active nests was estimated to be 12,017 and the maximum number of pairs 5,231. The maximum number of lone birds was 6,786.

We used direct counts to calculate the number of chicks because, during January, chicks rarely leave the nest and nearly always remain within the plot. The number of chicks was calculated to be 6,861 ± 401, or approximately 1 chick for every 2 nests or 1.31–1.36 chicks per adult pair. The total number of adults was calculated to be 17,248 (Table 2).

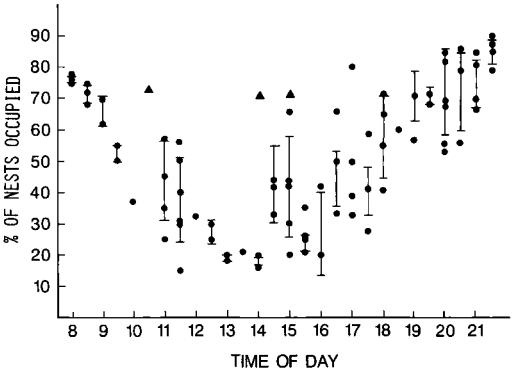

Fig. 3. Variations in percentage of nests occupied in a 100 m² sample plot at different times during the day. Points marked with (▲) were not taken into account, since they correspond to surveys carried out on cold, cloudy days when occupation was higher than would be expected for that time of day.

Penguins nested under bushes of *Chuquiraga avellanedae, Lycium ameghinoi, Marrubium vulgare,* and *Prosopis denudans* or dug burrows, but the physical topography and soil were major determinants of the location and type of nest. In the peripheral zone where nest density/100 m² was from 0–19 nests, the sand cover was very thin (about 15 cm; Table 1). In these zones, penguins tended to nest under the vegetation and did not dig burrows. Where nest density was 20–29 nests/100 m², the soil was mainly hard clay, and penguins nested under vegetation and did not dig burrows. In the rest of the colony, the soil was deeper, more cohesive and burrows were common. Numbers of nests, chicks and adults varied in the different density areas (Table 1, Fig. 2).

Our estimate of nesting area and total area was larger than Badano et al. (1982), but our estimate of the number of nests and adults was significantly smaller. Although we estimated a larger nesting area and used a higher occupation rate, our estimates of adults were only 70% and 56% respectively of the Badano et al. (1982) estimate (Table 2).

There was no significant difference between our counts of the number of nests in the colony at the end of the breeding season in March 1982 and in the middle of the season in January 1984. Over two breeding seasons, nest numbers remained constant. We believe the colony has been stable for some time. However, our maximum estimates are substantially lower than Badano et al.'s (1982).

The method used by Badano et al. (1982) is essentially that proposed by Scolaro et al. (1980), which consists of taking samples along strips perpendicular to the coastline. Unlike Scolaro et al. (1980), Badano et al. (1982) did not specify the criteria for choice of the number and distance between sample strips. Their lines of equal density tend to fall perpendicular to the strips they sampled. We found no such pattern in the field and, if such a pattern exists, it is difficult to know the kind of bias it would introduce in the density estimate. We tested for a bias in our procedures by examining 17 areas to determine if they were of equal density. Fourteen areas were homogeneous in density and only 3 needed to be subdivided into strata of different density because of their high variability.

The most obvious difference between the censuses is that Badano et al. (1982) included rocky outcrops in areas they considered medium densiy. This error would lead to an overestimate of total numbers. Only 1.5% of the colony area, however, was rock outcrop so this misclassification cannot account for the difference between estimates.

Our estimates of the number of nests with chicks and, consequently, of adults could be biased by the formation of creches by chicks and by weather conditions that affect adult colony attendance. Because we sampled while chicks were still close to the nest-site and corrected for the time of day when counts

TABLE 1. Parameters of Magellanic penguin nesting density, occupation, and soil texture at Cabos Dos Bahias, Argentina.

Number of nests	*n*	Nests/ 100 m² (mean)	SD	Area m²	Estimated chicks	Estimated nests	Confidence interval	% Occupation of chicks	Estimated pairs	Observations
0–9	6	5.58	3.17	22,546	182	1,258	±559	37.04	466	Texture sandy loam. Soil thickness less than 15 cm. Another sector, clayey texture.
10–19	44	14.31	4.72	29.956	2,193	4,287	±812	32.43	1,390	Texture sandy loam. Soil thickness less than 15 cm. Another sector, clayey texture.
20–29	5	27.00	3.67	3,537	655	955	±124	50.00	477	A small sector—clayey texture, with abundant vegetation. Rest sandy loam. Soil layer deep.
30–39	6	32.57	5.15	692	1,242	2,248	±393	42.18	948	Texture sandy loam; soil layer deep.
40–49	14	44.44	4.39	1,960	549	870	±91	34.20	298	Texture sandy, sandy loam. Deep soil layer.
Surveyed central area		6.78		41,475	1,466	2,815		44.44	1,252	
Peripheral area		2.00		82,548	564	1,655		24.07	400	Texture sandy loam; soil thickness less than 15 cm.
Totals		7.56		182,714	6,861	14,088	±702		5,231	

TABLE 2. Comparison of estimates of Magellanic penguin nesting area, nests, and numbers of birds at Cabos Dos Bahias, Chubut, Argentina.

Period of study	Nesting area occupied (m²)	Total area (m²)	Area of rock (m²)	Total nests	% of nests occupied	Active nests	Adults	Chicks
Badano et al. 1982	153,280	180,270	not specified	20.223	77%	not specified	30,989	
Mar. 1982				13,707				
Jan. 1984	182,714	185,513 (±1,752)	2,799 m²	14,088	85.3%	12,017	17,248	6,861

were made, these factors should have little effect. Moreover, we evaluated whether nests were used; abandoned nests were not included. Penguins often frequent more than one nest (Boersma unpubl. data). It is likely that, because of our counts of active nests and our assumption that nests are used by separate pairs or individuals, we overestimated the actual number of birds. Furthermore, we estimated the number of adults at the time of maximum occupation. Nevertheless, with assumptions that estimate the maximum active nests, and the maximum number of adults, our estimates (except for colony size) were far below those of Badano et al. (1982).

Our results demonstrate the need for standard methods and definitions which can be used by researchers to determine penguin colony-area and penguin numbers. Croxall and Kirkwood (1979) and Jehl and Todd (1985) point out many of the problems in estimating penguin numbers and that casual population estimates may be high. Our estimate of 14,088 nests, of which 12,017 are used, and 17,248 adult birds at Cabo Dos Bahias are maximum estimates. We predict that when accurate population estimates are available for other sites, Magellanic Penguin colonies will be smaller than previously thought.

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