Population Size of Humboldt Penguins Assessed by Combined Terrestrial and At-Sea Counts

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Abstract.-The Humboldt Penguin *(Spheniscus humboldti)* has been reported as declining along its distributional range and has recently been classified as vulnerable. The actual size of the Humboldt Penguin population is still unknown, and a complete population assessment is required. Here we present a study combining both counts of molting birds on land and counts of birds at sea during the molting period. We conducted our study in the Coquimbo Region, Northern Chile, and found 7,619 birds on land and 2,700 at sea, adding up to a total of about 10,300 Humboldt Penguins during the molting season (February 1999). Since these numbers are much higher than all other recent estimates, we emphasize that assessment on land and at sea need to be combined to provide more reliable estimates. *Received 20 July 1999, accepted 15 July 2000.*

Rey words.-Humboldt Penguin, population size, Northern Chile, counts at sea, molting.

Waterbirds 23(3): 506-510, 2000

Regular and accurate total counts of a population are important for any conservation program (Furness and Monaghan 1987). This is especially true for the Humboldt Penguin *(Spheniscus humboldti)* where the population is declining over the entire range and this species has recently been classified as vulnerable (Ellis *et al.* 1998). However, accurate estimation of the population size of Humboldt Penguins has received little attention. The most recently published figure originates from data obtained in 1996, when a total number of 13,000 penguins were estimated (see Ellis *et al.* 1998). This figure was from 1995-96, before the last El Niño of 1997-1998, and the actual colony sizes at that time were still unknown.

One methodology used is to conduct counts during the molting season (Simeone and Bernal 1998; Ellis *et al.* 1998) ; however, we believe that counting only molting penguins can produce an underestimate of the population because undetermined numbers of penguins are at sea at this time. This fraction of the population includes, principally, non-molting adults and juveniles. Here we present the results from a study combining terrestrial and at sea counts conducted in the IV Region of northern Chile. Our main objectives in this study were: a) to estimate the number of Humboldt Penguins during the molting season, b) to estimate the number of Humboldt Penguins at sea during thü same period, and c) to combine both methods to obtain a better estimate of the Humboldt Penguin population in the study area.

METHODS

We conducted all terrestrial and at-sea counts on the coast of Northern Chile, between 291 OS and 30°15 'S (Fig. 1). Molting individuals do not go to sea for food; at this time, the majority of the molting penguins are resting on the shore close to the water's edge. Here they form patchy aggregations that are easily visible and provide a good opportunity to conduct counts (Luna Jorquera 1997; Simeone and Bernal 1998). We counted molting birds on islands, points, and beaches included in the study arca, using binoculars and hand counters. To obtain an accurate figure, teso observers simultaneously counted the lame groups of birds of the colony. Both values obtained independently were compared, and, when differences were not greater than 5%, we accepted the smaller value as correct. At Tilgo Island we could not perform terrestrial counts because of sea conditions. We surveyed with a five-meter outboard boat, running at constant low speed. Two counts were ¡nade of molting birds (patchily distributed in small groups), summing all figures to obtain a total for this island.

We conducted all surveys between 1100 and 1400 hours, using the methods of Luna-Jorquera (1997), developed at the breeding colony on Pan de Azucar Is. (26°09'S). To examine whether significant differences in the number of molting birds exist during the day, counts were made on thrce consecutive days at these different hours (1100; 1400 and 1900 h) in one colony on Choros Island. This data were submitted to a Levene test to determine homogeneity of variante. Variantes in the

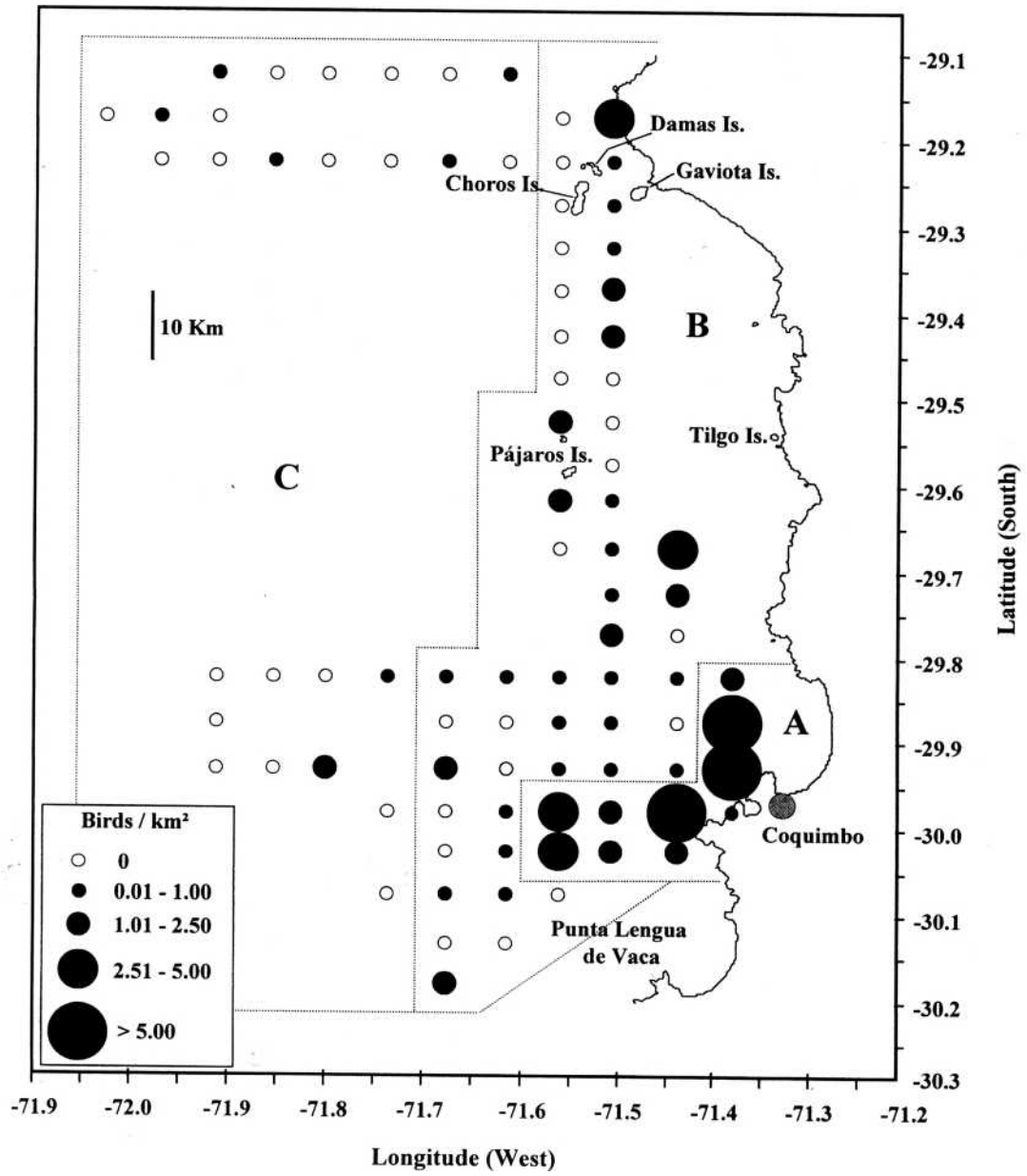

Figure 1. Distribution and density of Humbolt Penguins at sea during the molting period in the IV Region of Northern Chile. A = Coquimbo Bay; B = Coastal zone and C = Offshore zone (see text for more details).

counts made at different hours of the day were highly heterocedastic (ANOVA, P = 0.001). Consequently, the data were compared using a nonparametric test.

Penguin distribution and abundance at sea were assessed by ship-borne transects according to the methodology described by Tasker et al. (1984). All counts were carried out on board the research vessel "Stella Maris II" from 12 to 28 january 1999. All birds within 150 m of both sietes of the vessel were counted while the boas was sailing at about 7-9 knots. Bird numbers were summa-rized over 10-min intervals during which position were obtained using a GPS system.

We asume that some swimming Humboldt Penguins were certainly missed due to waves or swell, particularly those farther away from the observation platform. We corrected the density of swimming birds, using the distante sampling methodology developed by Buckland el, al. (1993) and obtained a correetion factor of 1.3, applying the half-normal function with cosine adjustment available in the software package DISTANCE (Laake el al. 1994).

Penguin densities were calculated for grids of about 5.6 km x 6.0 km (= ca. 34 km^2), covering the whole study arca (Fig. 1). For each grid, the density of penguins was

obtained by dividing the total number of penguins within the transect by the arca investigated within the grid. Total numbers of penguins at sea were estimated by largely following a procedure described by Spear et al. (1995): First, three major arcas of apparently different penguin distribution and abundance were derived from the distribution map, named offshore zone, coastal zone and Coquimbo Bay (Fig. 1). For each of three zones, the population size of penguins was calculated from the transect counts. Second, transects assumed to be independent of each other were selected. These were routes sailed within the respective zone on different days or on the same day but separated by time. Only transects with at least 5 km^2 of surveyed arca were used. Third, the penguin density was calculated for each transect by dividing the total number of penguins by the total arca surveyed. Fourth, densities were square-root-transformed to fit a normal distribution. Fifth, mean densities as well as 95% confidence intervals were calculated for each zone on the basis of the densities of the different transects. Sixth, mean densities and confidence intervals were back-transformed.

RESULTS

Data obtained from counts on three consecutive days at three different hours were not significantly different for the three different times of day when the counts were made (Kruskal-Wallis, $P > 0.05$). The coefficients of variation calculated for each hour on the thrce sampling days at Choros Island were 3.8% at 1100, 1.1% at 1400 and 6% at 1900 hr.

A total of 7,619 Humboldt Penguins were counted on land during the 1999 molting season (Table 1). The Pájaros Islets were the most important place for molting penguins in the study arca, containing 4,311 animals, equivalent to -57% of the total. Tilgo Island had 1,729 birds. In the colony at Choros Island, we found 1,479 penguins, corresponding to -19% of the total animals on land. No penguins were detected at the other islands (Gaviota and Damas) near Choros Island. Only 100 birds (~ 1%) were found at Punta Lengua de Vaca. This is the only place connected to the mainland where we found penguins.

Humboldt Penguins at sea were not evenly distributed within the study arca (Fig. 1). A major concentration was found near Coquimbo Bay, with densities of up to 29.5 birds km^2 per grid (Table 2). Medium to low densities were found close to the coast along the rest of the coastline in the study arca, although penguins were lacking in many grids. Farther offshore, densities were lower still (Fig. 1). Altogether, 2,700 birds were estimated with a confidence interval of ca. 500-7,000 birds (Table 2).

Table 1. Number of molting Humbolt Penguins found on land in Northern Chile.

Locality	Latitude	Number of Penguins
Choros Island	29°16°	1,479
Tilgo Island	29°33°	1,729
Pájaros Islet	29°35°	4,311
Punta Lengua de Vaça	30°14°	100
Total		7,619

Summing both the subtotal Humboldt Penguins counted on land (7,619) and the estimated number of birds at sea (2,700), we obtained a total for the study arca of 10,319 Humboldt Penguins during the molting season. In other words, at the time we conducted our study, roughly 26% of the penguins were at sea and 74% were on land.

DISCUSSION

The last complete census, carried out in 1995-1996 (data compiled by Luna Jorquera 1998) provided a total estimate of 7,500 breeding animals in Chile, with 1,050 in the Coquimbo region. In the present study, we estimated 10,319 birds for the Coquimbo region. Even if we just consider the molting birds (7,619), our estimate shows that the data obtained in 1995-1996 are a substantial underestimation. However, a direct comparison with previous data may not be possible since such data were obtained using a completely different methodology, namely counting occupied nests. Although this methodology allows estimation of birds which were actively reproducing, it may produce biased values, given that some nests may be found empty at different times of the day, and that breeding pairs may visit different nests within a colony (Duffy 1991). Additionally Humboldt Penguins are long-lived and may not reproduce each year, and a large proportion of the reproductive population may not breed at all in years with unfavorable conditions (e.g., El Niño).

Table 2. Density and numbers of Humbolt Penguins estimated at sea during the molting season in Northern Chile between 29°10'S and 30°15'S.

Zone	Area (km^2)	Number of transects	Total area surveyed (km^2)	Mean density (birds km^2)	Estimated population size	Confidence interval
Coquimbo Bay	340	9	109.1	3.44	1,170	77-3,559
Coastal zone	2,958	10	269.2	0.17	500	62-1,354
Offshore zone	5,202	4	91.7	0.20	1,030	362-2,037
Total	7,994	23	470.0		2,700	501-6,950

From our data, it seems that the ratio of penguins at sea to birds at land is roughly of 1:3. This suggests that estimates based only ora counts made at land during molting period would produce a significant underestimate of the population, because ara un-determined number of penguins would be at sea at that time. In the case of the Humboldt Penguin, accurate estimation of the population, considering both counts at sea arad at land, would be useful not only to evaluate conservation efforts, but also to investigate spatial variation of the Humboldt Penguins at sea during the non-reproductive season (but see Culik and LunaJorquera 1997a).

Accurate estimation of the population size of Humboldt Penguins should receive more attention in the future. It is clear that the methods and timing to be applied for ara accurate assessment must be standardized (Ellis el al. 1998). However, there are no guidelines available for this species and some basic consideration should be taken into account in planning censuses during the molting season. First, the time of the day at which counts are conducted is of great relevance. During the molting period, the number of birds near the beach follows a quadratic function related to the time of day: the number of individuals near the breaker zone reaches a maximum between 1100 and 1600 h (LunaJorquera, 1997). Non-molting penguins show essentially the same pattern, leaving the island to forage in the early morning and returning in the late afternoon (Wilson arad Wilson 1990; Luna- orquera arad Culik 1999; LunaJorquera and Culik 2000). Although this is also true for breeding Humboldt Penguins, the behavior of the young-of-the-year is little known. Prior to carrying out a census, it is advisable to determine the best time of day to observe any given colony, such that the maximum number of individuals can be counted. This pro-, cedure needs to be followed whenever possible so that the variance (or other measure of dispersion such as the coefficient of variance) of counts made ora successive days is reasonably low. The variances of our data ora birds from the colony at Choros Island were heteroscedastic, suggesting that time of day is ara important source of variation.

Second, the Humboldt Penguin molts once a year between January and March, showing peak activity during the last week of January (Zavalaga and Paredes 1997). The group of individuals undergoing seasonal molt is composed of reproductive adults which change plumage after the summer reproductive peak and of juveniles borra during the previous reproductive season. These (latter) individuals begin to return to the colony in the middle of November (Zavalaga and Paredes 1997; Simeone and Bernal 1998). A single census of individuals, as made in the present study, does not include birds which are still at sea. To obtain a more complete census of individuals in a given region which includes molting adults and juveniles changing to adult plumage, it would be necessary to increase the frequency of counts. Thus counts of molting individuals should be made during the entire period over which molting is known to occur (January to March) at 20-21 day intervals, as this is the period required for individuals to change plumage (Zavalaga and Paredes 1997; Duffy 1991). In this way, individuals that arrive at the colony to molt would be counted only once (see Randall el al. 1986).

Counts made by these methods do not include young-of-the-year, which do not molt until the following year, and whose behavior is little known.

Third, an important prerequisite for accurate estimates of penguins at sea is selection of representative transects around the colonies. According to satellite-tracking data (Culik and LunaJorquera 1997b), during the summer reproductive season, 95% of reproducing adult penguins remain within 50 km of the colony. There is evidence, however, that immediately after molting, some penguins are capable of moving as far as 600 km from the island (Culik and Luna-Jorquera 1997a). In the present study, transects perpendicular to the coast were ca. 70 km in length (Fig. 1), covering most of the crea over which penguins may distribute after molting. There are no previous data relevant to the distribution of young-of-the-year penguins, and available information concerning adults at the end of the molting season is scarce. Based on our experience, both the spatial distribution and the lengths of the transects selected for the present study were reasonable for the estimation of these penguins at sea during the molting period. Nevertheless, we cannot be sure that our present estimates truly represent the numbers of penguins at sea during the molting period and more detailed research is needed, particularly in this area.

ACKNOWLEDGMENTS

This work was made possible through a grant by the Volkswagen Foundation, Hannover, Germany, to SG and GLJ (Az.: I/74 573), and by the FONDAP, Santiago, Chile, to JAV. We are particularly grateful for the help offered by the crew of the "Stella Maris II".

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