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Re-evaluation of Historical Rockhopper Penguin Population Data in the Falkland Islands

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Abstract.—Over the past 70 years, three counts have been conducted on the Rockhopper Penguin (*Eudyptes chrysocome*) population on the Falkland Islands during the 1932/33, 1995/96 and 2000/01 breeding seasons. The results indicated a population decrease of more than 90% during this period, from more than three million breeding pairs in 1932/33 to less than 300,000 breeding pairs in the mid-1990s. However, a re-evaluation of these data revealed that the original population was substantially overestimated and the 1930s numbers were probably closer to 1.5 million breeding pairs. Modifications to the mid-1990s data produce a revised population estimate of about 263,000, rather than 297,000 breeding pairs. Based on these revised values, the overall decrease in the Rockhopper Penguin at the Falkland Islands between 1932 and 1995 still exceeded 80%, at a rate of ca. 2.75% per annum. In the most recent census, the population was estimated to be 272,000 breeding pairs, suggesting a stable population since the mid 1990s. These re-calculations of historical Rockhopper Penguin population trends in the Falkland Islands have important implications for the assessment of the global population size and long-term trends of this species. *Received 7 July 2002, accepted 30 October 2002*.

Key words.—Rockhopper Penguins, *Eudyptes chrysocome*, Falkland Islands, population trend, breeding pair numbers, census, historical data.

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Subantarctic and Antarctic penguins are recognized as important top consumers in the Southern Ocean food web (Croxall and Lishman 1987; Croxall and Wood 2002). Accordingly, it has been recommended that their numbers be monitored in order to quantify their specific ecological roles and biomass consumption (Ellis et al. 1998). However, nearly all penguin species have undergone dramatic population changes over the past decades (Woehler et al. 2001) and the reasons for which are generally poorly understood (Jouventin and Weimerskirch 1991; Croxall 1992; Woehler and Croxall 1997). For example, large decreases over the past decades have been exhibited in all three subspecies of the Rockhopper Penguin (Eudyptes chrysocome) at most of the subantarctic islands where they nest: e.g., for Northern Rockhopper Penguin (E. c. moseleyi) on Amsterdam Island (Guinard et al. 1998), Eastern Rockhopper Penguin (E. c. filholi) on Campbell Island (Moors 1986), Auckland Islands (Cooper 1992), Marion Island (Cooper et al. 1997) and Antipodes Islands (Ellis et al. 1998), and Southern Rockhopper Penguin (E. c. chrysocome) on the Falkland Islands (Bingham 1998). The reasons for these decreases are largely unknown, although at some breeding sites changes in sea surface temperatures are suggested to have affected food availability and were linked to the observed declines (Cunningham and Moors 1994; Guinard et al. 1998). Furthermore, the timing and magnitude of these decreases was often difficult to assess, partly due to the limited amount of historical data obtained, and partly to the large errors associated with some methodologies (e.g., interobserver variability and differences in the timing and nature of counts, e.g., whether of nests, eggs, pairs, individuals etc.).

Apart from the Falkland Islands, about 165,000 breeding pairs of the Southern Rockhopper Penguin inhabit islands off the southern Chilean coast, and a large colony

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holding about 180,000 breeding pairs has recently been discovered on Staten Island, Argentina (Schiavini 2000). However, the highest numbers of breeding pairs for this subspecies have been recorded on the Falkland Islands, where one of the largest declines has occurred (Bingham 1998). Despite the fact that the Falkland Islands have been permanently inhabited since the mid 19th century, historical data on the Rockhopper Penguin numbers are scarce. The first comprehensive island-wide census (excluding Beauchêne and Bird Islands) reported more than three million breeding pairs (Bennett 1933). Subsequently, local decreases have been reported and by the 1980s it was suggested that the breeding population had decreased considerably (Croxall et al. 1984). In the 1995/96 breeding season another island-wide census of breeding Rockhopper Penguins was performed in the Falkland Islands (Bingham 1998), reporting that the breeding numbers were only 297,000 pairs, a decrease in excess of 90%. These results formed the basis for the classification of the Rockhopper Penguin as a globally threatened (vulnerable) species under IUCN criteria (BirdLife International 2000). A third island-wide census was conducted during the 2000/01 breeding season, in which 272,000 breeding pairs were counted (Clausen 2001). In reviewing this assessment in the context of its predecessors, some potential inconsistencies in the 1932/33 data became apparent, together with some minor inaccuracies in the analysis of the 1995/96 counts. In this paper we undertake a comprehensive re-evaluation of the main census data for the Rockhopper Penguin in the Falkland Islands, to ensure as consistent and realistic a basis for comparison and for future work.

METHODS

The three, island-wide Rockhopper Penguin censuses undertaken in the Falkland Islands differed in the methodologies used.

1932/33 (Bennett 1933)

During the 1932/33 breeding season, questionnaires were distributed by Bennett, an experienced naturalist working for the Falkland Islands Government, to land-owners in the Falkland Islands, requesting estimates of the numbers of breeding pairs on their land. It is highly likely that colony sizes were estimated by the land-owners, rather than the numbers of breeding pairs being counted, resulting in substantial errors and inconsistencies in the estimates. Estimation of breeding pair numbers in larger breeding colonies, especially those situated on remote islands, was based on a calculation of nest density (0.50 pairs per yard², corresponding to 0.55 pairs per m²) and area covered (in yards²). For colonies on steep slopes, their size was estimated as the product of nest density and the length of a colony along the cliff face (based on 14.3 nests per yard of cliff face, corresponding to 15.6 nests per m). The exact magnitude of the error associated with this method is unknown, but it is likely to have been substantial. Furthermore, one of the largest Rockhopper Penguin colonies, that on Beauchêne Island and the colony on Bird Island, were not covered by this census.

1995/96 (Bingham 1998)

In the 1995/96 breeding season, smaller colonies were counted directly, whereas the estimates of breeding pair numbers in larger colonies were again based on a calculation using nest density per unit area. However, only the nest densities within these colonies were reevaluated, whereas the areas occupied by Rockhopper Penguins were based on results obtained in previous surveys (although stated otherwise in Bingham 1998). For example, the area of occupation on Beauchêne Island was taken from estimates made in 1980 (Lewis Smith and Prince 1985), and that for Steeple Jason Island from estimates made in 1987 (Thompson and Rothery 1991). Additionally, no detailed information was provided for the areas occupied by Rockhopper Penguin breeding colonies on Grand Jason and Bird Island. Generally, the error associated with direct counts of smaller colonies was estimated to be about ±5%, and that for larger colonies to be within $\pm 10\%$.

2000/01 (Clausen 2001)

Three different methods were used in the 2000/01 census. Numbers of breeding pairs in smaller colonies were counted directly, with an estimated error of less than 5%. Inaccessible sites were photographed from a boat and breeding pair numbers determined from the photographs. The error associated with this method, based on estimates of colonies counted directly, was estimated to be less than 5%. Breeding pair numbers in colonies too large to count directly were assessed by a nest density and area calculation, based on a re-estimation of both the areas occupied and the nest densities within each colony (Huin 2001). The error associated with this method was assessed to be within 10%.

RESULTS

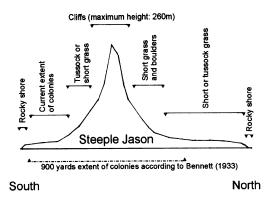
During the 1932/33 breeding season, Bennett (1933) estimated a total of 3,169,000 breeding pairs of Rockhopper Penguins in the Falkland Islands, excluding the large colonies on Beauchêne Island and Bird Island. More than 60 years later, Bingham (1998)

concluded that the numbers of Rockhopper Penguins in the Falkland Islands had decreased to 297,000 breeding pairs, including the previously uncounted colonies on Beauchêne Island and Bird Island. The 2000/01 census gave an estimate of 272,000 breeding pairs (Clausen 2001), suggesting a further decline. Crucial to interpreting all these results are the estimates for the four largest colonies on Steeple Jason, Grand Jason, Beauchêne Island and Bird Island.

Steeple Jason and Grand Jason

During the 1932/33 breeding season, more than 2,600,000 Rockhopper Penguin breeding pairs (82% of the total breeding numbers in the Falkland Islands) were estimated to occur on the Jason Islands (Bennett 1933), making them the most important breeding sites in the Falkland Islands. This calculation was based on an area occupation of a length of 2.5 miles (4,026 m) and a width of 900 yards (823 m) on Steeple Jason, and a length of 1 mile (1,610 m) and a width of 800 yards (731 m) on Grand Jason. However, when the area occupied by Rockhopper Penguin breeding colonies was measured accurately on Steeple Jason in 1987 (Thomson and Rothery 1991) and on both islands in 2000 (Huin 2001), the occupied areas were still of the same length (2.5 miles long on Steeple and 1 mile long on Grand Jason), but the width was much smaller. On both islands, colony widths ranged between 15 m and 120 m, with an average width of 50-70 m. From observations made whilst on the islands, and by using GIS techniques, the differences between the these values and the widths assumed by Bennett (1933) seem implausible (Fig. 1).

The extents of the colonies, as described by Bennett (1933) and as calculated in the last 2000/01 census, are shown in Figure 1. To fit the area of occupation used by Bennett (1933), colonies on Steeple Jason would have to range from the south side flats, over the central cliff ridge, down the north slope and half way across the north side flats. On Grand Jason, the colony would have to have started at the south side, go up the ridge and



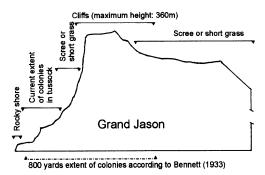


Figure 1. Cross sectional view of the Jason Islands, showing the extent of the colonies assumed by Bennett (1933).

carry on beyond the summit on the high scree. When breeding on their own, Rockhopper Penguins are known to breed on steep slopes and in flat areas on top of scalable cliffs. They also breed in mixed colonies with the Black-browed Albatross (Thalassarche melanophris) and the Imperial Shag (*Phalacrocorax atriceps*). In such cases, colonies are usually situated on flat ground, either close to the shore or on top of cliffs. However, there is no evidence either from traces of occupancy on the ground or from contemporary records, that the Rockhopper Penguin colonies on these islands were other than located on the flanks of the islands. Indeed Bennett (1933) noted that the colonies on Steeple and Grand Jason were situated on the south side of the islands only.

Therefore, we believe that Bennett (1933) made a basic error in estimating the width of the colonies. Given the dimensions of the island and the nature of the terrain it is impossible for the colony widths to have been of the order of the 900 and 800 yards (for

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Steeple and Grand Jason, respectively) which Bennett used in his calculations. Considering the terrain and signs of occupancy, it is highly unlikely that the average width of the colonies exceeded 90 and 80 yards, respectively.

If the colony width given by Bennett (1933) is adjusted by one order of magnitude (from 823 m to 82 m for Steeple Jason and 731 m to 73 m for Grand Jason), which roughly corresponds to the occupied area today, the area of the colonies appear more realistic (330,132 m² and 117,530 m² for Steeple and Grand respectively; Fig. 2). The nest densities applied to the colonies on the Jasons were slightly below the average found at other mainland colonies (Bennett 1933). Using the adjusted area of occupation and a nest density of 0.55 nests per m², breeding pair numbers would have been about 165,000 for Steeple Jason and 65,000 for Grand Jason. However, if the calculation is based on the highest nest density found in the Falkland Islands (1.3 nests per m² on Beauchêne Island 1980/81; Lewis Smith and Prince 1985), the Steeple and Grand Jason colonies would have contained approximately 430,000 and 153,000 breeding pairs, respectively, in 1932/33 (Table 1).

In the 1995/96 breeding season, a total number of 115,000 breeding pairs was estimated for Steeple Jason (Bingham 1998). However, whereas actual nest densities were recorded during this count, the area occupied by the colony was assumed to be the same as during the 1987/88 breeding season survey (Thompson and Rothery 1991). A reassessment of the areas occupied by the Rockhopper Penguin colony in the 2000/01 breeding season revealed a significant decrease compared with 1987/88, and the estimate by Bingham (1998) had thus to be corrected accordingly. Assuming a consistent linear decrease in area occupation over the corrected population figures would result in 96,000 breeding pairs in the 1995/96 breeding season (Table 1).

Beauchêne Island

The Rockhopper Penguin colony on Beauchêne Island was counted for the first

time during the 1980/81 breeding season, and was found to contain about 300,000 breeding pairs (Lewis-Smith and Prince 1985). Just seven years later, a survey revealed only 71,500 breeding pairs (K. Thompson, internal Falklands Conservation report), a decrease of more than 75%. A third survey performed during the 1995/96 breeding season revealed 74,300 breeding pairs (Bingham 1998). However, during both surveys the area occupied by penguins was again assumed to be the same as in 1980/81, and only nest densities were recorded. Most of the areas now un-occupied were covered with tussock grass. Assuming again a linear decrease in the colony area between the 1980/81 (230,239 m²; Lewis-Smith and Prince 1985) and 2000/01 (174,351 m²; Huin 2001) breeding seasons, the corrected figures would result in 63,000 breeding pairs in the 1987/88 breeding season, and 60,500 breeding pairs in the 1995/ 96 breeding season, respectively (Table 1). Furthermore, as Rockhopper Penguin numbers during the 1932/33 breeding season were unlikely to be less than during the 1980/ 81 breeding season, this figure has been added to the first census by Bennett (1933), which excluded the Rockhopper Penguin colony on Beauchêne Island (Table 1).

Bird Island

The breeding colony at Bird Island was omitted from Bennett's (1933) survey and was counted (without details of methods) for the first time during the 1995/96 breeding season, resulting in an estimate of 10,600 breeding pairs (Bingham 1998). However, if we assume that the decrease in the 60 years before this survey was similar to the other colonies, then up to 50,000 breeding pairs may have been present on Bird Island in the mid 1930s (Table 1). This is supported by the presence of areas with bare, eroded ground, indicating the existence of a larger colony in former times (NH, pers. obs.).

DISCUSSION

Based on the re-examination and re-analysis presented here, we suggest that the esti-

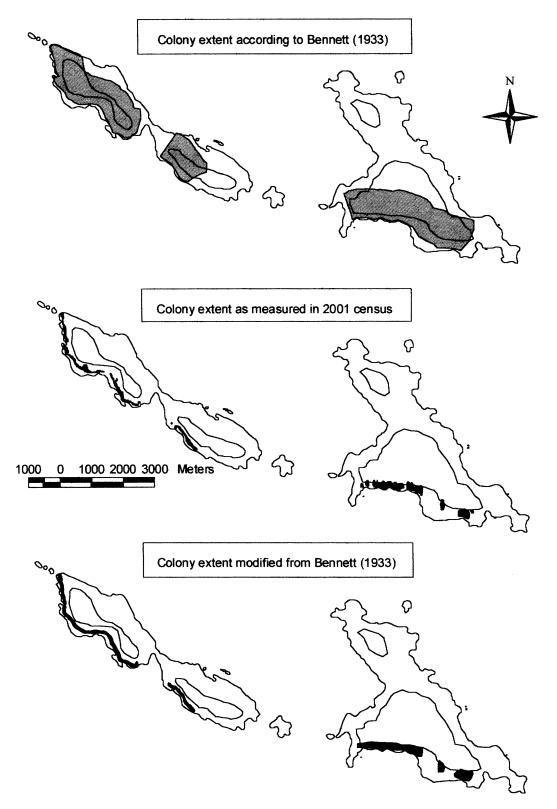


Figure 2. Map of Jason Islands, showing the extent of the colonies as assumed by Bennett (1933), as measured during the census in 2001 (Huin 2001) and as revised for the 1932/33 breeding season (this study).

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62

Breeding season	Steeple Jason	Gran Jason	Beauchêne Island	Bird Island	All others	Total	Source
1932/33	2,000	300	?		870	3,170	Bennett (1933)
Revised	165-430	65-150	300	10-50	870	1,410-1,800	This study
1980/81			300				Lewis-Smith & Prince (1985)
1987/88	190						Thompson & Rothery (1991)
			71.5				Thompson, internal FC report
1995/96	115	34	74.3	10.6	63.1	297	Bingham (1998)

63.1

264

273

10.6

Table 1. Estimates of Rockhopper Penguin breeding pair numbers (×1000) in the Falkland Islands over the past 70

mate of the Rockhopper Penguin breeding population in the 1932/33 breeding season in the Falkland Islands was appreciably overestimated. Our revised figures, although they include two previously uncounted colonies on Beauchêne Island and Bird Island, indicate that the estimates of the breeding pair numbers should be halved. However, the provision of a more accurate estimate was prevented by the lack of intermediate counts. Therefore, we had to assume a linear population decrease over time in our re-calculations, although rates of change are rarely lineary constant (e.g., Pistorius et al. 1999). For example, a mass mortality of Rockhopper Penguins occurred immediately after the 1985/86 breeding season, which was thought to be linked to starvation before moult (Keymer et al. 2001). Events like this have the potential to cause precipitous drops in numbers, and may subsequently be followed by slow recovery rates, thus contradicting our assumption.

96

90

Revised

2000/01

In any case, the decrease over 60 years has been substantial, and it can be assumed that it exceeded about 80%, or on average ca. 2.75% per annum, thus mirroring the population trends elsewhere (Moors 1986; Cooper 1992; Cooper et al. 1997; Ellis et al. 1998; Guinard et al. 1998). Therefore, it seems more than appropriate to classify the global Rockhopper Penguin population as vulnerable under IUCN criteria (BirdLife International 2000). The pronounced discrepancies from the previous published census values underline the importance of careful checking of methods used for estimation of the size of larger colonies, where precise

measurements of colony sizes and densities must be carried out to derive meaningful values. Photographic records are also valuable in assessing the plausibility of trends in breeding pair numbers.

Clausen (2001)

This study

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