THE DISTRIBUTION AND SIZE OF KING PENGUIN ROOKERIES ON SOUTH GEORGIA

By R. I. LEWIS SMITH *and* J. R. B. TALLOWIN*

ABSTRACT. An account is given of the past and present status of the king penguin (*Aptenodytes patagonica* Mill) on South Georgia. Data from all available records have been collated and an assessment made of the changes in numbers at the long-established colonies. Thirty-one widely separated sites with breeding birds were visited recently and are described; three others which had been reported previously no longer appear to exist. Rookery fluctuations are discussed in relation to the unique irregular 3 year breeding cycle of these birds and methods for obtaining reasonably accurate census data are considered. The approximate total population, including adults and young, at the time when counts were made is estimated as 39 000, while the approximate potential maximum population, including immature non-breeding adults and ineffective breeders, is estimated as 57 000 birds. These data suggest a substantial population increase during the past 50 years.

THE king penguin (*Aptenodytes patagonica*) has a circum-polar distribution, breeding on most of the sub-Antarctic and cool-temperate islands lying between lat. 52° and 55°S. All known breeding colonies lie north of the normal maximum limit of pack ice and north of the 0° C mean annual air isotherm (Conroy and White, 1973). The most recent account of the breeding status of the king penguin is by Conroy and White (1973), who provided an authoritative bibliography on this species and discussed the current knowledge of their distribution, pointing out that many reports of breeding colonies are based on erroneous information.

The breeding distribution of these penguins includes all the sub-Antarctic islands, i.e. South Georgia, Macquarie Island, Heard Island (but apparently excluding McDonald Island), Iles Kerguelen, Iles Crozet, Marion and Prince Edward Islands. The only other locality where breeding is known to occur is in the Falkland Islands where there are two small and several very small rookeries (personal communication from I. Strange). They formerly bred in southern Tierra del Fuego (Isla de los Estados and Isla Hornos) and possibly Diego Ramirez (Reynolds, 1935), but there is no recent information to suggest they still occur there. There are no records of king penguins currently breeding on Isla de los Estados (M. A. E. Rumboll, in literature). Similarly, there is no evidence to support the published reports that king penguins have bred in the South Sandwich and South Shetland Islands; certainly they no longer appear to breed there or on the more northerly Bouvetøya (Conroy and White, 1973). They are vagrants to New Zealand (North and South Islands) and the New Zealand shelf islands (Campbell, Auckland, Antipodes and Snares Islands, etc.), Tasmania and possibly Victoria, Australia, and Gough Island, all of which are well north of their breeding range, while occasional birds have been reported from the South Orkney and South Sandwich Islands and Elephant Island to the south of their breeding range (Conroy and White, 1973). A single adult was observed at Avian Island, south-west Adelaide Island (lat. 67°46′S) on 16 January 1975 (personal communication from W. N. Bonner). The evidence provided by these and other authors indicates that the king penguin is increasing in most, if not all, its breeding localities.

This paper reviews the past and present distribution and approximate size of king penguin rookeries on the sub-Antarctic island of South Georgia (lat. 54–55°S, long. 36–38°W) (Fig. 1). In order to trace population fluctuations, all reports available to the authors have been quoted. Most of the recent information on rookery location and number of birds was obtained during the 1968–74 botanical survey of South Georgia and by geological field parties working around the island between 1970 and 1977.

During the recent botanical survey, the distribution of plant species and penguin colonies around the island was investigated by systematically landing at most of the snow-free coastal areas which lie within the 5 km grid squares on the 1:200 000 map of South Georgia (D.O.S.

* Present address: The Grassland Research Institute, Hurley, Maidenhead, Berkshire SL6 5LR.

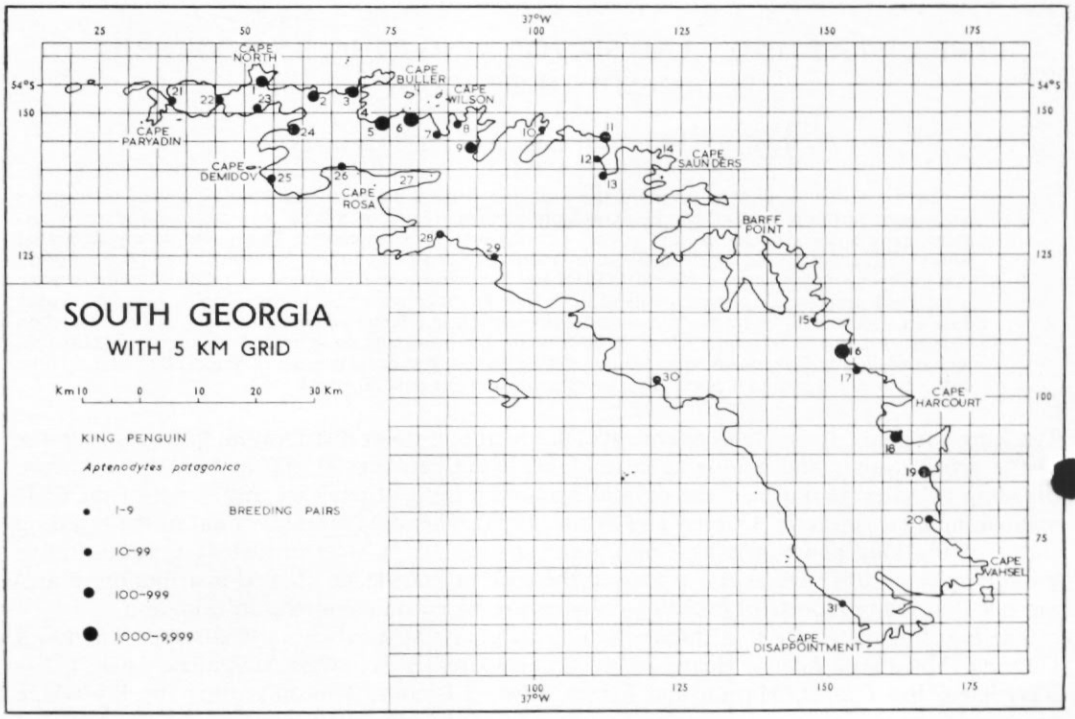

Fig. 1. Location and approximate size of king penguin breeding sites on South Georgia.
1. Right Whale Bay; 2. Wales Head; 3. Cape Buller peninsula; 4. Sunset Fjord; 5. Ample Bay; 6. Salisbury Plain; 7. Sealeopard Fjord; 8. Beckmann Fjord; 9. Possession Bay; 10. Windy Cove; 11. Cape Best; 12. Anchorage Bay; 13. König Glacier; 14. Hercules Bay; 15. Hound Bay; 16. St. Andrews Bay; 17. Doris Bay; 18. Royal Bay; 19. Gold Harbour; 20. Iris Bay; 21. Undine Harbour (including subsidiary colony); 22. Schlieper Bay; 23. Morsa Bay; 24. Miles Bay; 25. Elephant Cove; 26. Cheapman Bay; 27. King Haakon Bay; 28. Holmestrand; 29. Horten; 30. Rocky Bay; 31. Paradise Beach.

Information on the Nilse Hullet and Alert Cove rookeries became available after this paper went to press and therefore their locations do not appear on the above map nor are their population numbers given in Table I.

(Misc.) 372A, 1964, based on D.O.S. 610, South Georgia, 1958). Almost all of the 165 coastal squares were visited, with the exception of seven. Of these, four represent parts of glaciers and, although the remaining three possessed snow-free ground, they do not have beaches and it is unlikely that they contain any king penguin rookeries. However, within some of the squares investigated there are localities which may be suitable as breeding sites but which were not visited.

The major problem in interpreting reports of population numbers is in relating the census count or estimate at a particular time of the year to the composition of the colony and determining what proportion of the total rookery population this may represent. Since king penguins have an exceptionally long breeding cycle (14–18 months), they can complete only two cycles every 3 years, i.e. an "early" year when they lay their egg from November to January, followed by a "late" year when they lay in February–April, followed by a year when they are "ineffective" breeders (Stonehouse, 1960). Consequently, a census taken in spring will include the surviving chicks of the previous summer together with an increasing number of breeding pairs and non-breeding single adults returning to the rookery; a census taken in mid-summer will include both chicks of the current and previous year together with single incubating adults and some non-breeders; and a census taken in late summer (April) will

include only the current year's chicks but in two size classes, and only a small proportion of the adults since both the previous year's chicks and most of the breeding adults will have left the rookery by this time. Similarly, the number of adults is very variable depending on the time of year. For example, in spring and mid-summer a relatively high proportion of adults will comprise breeding pairs of the early and late breeders, respectively, while in early and late summer only one of each pair is generally present except for the brief changeover periods when both birds are present in or near the colony. Furthermore, since adults probably do not reach sexual maturity until they are at least 6–8 years old, these birds must boost the numbers of non-breeding adults associated with rookeries to a considerable and varying degree, again depending on the time of year. For these reasons and because few early reports distinguished between total birds present or adults (with or without eggs) and/or chicks, it is not possible to provide accurate censuses for many rookeries. To obtain a more accurate estimate of rookery size, in terms of breeding pairs, counts of chick numbers should be made in the late autumn (time of maximum chick numbers) over three consecutive seasons; similarly, to obtain an estimate of net colony production, counts should be made in early spring (time of minimum chick numbers, indicating mortality rate and the proportion which survived their first winter and therefore likely to reach maturity). While a reasonably accurate estimate of breeding adults can be extrapolated from chick numbers, no accurate indication can be obtained for non-breeding birds which vary considerably in number and location throughout the year. Probably the most reliable means for obtaining accurate censuses of the larger rookeries is by the aid of low-altitude vertical air photographs, a method used successfully for king and macaroni penguins on Iles Kerguelen and Iles Crozet (Bauer, 1967). The figures presented in this paper provide an indication of the relative, and in several cases absolute, sizes of the South Georgian king penguin rookeries.

All but one of 29 widely separated sites with breeding birds were visited at least once since 1970, while three which had been reported prior to this date no longer appear to exist. The most recent documentation of the king penguin rookeries of South Georgia was provided by Conroy and White (1973), who listed 12 rookeries, but of these they presented post-1960 data for only six; these were in St. Andrews Bay, Fortuna Bay, Doris Bay, Royal Bay, Undine Harbour and the Lucas Glacier (= Salisbury Plain) rookery in Bay of Isles. The locations of all colonies where breeding birds have been seen, together with those of several unconfirmed rookeries, are indicated in Fig. 1. The arrangement of rookeries in the following account is based on their distribution in eight sectors of the island; in each there is generally one large rookery and one or more small ones which may represent "overspill" colonies.

Location and Size of Rookeries

Cape North to Cape Buller

Right Whale Bay

This rookery occurs on the slope of a tussock-covered ridge about 50 m above the extensive glacial outwash deposits of Binder Beach. It is one of the largest colonies not situated close to a glacier.

In early 1914, Allen (1920) reported a colony of about 400 birds and in 1926 Matthews (1929) stated that this was one of the largest rookeries but gave no indication of the number of birds. On 23 December 1931, A. Saunders counted 25 birds, all incubating eggs (unpublished notes of B. B. Roberts); this observation was attributed to Roberts by Rankin (1951). This is probably the same group as Saunders (1950, p. 57) photographed and referred to as nesting in a "harbour" which served as a depot for ships' supplies at the time of the *Discovery II* expeditions of the early 1930's. Although Rankin (1951) failed to locate the colony in 1946, he saw four adults on the shore. According to W. N. Bonner (*in* Stonehouse, 1960) the colony no

longer existed in 1958. However, Bonner (personal communication) found about ten adults and ten chicks in one group and a further small group of adults with one chick on 8 November 1959. D. C. Lindsay (personal communication) counted about 250 birds, excluding scattered groups on the beach, of which about 80 were incubating in early January 1972. A count made from a photograph taken by W. N. Bonner on 1 January 1975 revealed 500 birds, only about a dozen of which could be identified as yearlings; a large number of the adults were incubating eggs.

Wales Head

This rookery, lying on the slopes of Tawny Gap about 1 km south of Wales Head, was discovered on 30 January 1977 by D. I. M. Macdonald (personal communication). It is situated amongst tussock grass about 500 m from the shore on the bank of a small stream. Of about 400 adults, 220 were incubating eggs and a few had newly hatched chicks. There were about ten previous season's chicks, three of which were moulting. Non-breeding adults were not counted.

Cape Buller peninsula

A rookery was discovered in January 1977 (personal communication from D. I. M. Macdonald) on the eastern side of an un-named bay 5 km east of Wales Head at the south-west side of Cape Buller peninsula opposite Rosita Harbour. The breeding colony, situated about 100 m from the shore in a small barren valley formed by a melt stream from an arm of Brunonia Glacier, comprised 150–200 adults, 80% of which were incubating, and 14 previous year's chicks. A further 30 adults were present in a group about 100 m up-stream in the valley, while two groups of 54 and 28 chicks, respectively, were seen on the raised beach towards the shore.

Cape Buller to Cape Wilson

Bay of Isles

Salisbury Plain. This is probably the largest rookery on South Georgia, lying about 1 km inland on the slopes of a partially tussock-covered ridge separating the eastern side of Salisbury Plain from Lucas Glacier.

When Murphy (1915) visited the colony on 24 December 1912 there were about 350 king penguins including many incubating birds and numerous yearlings; he also noted that 4 years earlier the same colony had contained a far greater number of birds during the breeding season, suggesting that the rookery had suffered seriously from the ravages of the seal and penguin hunters. However, this apparent discrepancy in numbers may be simply the difference between early and late season counts. Over 200 young birds were reported from an unspecified colony in the Bay of Isles in 1914 (Allen, 1920*) and, in view of Murphy's (1915) comment that the Lucas Glacier rookery was the larger of the two in this bay, it is likely that these young birds belonged to this rookery. Matthews (1929) referred to the Bay of Isles as possessing one of the largest colonies on the island in 1926 but he provided no estimate of numbers. On 22 and 24 October 1936, B. B. Roberts (unpublished notes†) counted 1 100 adults (about 550 breeding pairs) of which 71 were segregated with a creche of 672 chicks. Rankin (1951) quoted Roberts' count as 550 birds. When Rankin (1951) visited the rookery in early 1947, he counted 1 800

* This account is based on a census of king penguins made by Captain Rasmussen of S.S. *Undine* in the late summer of 1914. The rookery counts were conveyed to the Colonial Secretary, Port Stanley, Falkland Islands, by J. Innes Wilson, Stipendiary Magistrate at South Georgia in a report dated 14 May 1914.

† All information provided for 1936–37 is taken from the unpublished field notes of Dr B. B. Roberts, made during the British Graham Land Expedition, 1934–37. The king penguin data contained in these notes differed from corresponding data entered on Roberts' unpublished sketch maps depicting penguin colonies on South Georgia. These were much less accurate than the former data and, unfortunately, it was Roberts' map data to which Rankin (1951) referred.

breeding pairs (i.e. adults with chicks) which he estimated represented a total colony of about 5 000 penguins.

C. M. Clapperton recorded 2 100 adults and 1 750 chicks in April 1969 (*in* Conroy and White, 1973), while R.I.L.S. counted about 1 700 adults and about 1 450 chicks on 10 November 1969. The reduction in numbers between these two dates is to be expected as not all the breeding adults would have returned to the rookery by November and the chicks represented those which survived the winter; the apparent loss of 17% of the chicks corresponds almost exactly with Stonehouse's (1960) observation on the Ample Bay rookery where, of the 2 500 eggs laid, 2 100 chicks survived the winter (i.e. 16% mortality). On 16 April 1971, R.I.L.S. counted about 3 500 adults and about 2 500 current year's chicks. Of these adults there was a group of over 150 at the margin of a small fresh-water lake some distance up-hill and inland from the rookery; several birds were swimming (see also Rankin (1951, p. 121)). At least 200 of the adults were scattered in groups between the colony and the shore.

The most recent and probably most accurate census made of this rookery was by F. S. Todd (in literature) on 1 April 1977. He recovered the following numbers, which are by far the greatest estimate of birds made for this rookery: 6 270 adults in the rookery, 850 adults below the rookery, 1 020 adults on the beach, and to the west about an additional 3 000 adults, making at least 11 100 adults associated with the rookery. There were about 3 550 chicks excluding those under abdominal folds. 10–20% of the adults were covering eggs or very young chicks. Less than 0.1% of all adult-sized birds were under 2 years old and no chick exceeded 4 months of age, indicating that all previous season's chicks had already left the colony.

Ample Bay. The second rookery in the Bay of Isles is situated on Paul Beach, Ample Bay, about 150 m from the shore and 0.5 km west of Grace Glacier towards Markham Point.

It was visited by Murphy (1915, 1948) on 16 December 1912 but he gave no count; however, he mentioned that many of the birds were incubating eggs and there were also six young of the previous year (Murphy, 1915). The earliest data were provided by Roberts (unpublished notes), who recorded 597 adults with 267 chicks and nine eggs on 10 April 1937. Unfortunately, Roberts' count was misquoted by Rankin (1951) as being a total of 75 birds. Around December 1946–January 1947, Rankin (1951) counted "1,100 kings actually with eggs, giving a total population of not less than 2,500." Between October 1953 and December 1954, Stonehouse (1956) estimated 5 000 breeding birds and, on 8 April 1954, "between 2,000 and 2,500 adults were present at the rookery and 1,750 adults and juveniles were counted along the beach" (Stonehouse, 1960). An estimate of about 5 000 birds was obtained in February 1973 (personal communication from R. A. S. Clayton). The most recent information for this colony was provided by F. S. Todd (in literature), who estimated at least 3 000 adults occupied the main rookery, making at least 6 000 adults associated with the rookery on 1 April 1977; there were also many chicks of all ages.

Beckmann Fjord

This newly discovered small breeding colony was reported on 22 February 1977 (personal communication from J. A. Jewell). It lies about 100 m from the shore amongst tussock grass and, although not all adults were counted, 32 were incubating eggs and there were 21 recently hatched chicks.

Sealeopard Fjord

This small rookery was first reported by Matthews (1977) in the mid 1920's, being situated near the north end of the beach to the north-west of Morris Glacier. There were about three dozen birds including a creche of 11 young; nine of the adults had eggs. All but six of the

colony were captured for a zoo and most of the eggs were broken. The fjord had been closely examined by Murphy (1948) in 1912, by Roberts (unpublished notes) in 1936 and by W. N. Bonner (personal communication) in the 1950's, but no rookery was seen on any of these occasions. However, it was re-discovered in January 1973 (personal communication from R. A. S. Clayton) when fewer than 50 birds, including about 15 incubating, were seen on the morainic debris near the shore at the western side of Morris Glacier.

Cape Wilson to Cape Saunders

Fortuna Bay

Cape Best. A recently discovered large rookery lies several hundred metres inland on the north-eastern corner of Fortuna Glacier south-west of Cape Best.

Although W. N. Bonner (personal communication) noted 12 adults and 28 chicks on 14 September 1958 on the beach at the north-eastern side of Fortuna Glacier near Cape Best, the main colony was located in early January 1974 by T. C. Gunn (personal communication), who reported a total of about 1 500 birds including many newly hatched chicks and over 100 yearlings. The only route which the penguins can take from the shore to the breeding area is along a narrow passage, barely 1 m wide, between the ice wall of the glacier and a high rock wall. In the event of an ice fall, this corridor could be easily blocked and the rookery completely isolated. W. N. Bonner (personal communication) has commented that this corridor did not exist during his visits to this area in the 1950s and that it was unlikely a large rookery was present there then as the beach was regularly visited for sealing. Photographs of this colony taken on 7 December 1975 by P. W. G. Tanner revealed about 1 000 adults and about 550 chicks of which 60 were moulting.

Anchorage Bay and König Glacier. There are possibly two small rookeries actually in Fortuna Bay but early reports of breeding colonies did not specify the exact locality. The earliest reference to a colony appears to be by Lönnberg (1906), who reported that two young birds were captured in Fortuna Bay in mid-September 1905. No colony was mentioned in the 1914 census by Allen (1920) but Matthews (1929) listed the bay as having one of the larger colonies on the island, although no numbers were given. W. N. Bonner (*in* Stonehouse, 1960) recorded seven adults and three chicks in October 1957, and on 9 September 1958 Bonner (personal communication) saw only two adults with four chicks. Bonner's observations were made in Anchorage Bay close to the shore near a melt stream on the outwash debris below a glacier tongue originating from Fortuna Glacier on the western side of the bay.

An early season count in 1965 by S. H. Down (*in* Conroy and White, 1973) at an unspecified locality gave 37 birds, of which only two were incubating. It is thought that most of these observations at unspecified sites were made near the north-western corner of König Glacier. It was near hear, in January 1974, that D. W. H. Walton (personal communication) reported a group of 120 apparently non-breeding and moulting adults. On 28 November 1975, D. I. M. Macdonald (personal communication) noted 150–200 birds, including 40 chicks and a further 10–20 moulting chicks about 0.75 km inland below some rocky knolls east of Breakwind Ridge by a large melt stream flowing on the west side of the outwash plain below König Glacier.

Possession Bay

Although Cook (1777, vol. 2, p. 214) observed several groups of king penguins in Possession Bay when he landed there on 17 January 1775, the first record of a rookery in this bay was provided by Murphy (1915). A small colony on the west shore (Alert Point or Brighton Beach) comprised only 12 birds on 25 February 1913. He referred to at least one yearling and indicated that this could be considered as a breeding site. When several of the major beaches

were visited in early 1974, no rookery could be located (personal communication from T. C. Gunn and D. W. H. Walton). However, a thriving colony was discovered by J. A. Jewell (personal communication) on 19 February 1977 on the beach to the north of Purvis Glacier. There were 86 adults with eggs, 21 current year's chicks and several dozen adults nearby.

Antarctic Bay

There is a small rookery of fluctuating size on the tussock-covered slopes of a rocky ridge bordering a broad well-vegetated basin about 250 m from the shore of Windy Cove on the north-west side of Antarctic Bay. It is also one of the few colonies not associated with permanent ice.

The colony appears to have been discovered by C. A. Larsen, who, on 11 March 1905, counted "about 25 pairs of breeding birds" (Lönnberg, 1906). Some of these had large chicks while others still had eggs, ten of which were collected and some found to be freshly laid. By late June 1905, however, only four chicks and a few adults remained. Allen (1920) provided a figure of about 100 birds in early 1914, although Murphy (1915) had failed to locate the rookery 2 years earlier. No other counts were made until 25 October 1936 when Roberts (unpublished notes) found 41 adults and ten chicks about 9 months old. Rankin (1951) quoted Roberts' count as 25 birds but on 4 January 1947 he recorded 24 birds of which nine were incubating. No further visits appear to have been made until 5 April 1970 when R.I.L.S. recorded two with three large current year's chicks, together with a group of 34 adults nearby and a further adults half dozen on the beach.

Cape Saunders to Barff Point

Alert Cove, Stromness Bay

A small breeding colony of 20–30 adults with 6–12 chicks, representing both breeding phases for the current year, was observed by N. Lowthrop (personal communication) in early May 1977 in the tussock zone close to the shore in Olsen Valley. He also reported 124 adults, one of which was incubating, on 18 January 1978. About another 120 adults were in groups around Alert Bay.

Barff Point to Cape Harcourt

St. Andrews Bay

This is another of the largest rookeries on the island, being situated on the north side of Cook Glacier about 150–200 m from the shore on an extensive area of outwash debris, moraines and also on the glacier margin (Fig. 2).

von den Steinen (1890) reported a group of 20 birds on 14 May 1883. By early 1914 the colony was estimated to consist of 30 birds (Allen, 1920) and by May 1925 the manager of Compañia Argentina de Pesca (Grytviken) stated there were about 1 100 king penguins in the rookery (unpublished notes of B. B. Roberts). In 1926 this was considered as one of the largest rookeries on the island (Matthews, 1929). Although Rankin (1951) made no count here during his ornithological studies in 1946, he quoted 700 birds for this colony in 1936 (attributed to B. B. Roberts). However, Roberts (unpublished notes) actually recorded 1 195 adults and 942 chicks ($\pm 3\%$) on 28 October 1936. The chicks were segregated from the main group and under the care of 123 of the adults.

Conroy and White (1973) noted that 4 000 birds, of which 2 500 were breeding, were counted (by S. H. Down, Combined Services Expedition) in early 1965. They also quoted 1 500 birds for December 1971 but this figure referred to a seemingly non-breeding group on the beach about 2 km to the south of the rookery on the south side of Cook Glacier (personal communication from P. Stone). Counts made between the winter of 1972 and February 1974

a

b

Fig. 2. a and b. Part of the large king penguin rookery on the outwash plain adjacent to Cook Glacier, St. Andrews Bay. Most of the birds are previous season's chicks with only a few attendant adults; 6 September 1975. (Photographs by N. Leader-Williams.)

(J.R.B.T.; personal communication from P. Stone) provided a total population of 6 000–7 500 birds including over 2 000 chicks. On 10 November 1976, R.I.L.S. visited the rookery and counted about 3 500–4 000 chicks and about 2 000 adults, the majority of which were moulting in large groups extending over the entire beach and moraine system between Heaney Glacier and the shore. At least half of the chicks were on the lower ice ramp of Cook Glacier, extending up to 1 km inland.

Doris Bay

Almost 80 years separate the first two published observations of king penguins at this rookery. von den Steinen (1890) reported several adults and six chicks near Nachtigal Glacier, Little Hafen (= St. Andrews Bay), on 14 May 1883. Although W. N. Bonner (personal communication) visited this area during the 1950s, he did not observe any rookery. However, Conroy and White (1973) recorded a colony of 250 birds, ten of which were incubating, in December 1971 but they did not indicate who reported these. P. Stone (personal communication) counted over 100 adults, eight of which were incubating, and 24 chicks in the rookery in February 1974. This may be an overspill population from the large rookery on the north side of Cook Glacier, 4 km to the north-west in St. Andrews Bay. Stone also noted *c.* 1 500 non-breeding adults about midway between the two rookeries on the south side of Cook Glacier in December 1971 (see St. Andrews Bay rookery).

Hound Bay

A group of less than 50 birds, including one incubating, was observed by P. Stone (personal communication) near the shore to the north of lower Lönnberg Valley on 2 March 1974.

Cape Harcourt to Cape Vahsel

Royal Bay

This large rookery is situated below a low hill amidst tussock grass close to the north-eastern corner of Weddell Glacier, 2 km south of Will Point and about 250 m from the shore.

The earliest report of this colony was provided by von den Steinen (1890) when he observed 500 adults and 200 chicks on 6 June 1883. A similar count of over 300 adults with several scattered groups of up to 20, and about 500 previous year's chicks, was noted by Wilson (1914) in mid-September 1914. About 500 king penguins were present during the summer of that year (Allen, 1920). In October 1936, Roberts counted about 700 birds (unpublished notes; Rankin, 1951) (*not* 7 000 as quoted by Conroy and White (1973)). However, when Rankin (1951) visited the rookery in 1946, he estimated "a round figure of 4,000 incubating penguins. Eight thousand breeding birds, with hangers-on, would mean a colony of at least 10,000." This figure was determined by multiplying the density of birds estimated in a sub-sample of the rookery by the appropriate fraction of the approximate breeding area. According to Sutton (1957), there were over 7 000 incubating birds in the main and subsidiary rookeries on 20 January 1955. When W. N. Bonner (personal communication) visited the rookery on 16 September 1960, he counted about 1 500 chicks but did not note the number of adults present.

A count made by S. H. Down (*in* Conroy and White, 1973) in early 1965 gave only 1 610 breeding birds, while another count, made from a photograph taken by D. W. H. Walton on 31 March 1968, gave 1 700 adults and 550 chicks in the rookery and a further 200–300 adults on the beach nearby. An independent count quoted by Conroy and White (1973) for the same visit provided an estimate of 2 000 breeding birds. When visited in December 1971, about 600 incubating birds were counted from a photograph taken by J.R.B.T., who estimated that over 2 000 adults and about 750 yearlings were present in and around the colony. However, an unknown number of late breeders would certainly increase this total by January–February.

Approximately 1 600 adults, most of which were incubating, were counted from photographs taken by R. M. Laws in December 1974.

Gold Harbour

This moderate-sized rookery occurs on a tussock-fringed level area among moraine ridges and adjacent to a melt stream issuing from the north side of the snout of Bertrab Glacier, a few hundred metres from the shore.

Matthews (1929) indicated that it was one of the larger colonies but the first indication of its size was given by Roberts, who counted 210 birds in October 1936 (unpublished notes; Rankin, 1951); however, Roberts' unpublished map indicates about 200 nests. On 10 February 1947, Rankin (1951) counted 55 incubating birds, another 100 were in various stages of moult and a further 100 were scattered along a dry river bed nearby; he estimated the total population to be about 400 birds. W. N. Bonner (personal communication) visited the colony on 2 November 1960 when he counted 244 chicks near the beach, about 200 m from the site of the rookery; adults were not counted. The most recent counts were made by J.R.B.T., who, on 19 December 1971, estimated about 150 chicks and about 350 adults, of which about 50 were incubating, and by P. Stone and D. C. Lindsay (personal communication), who estimated about 500 birds with at least 40 incubating in February 1972. Unlike many of the rookeries on South Georgia, this population seems to be relatively stable.

Iris Bay

A small rookery is situated on the flat-topped crest of a low tussock-covered moraine on the north side of Herz Glacier.

Although about 600 birds were reported from Sandwich Bay (= Iris Bay) in early 1914 (Allen, 1920), no further estimates appear to have been made until J.R.B.T. counted about 100 adults, including 24 incubating eggs, on 26 December 1971. P. Stone (personal communication) provided further data on 19 December 1973 with about 100 adults, of which 12 were incubating, and 22 year-old chicks.

Cape Paryadin to Cape Demidov

Miles Bay

This rookery was discovered in December 1970 and is situated near the shore on the fluvioglacial outwash fan close to the north side of an un-named glacier west of Warburton Peak.

D. W. H. Walton (personal communication) estimated a total population of about 300–400 birds, including about 80 incubating, and only one previous year's chick. Three years later there were about 1 000 birds with many incubating when R. A. S. Clayton (personal communication) visited the colony in January 1974. The beaches of this bay were frequently visited by sealers but no king penguin rookery existed there during the 1950s (personal communication from W. N. Bonner). It is possible that early reports of groups of king penguins seen on the beach at Narval Bay (Allen, 1920), about 5 km to the north, were of birds from the Miles Bay rookery.

Schlieper Bay

D. I. M. Macdonald (personal communication) reported a small rookery in this bay for the first time on 4 January 1977. It is situated about 300 m from the shore on the north side of the bay on a stony tussock-covered knoll by a stream. On 13 January 1977, there were about 100 adults, of which 45 were incubating eggs, but no previous season's chicks were seen. Besides numerous non-breeding adults in the colony, there were at least 25 in a group on the nearby beach.

Undine Harbour

Weddell (1825) landed in only one locality on South Georgia, namely in Adventure Bay (= Undine Harbour), where his ships *Jane* and *Beaufoy* were anchored from 12 March to 17 April 1823. In referring to the king penguin, he mentioned "large flocks along the shore".

This currently small rookery is situated amongst tussock grass several hundred metres from the sea on a low ridge in Hope Valley running north-eastward from the eastern end of the bay (Fig. 3); in some years the colony occurs on the moss- and tussock-covered bank of the Hope Valley stream.

The first record of a breeding bird here was on 26 December 1926 when a solitary king penguin was seen incubating an egg at the edge of a gentoo penguin colony (Matthews, 1929; Hardy, 1967), while Roberts (unpublished notes) saw three or four king penguins in October 1936 on the beach at Elsehul on the north side of the isthmus from Undine Harbour. A single incubating bird was also reported in 1960–61 (*in* Conroy and White, 1973). When the present authors visited the site on 27 December 1970, there were 38 adults including at least 18 incubating eggs but no yearling chicks; several small groups of adults were scattered between the rookery and the shore where a group of 17 included eight moulting birds. In January 1972, M. R. Payne (personal communication) counted at least 25 incubating and several non-breeding birds but there were no previous year's chicks. On 23 November 1973, 34 chicks were counted by W. N. Bonner (personal communication). However, on 9 December 1973 there were only six previous season's chicks, together with 59 adults, only six of which were incubating (personal communication from P. W. G. Tanner). On 25 March 1976, T. S. McCann (1976) counted 90 adults, of which 14 were incubating eggs; there were also 63 chicks. Some distance away on the beach, two birds were incubating eggs and there were also about 60 adults in small groups. By early November 1976, McCann reported only 50 chicks surviving, indicating a 37% mortality during the winter, assuming that all the 63 chicks were hatched during the 1975–76 summer; any belonging to the previous season would have left the rookery before the onset of winter. On 13 April 1977, F. S. Todd (in literature) reported a total of 73 adults and 49 current year's chicks.

Morsa Bay

Allen (1920) stated that a number of king penguins had been seen at North Bay (= Narval Bay), on the north side of Ice Fjord, in early 1914. Roberts (unpublished notes; *in* Rankin, 1951) was informed by sealers that some had been seen ashore there in October 1936. That a breeding colony does exist in Ice Fjord was confirmed by D. I. M. Macdonald (personal communication) on 18 January 1977 when a small rookery with about 80 adults, 35–40 of which were incubating eggs, was found at the west end of Morsa Bay 2–3 km south-west of Narval Bay. There were no previous year's chicks. The colony was 200 m from the shore on the landward side of a small unvegetated moraine at the snout of a glacier.

Cape Demidov to Cape Rosa

Cheapman Bay

On 4 January 1971, the authors discovered a rookery about 1 km from the shore of Cheapman Bay on an unvegetated moraine about 50 m a.s.l., at the side of a small valley and at the south-western edge of Price Glacier (Fig. 4). The colony consisted of 93 adults including 50 incubating eggs and 18 year-old chicks of which 12 had just moulted; a further 90 adults were scattered in groups on the raised beach area close to the shore.

Nilse Hullet

A small rookery comprising 28 adults and eight chicks was reported by R. A. S. Clayton (personal communication) in March 1974 close to a large gentoo penguin colony in Nilse Hullet, west of King Haakon Bay.

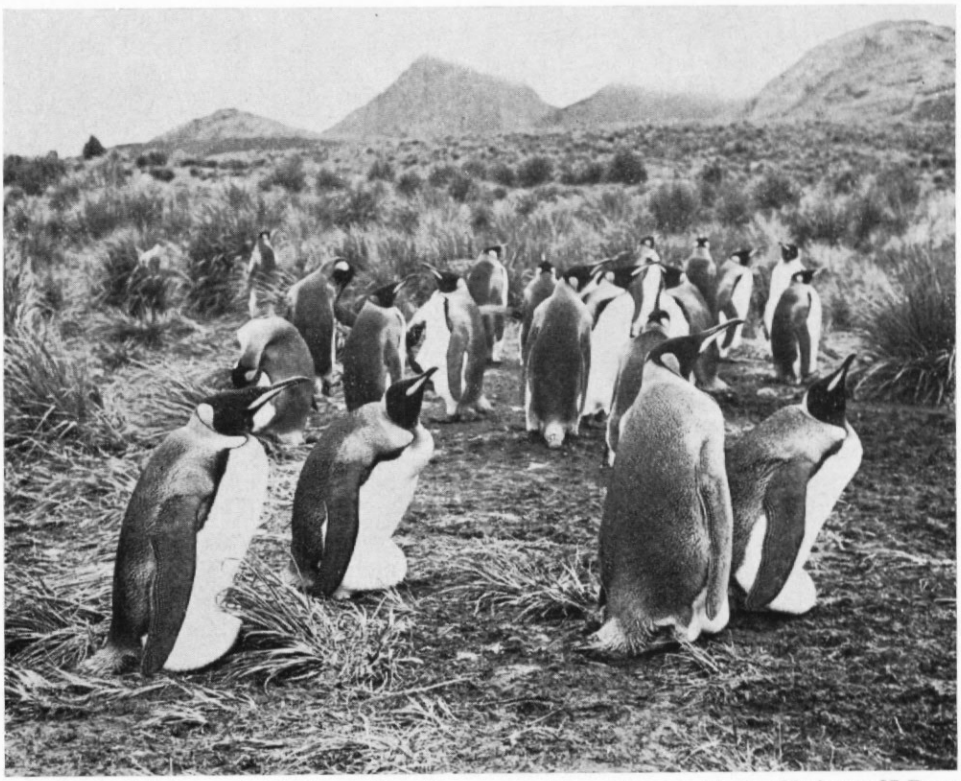

Fig. 3. Incubating king penguins in the small rookery amongst tussock grass, Undine Harbour; 27 December 1970.

Fig. 4. Incubating king penguins in the small rookery on a moraine adjacent to Price Glacier, Cheapman Bay; 4 Janaury 1971.

Elephant Cove

A small rookery was recently discovered on the tussock-covered outwash fan about 0.5 km inland from this cove. Although no king penguins were noted in the vicinity of this rookery in the 1950s by W. N. Bonner (personal communication) or by the authors in January 1971, R. A. S. Clayton (personal communication) counted 27 chicks and a total population of less than 50 adults in March 1974.

Cape Rosa to Cape Disappointment

Holmestrand

Although the extensive beach area of this bay to the north of Jossac Bight had been visited frequently in the 1950s by W. N. Bonner (personal communication) and in 1961 by S. W. Greene (personal communication), no king penguin rookery had been observed. However, a small colony was discovered by D. I. M. Macdonald (personal communication) in March 1975 about 100 m from the beach at the edge of the tussock fringe adjacent to Esmark Glacier. On 8 March 1975 there were seven adults each with a chick and 13 others incubating; one egg was abandoned and 30 non-breeding adults stood nearby. On 19 March 1975, 44 adults were counted and by 8 April 1975 there were 37 adults and 15 young chicks of various sizes.

Rocky Bay

This small colony was discovered on 30 November 1976 on a small headland at the western side of Rocky Bay (personal communication from J. Hall). It was situated in the midst of a gentoo penguin colony, in the small melt-stream valleys separating several tussock-covered moraine ridges. The rookery was about 25 m from a small lake lying close to the foot of an un-named glacier west of Helland Glacier. Of 25 adults, there appeared to be five pairs, although no eggs were yet laid, and nine yearling chicks of which one had already completed moulting.

Horten

A single king penguin incubating an egg was observed during January and February 1976 by C. E. Johnson (personal communication) in the centre of a gentoo penguin rookery about 300 m from the beach at Horten, Jossac Bight, close to the edge of Keilhau Glacier. A group of 20–25 moulting adults was also seen on the beach.

Paradise Beach

A group of about ten birds, one of which was incubating, was observed by J.R.B.T. near the beach close to the southernmost tongue of Graee Glacier in December 1972. This is the most southerly record of a king penguin breeding on the island.

Rookeries no Longer in Existence

Hercules Bay

Roberts (unpublished notes) was informed by H. Hansen that prior to 1936 there had been a small king penguin rookery on the low promontory west of Hercules Cove but that it no longer existed in 1936. Roberts suggested that its extinction was clearly due to human interference, probably by whalers from the Leith Harbour whaling station. He noted on a map (unpublished) of the distribution of penguins on the island 150 king penguins in October 1936 on Bjelland Point, a low promontory between Fortuna and Hercules Bays. It is possible that this is the same locality as that reported by Hansen, although they would appear to lie about 4 km apart.

Sunset Fjord

Roberts (unpublished notes) carried out a thorough investigation of the shoreline of the Bay of Isles in October 1936 but he failed to locate a rookery which was reputed by sealers to have existed in Sunset Fjord at the south-west side of the bay. It is probable that the rookery referred to was the one in Ample Bay, 2.5 km to the east.

King Haakon Bay

Although there have been unconfirmed reports of a rookery in King Haakon Bay (Stonehouse, 1960), to the east of Cheapman Bay, W. N. Bonner (*in* Stonehouse, 1960) found no evidence of a breeding colony there during the 1950's. Landings made by botanical and geological field parties in recent years also failed to locate any breeding colonies there.

Discussion

From the recent survey of king penguin rookeries on South Georgia, numerous colonies have been discovered which had not been reported previously (i.e. those at Beckmann Fjord, Cape Best, Cape Buller peninsula, Cheapman Bay, Elephant Cove, Holmestrand, Horten, Hound Bay, Miles Bay, Morsa Bay, Paradise Beach, Possession Bay, Rocky Bay, Sealeopard Fjord, Schlieper Bay and Wales Head), although many of the localities were visited regularly by sealers until the late 1950s. This suggests an expanding population with new small rookeries being established as "overspill colonies" formed by birds originating from the major rookeries in the Bay of Isles, St. Andrews Bay and Royal Bay, and possibly some others. However, this can be confirmed only by a large-scale marking and recovery programme over several years at a number of the principal colonies. The common occurrence of groups of up to ten or occasionally in excess of 50 king penguins, particularly moulting birds, on beaches around the island throughout the summer indicates that there is considerable dispersal from the rookeries. Stonehouse (1960) reported that of over 30 1-year-old chicks banded none returned to their rookery in the following season, although five 2-year-old juveniles in moult returned for a few weeks in adult plumage. He suggested that it is the second year in a bird's life cycle when they will disperse and attach themselves to a new colony and that it is the colony in which the juvenile moults where it is likely to remain and subsequently breed. Stonehouse also recorded a single instance of a 1-year-old chick banded at Ample Bay, Bay of Isles, in January 1954, which was recovered 13 months later among a group of moulting birds in Royal Bay. Studies of king penguins at Iles Crozet have revealed that, whereas adults do not appear to move from one rookery to another in successive years to breed, juveniles hatched in one colony not infrequently breed in another rookery within the archipelago when they are mature (personal communication from B. Despin).

In attempting to determine the number of breeding pairs which comprise a rookery, various factors relating to the irregular breeding cycle must be taken into account. An indication can be obtained from an assessment of the number of chicks and incubating birds present. The situation in a simplified long-established stable population, not allowing for mortality during summer, may be considered as:

Year 1		*Year 2*		*Year 3*
$\frac{1}{3}$ early breeders	→	$\frac{1}{3}$ late breeders	→	$\frac{1}{3}$ ineffective breeders
$\frac{1}{3}$ late breeders	→	$\frac{1}{3}$ ineffective breeders	→	$\frac{1}{3}$ early breeders
$\frac{1}{3}$ ineffective breeders	→	$\frac{1}{3}$ early breeders	→	$\frac{1}{3}$ late breeders

Therefore, chick censuses will give an estimate of only two-thirds of the total breeding adults, since it is assumed that one-third will be ineffective breeders in any one season. The *breeding population* may be calculated as follows, depending on the time of year when the chicks are counted:

i. In April–May the number of chicks (assumed to be all of the current year as all previous year's chicks should have left the rookery by now) will approximate to the number of breeding pairs in the colony.

ii. In October–November the number of chicks will represent about 84%* of those present at the beginning of the previous winter. Therefore, the number of breeding pairs *in the previous season* will be the number of chicks in spring times 1.19 (i.e. 100/84).

iii. In December–January the number of chicks will include the same proportion (about 84%) of previous year's chicks as were present in October–November plus about 50% of the *current year's chicks* and eggs (i.e. those of the early breeders and assuming equal numbers of early and late breeders, but see below). Therefore, the same value for previous year's breeding pairs should be derived from these data as for (ii) above, together with an estimate for the current year's breeding pairs (i.e. twice the number of eggs plus young chicks).

iv. In late February–March most of the previous year's early chicks should have left the rookery, leaving only the late chicks of that season, i.e. approximately 42% of the original total (about half the 84% remaining after winter), together with both early and late chicks and eggs of the current season. However, an unknown but probably very small percentage of the previous year's chicks may be assumed to die during the summer. The approximate number of breeding pairs for the previous year may be calculated as the number of second-year chicks plus 42% (early chicks) plus 16% (total chick winter mortality). The current season's breeding pairs will be approximately the number of chicks and eggs present.

Almost certainly, the composition of a rookery is not as evenly balanced as indicated above. In fact, many of the small, apparently recently established colonies had no previous year's chicks when visited, while some had only a few previous year's chicks and no current year breeders. This suggests that these unstable rookeries may comprise birds which are almost all in the same breeding phase. Furthermore, in these establishing rookeries breeding success appears to be very low. For example, at the small rookery at Undine Harbour in December 1970 there were no previous year's chicks but 18 eggs, yet in January 1972 in the following summer there were again no chicks but a further 25 eggs. This indicates that all the previous year's chicks had died before or during the winter. Of the 25 eggs, six chicks survived to the following December (76% mortality). It appears to have taken the rookery another 2 or 3 years before it became well established, i.e. by March 1976 there were 63 chicks and another 16 eggs (two being in a subsidiary "colony"). By the following November, 37% of these offspring had perished. Presumably, if the rookery continues to increase, within a few years it will reach equilibrium with a winter mortality of about 10–20%. However, Stonehouse (1960) provided evidence that even in a large rookery such equilibrium is not maintained, for during the 1953–54 season he estimated for the Ample Bay colony "that late breeders outnumbered early breeders approximately in a ratio of 3 to 2, while intermediate breeders accounted for less than one-tenth of the total breeding population". This suggests a population composition of approximately 37% early breeders, 8% intermediate breeders (i.e. the "few birds which breed in the period between the waves of early and late breeders") and 55% late breeders. In the following year, therefore, this ratio may be expected to have been about 37% late breeders and about 55% early breeders, assuming that all of the latter were ineffective breeders in the previous year, but it would be quite possible that the influx of early breeders would represent a completely different percentage. Consequently, the population numbers will

* This figure is derived from a 16% mortality, calculated from Stonehouse's (1960) data for the Ample Bay rookery between the summer of 1953–54 and the spring of 1954–55. It is probable that winter mortality varies from 10 to 20% as it will fluctuate from year to year within a single rookery and between rookeries. A considerably higher proportion of the early chicks than the late chicks generally survive; survival success of the latter is very much dependent on the weather conditions in early winter.

TABLE I. ESTIMATE OF TOTAL NUMBERS OF KING PENGUINS IN ALL KNOWN ROOKERIES ON SOUTH GEORGIA, BASED ON MOST RECENT DATA

Rookery location	*Date*	*Number of adults*	*Number of eggs*	*Number of chicks*	*Approximate total population at time of count*	*Approximate potential maximum total population**
Bay of Isles (Salisbury Plain)	1 April 1977	11 120	1 500	3 500	16 000	18 300
St. Andrews Bay	10 November 1976	2 000	0	3 500–4 000	5 500–6 000	16 500
Bay of Isles (Ample Bay)	1 April 1977	6 000	?	Many (? 1 500)	7 000	7 500
Royal Bay	December 1971	2 000	600	750	3 350	3 500
Cape Best	7 December 1975	1 000	?	550	1 550	2 400
Right Whale Bay	1 January 1975	500	? 250	12	750	1 800
Wales Head	30 January 1977	400	220	20	650	1 600
Miles Bay	January 1974	>500	Many	?	750	1 100
Cape Buller peninsula	January 1977	200	150	96	450	1 100
Gold Harbour	December 1971	350	50	150	550	650
Schlieper Bay	4 January 1977	125	54	0	180	400
Cheapman Bay	4 January 1971	183	50	18	250	350
Possession Bay	19 February 1977	120	86	21	220	350
Fortuna Bay (König Glacier)	28 November 1975	200	0	55	250	250
Undine Harbour (including subsidiary colony)	25 March 1976	90+60	14+2	63+0	230	250
Morsa Bay	18 January 1977	80	40	0	120	250
Beckmann Fjord	22 February 1977	50	32	21	100	200
Doris Bay	February 1974	>100	Some	24	150	180
Iris Bay	December 1973	100	12	22	130	150
Sealeopard Fjord	January 1973	>50	15	?	60	110
Elephant Cove	April 1974	25	0	23	50	80
Holmestrand	8 April 1975	37	0	15	50	60
Rocky Bay	November 1976	25	0	9	35	40
Fortuna Bay (Anchorage Bay)	October 1958	2	0	4	6	20
Antarctic Bay	5 April 1970	36	0	3	40	10
Hound Bay	March 1974	50	1	0	50	0
Horten	February 1976	25	1	0	25	0
Paradise Beach	December 1972	10	1	0	10	0
APPROXIMATE TOTALS		25 500	3 250	10 800	39 000	57 150

* Calculated from chick and egg numbers according to the formulae on p. 272, e.g. for St. Andrews Bay, the November count of 3 500–4 000 chicks represents about 4 500 previous year's chicks, assuming 10–20% mortality; this indicates 9 000 adult breeding birds which is about two-thirds of the total breeding population, assuming one-third are ineffective breeders (i.e. a further 3 000 birds).
For Wales Head, the January count of 220 eggs (all chicks assumed to be from the previous year) represents 440 early breeding adults; assuming equal number of early and late breeders, there will be a further 220 eggs and 440 adults towards the end of the summer; these 880 adults form two-thirds of the total breeding population, i.e. there are about a further 150 ineffective breeders.
For Salisbury Plain, the April count of 3 500 current year's chicks and 1 500 eggs represents 10 000 breeding adults which are two-thirds of the total breeding population, i.e. a further 3 300 adults are ineffective breeders.

oscillate from year to year with a higher proportion of chicks dying in some years than in others depending on the ratio of early to late breeders and the severity of the weather in early winter.

The distribution of the South Georgian king penguin rookeries, classified in very broad population categories, is given in Fig. 1. From the actual counts made in recent years (see Table I), a total of about 36 000 adults and chicks has been estimated, although in addition at least 3 000 eggs were being incubated at some colonies when the counts were made. Applying the formulae given above, the island's total population is estimated to be about 57 000 king penguins. It is fully realized that the estimates listed in Table I do not take into account many of the variable factors which must alter the breeding success from year to year. This represents a very substantial increase over the past 60 years; the censuses of 1914 (Allen, 1920) and 1936 (unpublished notes of B. B. Roberts) both indicated less than 2 500 birds, while that by Rankin (1951) in 1946 gave over 12 000. Similar increases have been reported for most of the other breeding localities (Conroy and White, 1973).

A useful indicator of the dynamics of king penguin (and also gentoo penguin) rookeries is the state of the vegetation, particularly tussock grass, around the colonies. Long-established rookeries occupy sites which have become devoid of vegetation due to trampling, excessive amounts of guano and mud and toxic concentrations of nitrogen and phosphorus in the excrement. Recently established rookeries tend to vary in position within a few hundred metres from year to year and consequently damage to the vegetation is generally slight. An expanding rookery, particularly a large one, tends to invade the surrounding tussock grass or other vegetation, which appears in varying stages of degeneration. However, several rookeries occur on barren ground and "botanical monitoring" is not feasible.

As with the very considerable population increase in fur seals on South Georgia during the past few decades (Laws, 1973; Payne, 1977), the rise in king penguin numbers on the island may be correlated with increased food availability (mainly cephalopods and fish) which in turn may have increased as a result of higher krill production due to the reduction in stocks of baleen whales. The suggestion that their increase was due to the cessation of penguin slaughtering, as suggested by Conroy and White (1973), must be treated with caution as there are no reliable first-hand accounts of this. All references to penguin persecution at South Georgia (e.g. Matthews, 1931; Murphy, 1915, 1936) appear to have derived from Klutschak (1881). However, even Klutschak's information was not first-hand: "I was told (though I would not presume to maintain the truth of this story against a better informed person) that . . . great ships were engaged in catching these creatures [penguins] in their thousands, killing them, and boiling them down for their oil . . . proof that this did happen in former times can be seen all along the north and north-eastern coast. Countless numbers of little iron vessels which were used can be found everywhere, standing together in pairs."

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