EFFECTS OF REINDEER ON PLANT COMMUNITIES IN THE ROYAL BAY AREA OF SOUTH GEORGIA

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ABSTRACT. The effects of grazing and trampling by reindeer on grass heath, bryophyte banks and tussock communities in the Royal Bay area of South Georgia are described briefly, the main change being the almost total eradication of "reindeer lichens". Changes in the vegetation are compared briefly with grazed areas in Alaska and Newfoundland.

ALTHOUGH reindeer have been present on the sub-Antarctic island of South Georgia (lat. 54°S., long. 37°W.) for over 60 years (Bonner, 1958), their effects on the vegetation have attracted little attention until recently. During a lichenological survey of the island in 1971–72, areas in Royal Bay were visited which have only recently been subjected to grazing and trampling, and it is the purpose of this paper to draw attention to some of the effects on the vegetation of the Royal Bay area resulting from the presence of reindeer.

DISTRIBUTION OF REINDEER

The first introduction of reindeer to South Georgia was made in 1909 by C. A. Larsen, who released 11 animals at Ocean Harbour, Barff Peninsula, and further introductions were made at Leith and Husvik, in Stromness Bay, up to 1925 (Bonner, 1958). Since then the reindeer have increased considerably in numbers and, according to Bonner (1958), the size of the Barff Peninsula population had reached *c.* 4,000 and that of the Stromness Bay herd *c.* 100–200. Recent surveys during 1972 by Payne (1972) and H.M.S. *Endurance* have shown that the Barff Peninsula herds number about 1,300 animals.

Bonner (1958) considered these two populations to be restricted to their areas of introduction by the heavily crevassed glaciers and the steep mountains which contain them. However, the reindeer have recently spread from the south end of Barff Peninsula to the peninsula forming the north shore of Royal Bay (Fig. 1). The reasons for this dispersal are unknown but it may have been pressure on grazing grounds due to increase in the size of the herds after hunting from the whaling station at Grytviken ceased in 1964. This spread to the Royal Bay area is certainly very recent for according to S. W. Greene (personal communication) no reindeer were present in this locality when he worked there in February 1961. Burley (1965) noted several herds in the valleys above Doris and Kelp Bays on the north-west side of the peninsula in February 1965 but there was no trace of them in the Moltke Harbour area on the south side of the peninsula. Burley considered that the reindeer had crossed from Barff Peninsula to the Royal Bay area by Heaney and Cook Glaciers, on which he found hoofprints and droppings. The spread of reindeer into the Moltke Harbour area from Doris and Kelp Bays thus appears to have occurred after February 1965. During the recent survey by H.M.S. *Endurance*, 14 reindeer were seen crossing Cook Glacier.

INFLUENCE OF REINDEER ON VEGETATION

It is not particularly easy to establish precise details of the type and extent of the plant communities that existed on the north shore of Royal Bay before the arrival of the reindeer, although several botanists had visited the area.

Will (1890) spent a year with the German International Polar-Year Expedition of 1882–83 based at Köppen Point and, although he provided considerable autecological notes on the more prominent species, no descriptions were given of the plant communities. However, it is possible from his notes to reconstruct the vegetation pattern for several areas, particularly Whale Valley. Will (1890) noted the occurrence of well-developed plants of *Acaena adscendens* (= *A. decumbens*) in the upper part of Whale Valley. He noted (p. 184) that *c.* 4 km. removed from the beach of Moltke Harbour there is a rich development of vegetation of tussock grass (*Poa flabellata*) and *Acaena adscendens*. On the same page he referred to the lower part of Whale Valley, below the ravine, as the only locality which was favourable for the development

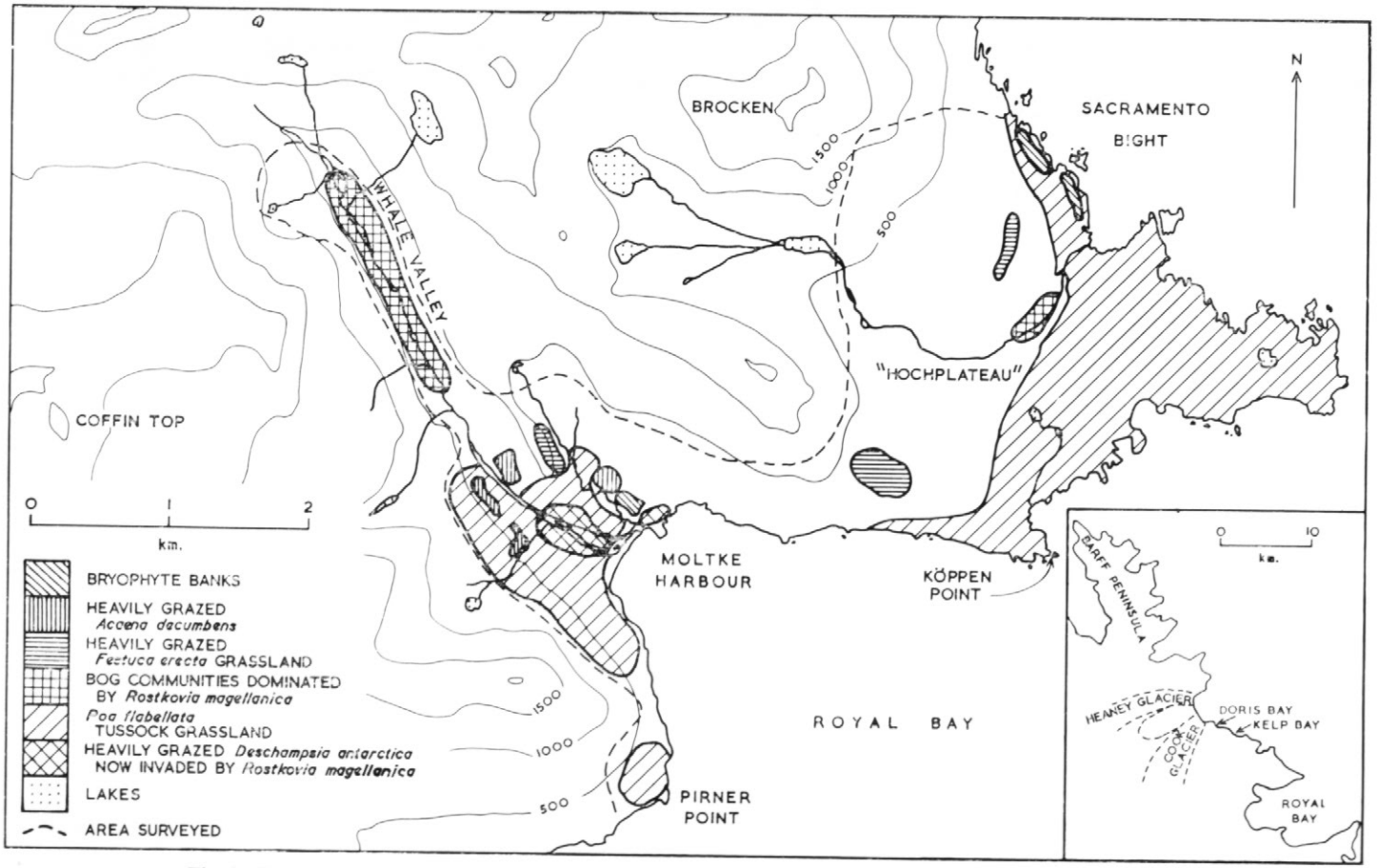


Fig. 1. Sketch map of the peninsula on the north side of Royal Bay, showing localities mentioned in the text and the distribution of major vegetation types in January 1972. Areas left blank have communities dominated by cryptogams and have not been much affected by reindeer.

of plants by virtue of its north-west to south-east aspect. Of particular interest was Will's mention of *Stereocaulon magellanicum* (probably = *St. glabrum*) growing in great abundance in lower Whale Valley. He also mentioned that the "Hochplateau", an extensive undulating area to the north of Köppen Point, was rich in bryophytes and lichens, where he noted *Cladonia rangiferina*, *Sticta endochrysea* (= *Pseudocyphellaria endochrysea*) and *Sticta freycinetii* (= *Pseudocyphellaria freycinetii*) widely distributed on moss. Skottsberg (1912) gave a brief description of the main vegetation types on South Georgia and, although he visited the Köppen Point area in 1902, he noted only a few lichens growing on *Polytrichum alpestre* banks. These included *Cladonia squamosa* (= *C. furcata*), *Leptogium tremelloides* (= *L. menziesii*), *Ochrolechia tartarea* (= *O. frigida*), *Parmelia enteromorpha* (= *Hypogymnia lugubris*) and *Sphaerophorus coralloides* (= *Sphaerophorus globosus*). S. W. Greene (personal communication) visited Whale Valley and the "Hochplateau" in February 1961 and noted the widespread development of tussock and extensive swards of *Deschampsia antarctica* and *Acaena decumbens* in the former locality and localized development of *Festuca erecta* grassland in sheltered areas at the latter area.

From a collation of the observations of Greene, Skottsberg and Will, it appears that the structure and distribution of communities on the north side of Royal Bay, before the immigration of reindeer, were broadly similar to, but often more sparsely developed than, those in ungrazed areas in Cumberland East Bay. Thus the lower part of Whale Valley was densely covered with tussock, with swards of *Deschampsia antarctica* occurring in open areas on shingle and near the edges of trampled zones at the periphery of gentoo penguin rookeries. *Rostkovia magellanica* bog occurred in wet hollows near the stream in Whale Valley, while *Acaena decumbens* and *Festuca erecta* were locally abundant towards the upper part of the valley. S. W. Greene (personal communication) commented particularly on the extensive development of lichen-rich *Polytrichum alpestre–Chorisodontium aciphyllum* banks on the northern side of the lower part of Whale Valley and along the cliff edge leading towards Köppen Point. He remarked that on the "Hochplateau", a cryptogam-dominated vegetation was prominent with numerous epiphytic lichens and stands of incipient *Festuca erecta* grassland confined to sheltered areas on the terraces above Sacramento Bight. This latter area was probably much as it is today, consisting of *Rostkovia magellanica* bog and moss-carpet and turf communities typical of wet areas. *Poa flabellata* probably never grew on the wet valley floor, which consists of glacial debris overlain by a thin layer of *Drepanocladus uncinatus*, but it may have grown at the bottom of slopes on the sides of the valley, although there are no traces of former tussock stools anywhere in upper Whale Valley.

The distribution of vegetation types on the north shore of Royal Bay, as observed in January 1972, is shown in Fig. 1 and quantitative floristic comparisons of grazed grass-heath and moss-bank communities with their ungrazed counterparts are given in Tables I and II, respectively. Within the grazed grass-heath communities, *Acaena decumbens* appears to decrease only slightly in cover (Table I), but it should be realized that a high cover will still be provided by the intertwined rhizomes even if they bear very few green shoots. R. I. L. Smith (personal communication) noted that throughout Barff Peninsula, where reindeer have been long established, *Acaena decumbens* has been almost completely eradicated. In several parts of lower Whale Valley the remnants of large swards of this species were seen on dry, sloping stony ground (Fig. 2) with young shoots, where they could be found, unexpanded even in January. *Festuca erecta*, which is apparently not grazed by the reindeer, may increase in cover when competition from other species ceases, but it may suffer as a result of trampling. This latter effect was especially noticeable towards the south-western edge of the "Hochplateau", where a small area of previously lichen-rich *Festuca* grassland had obviously been heavily grazed. The reindeer, in foraging for lichens in this area, have trampled the *Festuca* so that most shoots were flattened. There appears to have been a considerable increase in abundance of *Rostkovia magellanica* in the intensively grazed *Deschampsia antarctica* swards of the lower part of Whale Valley (Fig. 3). This rush, which does not appear to be grazed, is most characteristic of wet valley floors and hollows and is usually only a casual associate in grassland and cryptogamic communities.

The well-developed swards of *Deschampsia antarctica* which S. W. Greene noted at the

TABLE I. COMPOSITION OF GRASS-HEATH COMMUNITIES IN UNGRAZED AND GRAZED AREAS

Species	*Ungrazed area* Gull Lake, King Edward Cove, Cumberland East Bay	*Grazed area* lower Whale Valley, Moltke Harbour, Royal Bay
Vascular plants		
Acaena decumbens	14·5; 100	13; 100*
A. tenera	5; 20	—
Colobanthus quitensis	—	5; 10
Deschampsia antarctica	—	8; 40
Festuca erecta	19·5; 100	28·5; 40
Phleum alpinum	3·5; 50	8; 40
Poa flabellata	—	35; 40
Rostkovia magellanica	5·5; 40	42·5; 80
Lichens		
Cetraria islandica	7; 60	—
Cladonia balfourii	4·5; 90	2; 10
C. bellidiflora	2·5; 90	—
C. carneola	—	2; 20
C. furcata	22·5; 100	2; 20
C. gracilis	7; 80	—
C. phyllophora	4; 90	—
C. rangiferina	29; 100	—
C. squamosa	4; 70	—
Leptogium menziesii	—	5; 30
Ochrolechia frigida	—	2; 20
Pseudocyphellaria freycinetii	5·5; 40	5; 70
Psoroma hypnorum	—	2; 20
Stereocaulon glabrum	4; 80	—
Mosses		
Chorisodontium aciphyllum	5; 90	30; 50
Polytrichum alpinum	13·5; 100	15; 40
Tortula robusta	4; 50	5; 70
Other Musci	5; 30	10; 10
Hepaticae	8; 100	7·5; 20
Substratum		
Bare ground	—	20; 20

* The cover of this species in this locality is attributable almost entirely to rhizomes, not foliage.
The first figure is mean percentage cover, the figure after the semi-colon being percentage frequency.
Data calculated from 20 1 m.^{2} random quadrats at each locality. — Indicates absence of species.

seaward edge of the tussock zone on the north side of Moltke Harbour in February 1961 have now totally disappeared from this locality, although smaller swards at the periphery of the gentoo penguin rookeries are showing little sign of grazing pressure.

The group of plants most seriously affected by grazing and trampling were the lichens. Table I indicates that several species typical of *Festuca* grassland were absent from grazed areas in Whale Valley, the most noticeable being the disappearance of the "reindeer lichen" *Cladonia rangiferina*. Will (1890) had noted that the "Hochplateau" was rich in bryophytes and lichens, but the damage is now so severe that all macrolichens are poorly represented in this area.

While the bryophyte-bank communities have been influenced by grazing, trampling by reindeer appears to have had a more deleterious effect. Table II provides a comparison of the epiphytic lichen flora typical of bryophyte banks in grazed and ungrazed areas. The lichen most affected was *Pseudocyphellaria freycinetii*, a foliose species in which the thallus frequently exceeded 25 cm. across (Fig. 4a). In Whale Valley and the "Hochplateau" area, this species was seen only as small fragments, *c.* 1 cm.^{2}, scattered over wide areas (Fig. 4b). At a site near the north shore of Moltke Harbour, the remains of a dense stand of *Cladonia rangiferina*,

TABLE II. COMPOSITION OF LICHEN-RICH BRYOPHYTE BANKS IN UNGRAZED AND GRAZED AREAS

Species	*Ungrazed area* Gull Lake, King Edward Cove, Cumberland East Bay	*Grazed area* lower Whale Valley, Moltke Harbour, Royal Bay
Vascular plants		
Acaena decumbens	9; 100	5; 80
A. tenera	4; 30	—
Festuca erecta	17; 100	—
Phleum alpinum	7·5; 100	—
Rostkovia magellanica	5; 40	40; 100
Lichens		
Cetraria islandica	10; 60	—
Cladonia balfourii	4; 80	—
C. carneola	—	2; 80
C. furcata	6; 70	1; 40
C. rangiferina	10; 70	—
Ochrolechia frigida	5; 80	2; 80
Pseudocyphellaria freycinetii	23; 100	5; 100
Psoroma hypnorum	5; 20	3; 80
Stereocaulon glabrum	5; 20	—
Mosses		
Chorisodontium aciphyllum	21·5; 100	40; 100
Polytrichum alpinum	20·5; 100	40; 100
Tortula robusta	4; 20	—
Other Musci	4; 80	—
Hepaticae	6; 100	10; 100

For an explanation of the figures see Table I.

c. 15 m.^{2}, consisted entirely of fragments, the clear result of either grazing or trampling. *Sphaerophorus globosus*, a fruticose lichen very prominent on bryophyte banks and moss-covered boulders in the Cumberland Bay area, was rare in Whale Valley and the "Hoch-plateau" where there were only small thalli grazed to the level of the substratum. Bryophytes do not appear to be eaten but where the reindeer cross the banks, their hooves tear out pieces of moss and lichen, leaving holes *c.* 15 cm. deep and *c.* 10 cm. by 5 cm. across. The surfaces of these banks are, therefore, very susceptible to wind erosion, particularly on the *Polytrichum alpestre–Chorisodontium aciphyllum* banks at the north-east corner of lower Whale Valley, which were noted by S. W. Greene as being particularly rich in rare and uncommon species of bryophytes.

Drepanocladus uncinatus carpets, which cover parts of upper Whale Valley, do not appear to show any effects of trampling as yet, although R. I. L. Smith (personal communication) has noted the degradation of such carpets on heavily trampled areas on Barff Peninsula.

The tussock community, widespread in the lower part of Whale Valley and the eastern edge of the "Hochplateau", seems to have suffered little as yet from the effects of reindeer, which may graze on the young shoots but do not appear to harm the plants by trampling and over-grazing as in the case of *Acaena decumbens*. However, a few stands of tussock at the western edge of the tussock-dominated area east of the "Hochplateau" have stools which have become flattened and yellowish in appearance, with only very sparse production of new shoots.

The *Rostkovia magellanica* community, although not grazed, suffers locally as a result of trampling, as in some wet areas of Whale Valley which the reindeer traverse when passing from one browsing ground to another. Under these conditions the substratum becomes churned up and puddles develop, the *Rostkovia* and associated bryophytes being destroyed until eventually only bare peaty mud is left.

Saxicolous macrolichens, such as *Usnea antarctica* and *U. fasciata*, which are widespread and abundant in the Royal Bay area, do not appear to have been grazed by reindeer. These

Fig. 2. Lower part of Whale Valley, viewed from the east, showing the distribution of *Poa flabellata* and grazed areas (indicated by arrows) of *Acaena decumbens* rhizomes. December 1971. (Photograph by P. Stone.)

Fig. 3. Reindeer grazing *Deschampsia antarctica* sward now invaded by *Rostkovia magellanica*; lower part of Whale Valley. January 1972. (Photograph by P. Stone.)

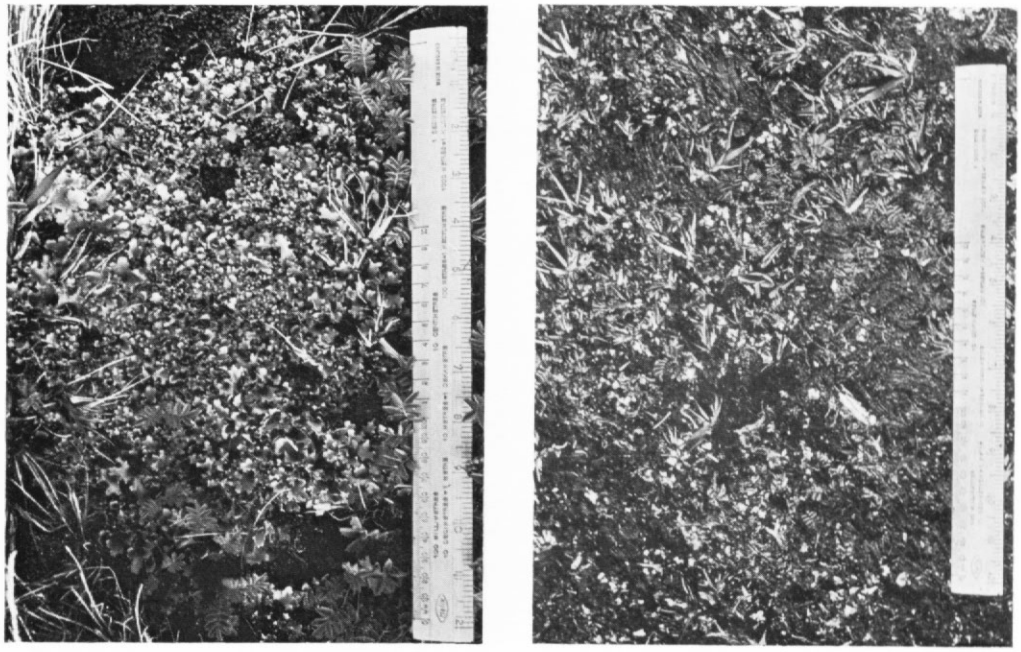
species are, however, uncommon on Barff Peninsula, where it appears that saxicolous macrolichen communities are being grazed (personal communication from R. I. L. Smith).

Thus, although only a few species form the staple food of the reindeer, almost all plant communities have suffered as a result of trampling. These animals were seen to forage from the shoreline to over 300 m. in search of food and in the upper part of Whale Valley, for example, well-worn reindeer tracks were noted on scree slopes at an altitude of 335 m. This suggests that no phanerogam-dominated communities, which tend to become very open at altitudes over 200 m., escape the influence of the reindeer. Thus it is only in inaccessible habitats, such as cliff ledges, that the typical grass-heath lichens, for example *Cladonia rangiferina* and *Cetraria islandica*, stand any chance of long-term survival.

Although other animals, such as gentoo penguins, elephant and fur seals may locally modify stands of vegetation, their influence is largely confined to coastal areas and so may be considered to have a less extensive effect than the wide-ranging reindeer.

Comparison with the Arctic

The effects of grazing and trampling by reindeer and caribou in Arctic regions have received a great deal of attention due to the economic importance of these animals. Lynge (1921), for example, discussed the importance of lichens as reindeer fodder in Norway and noted that "it is well-known in reindeer districts that intense trampling can destroy a lichen field for a long time, and this has been fully confirmed by experiments" (Lynge, 1921, p. 15). Pegau (1970*a*) has shown that trampling by a herd of caribou can totally transform the nature of the vegetation in a very short period of time. He herded a group of about 550 caribou over a previously ungrazed area of an extensive *Cladonia*-rich *Eriophorum–Carex* dwarf shrub meadow near Nome, Alaska, and after only one season he found that 68 per cent of the lichens were dislodged and lying loose on the ground and 16 per cent were fragmented into segments less than 1·25 cm. long.



a b

Fig. 4. *Pseudocyphellaria freycinetii*.
a. Typical plant from ungrazed area; Gull Lake, King Edward Cove, Cumberland East Bay. February 1972.
b. Fragmented thalli in heavily grazed and trampled area; lower Whale Valley, Moltke Harbour, Royal Bay. January 1972.

Pegau (1970*b*) has also described experiments in which reindeer-grazed pasture in Alaska was fenced off and allowed to recover naturally. In some quadrats there had been no recovery of lichens after 30 years. In others recovery had occurred, but after more than 30 years the lichens had not attained their former abundance, which is surprising in view of the comparatively fast growth rates of "reindeer lichens" in Alaska (Pegau, 1968). However, it must be borne in mind that during recovery, the lichens were in competition with vascular plants which often have more rapid growth rates. Pegau (1970*b*) also noted that any increase in abundance was by regeneration of previously established plants rather than from re-colonization.

According to Pegau (1970*a*), trampling can remove the insulating mat of vegetation and allow water from the thawing subsoil to inundate rapidly the trampled area. However, Rouse and Kershaw (1971) have noted that removal of the water-retaining base of the lichen layer from ground in the sub-Arctic resulted in a decrease in soil-moisture content by as much as 40 per cent. This latter effect has not been noticed in the grass-heath or bryophyte banks on South Georgia where layers of lichen have been removed, probably because heavy trampling has obscured any other effects the reindeer may have on vegetation. Although permafrost does not occur on the island, trampling does seem to alter the water balance of the habitat. As indicated in Table I, trampling results in the replacement of the normal grass-heath lichens such as *Cladonia rangiferina*, *Cetraria islandica* and *Stereocaulon glabrum* by small quantities of lichens typical of moss banks and soil. For example, the presence of *Leptogium menziesii*, a moderately hydrophilous lichen, in several grass-dominated stands at Moltke Harbour indicates that habitats have become wetter as a result of trampling.

In Arctic regions, controlled grazing of lichen stands by reindeer is recognized as being very important in maintaining adequate feeding grounds. In Newfoundland, Ahti (1959) estimated the caribou population at *c.* 10,000 animals, an approximate density of one animal

per 110 km.^{2}, a sufficiently low density to allow recovery of lichen-rich tundra after grazing. On South Georgia, however, the present density of reindeer is very much higher. If the reindeer population on Barff Peninsula, an area of *c.* 1,450 km.^{2}, is taken to be 1,300 (Payne, 1972), this gives a density of one animal per 1·11 km.^{2}. These areas include permanent snow and ice, scree and areas of bare rock, so that the area of lichen tundra suitable for reindeer grazing is rather less, and the density of animals is higher than these figures indicate. On the peninsula on the north shore of Royal Bay, an area of *c.* 55 km.^{2}, the reindeer population was estimated at *c.* 780 in 1972, a density of one animal per 0·07 km.^{2}. The densities of reindeer on South Georgia are thus extremely high compared with Newfoundland, for example, and their pressure on the vegetation must be correspondingly very much greater. From these figures and Pegau's (1970*a*) experiments, it may be concluded that the rapid total elimination of lichens from grass-heath and bryophyte-bank communities throughout Barff Peninsula and the peninsula on the north side of Royal Bay is inevitable, and there is little hope for the eventual recovery of the lichens or of certain phanerogams (e.g. *Acaena decumbens*) unless the numbers of the reindeer are drastically reduced immediately.

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