BIRD ISLAND South Georgia
Environmental Assessment

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An Assessment of Environmental Impacts Arising from Scientific Research and its Logistic Support at Bird Island, South Georgia

by

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COVER PHOTOGRAPH: RESUPPLYING BIRD ISLAND STATION (PHOTOGRAPH SUPPLIED BY ROYAL NAVY)

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PREFACE

Scientists working in the field have a responsibility to respect the environment and ensure that their activities do not have unnecessary adverse effects. This responsibility is greater when the work is done in a wilderness area where other, non-scientific, impacts of Man's presence are less obtrusive than elsewhere.

Bird Island is such a wilderness area. On this small island, to the north-west of South Georgia, are some of the most spectacular colonies of birds and seals to be seen anywhere in the world. These birds and seals, by virtue of their accessibility and lack of fear of Man, afford the scientist unique opportunities to pursue studies relating to population dynamics, the energetics of feeding and resource utilisation, and the description and understanding of reproductive behaviour and strategies. What is learnt at Bird Island can be used to add to our general understanding of biology and the world we live in so that we may use its resources more wisely and safeguard our own environment.

To preserve the wilderness qualities of Bird Island, while at the same time continuing our important scientific research there, we need to examine how our activities affect the environment and, having made such an examination, to modify our operations so as where possible to mitigate or eliminate the impacts identified.

This report is an assessment of environmental impacts at Bird Island. It has been prepared by Nigel Bonner whose association with Bird Island goes back more than 30 years, a longer period than any other, and John Croxall, who is in charge of bird and seal research in British Antarctic Survey. They were assisted in this task by several other biologists from British Antarctic Survey. Together they have produced a document which should serve as a baseline from which to measure our future progress in controlling environmental impact at Bird Island.

All of us who have had the privilege of visiting this fascinating island will know the importance of this task. Public awareness of the need for environmental concern, not least in the Antarctic, is increasing. By formally examining its activities at its scientific research stations British Antarctic Survey is taking a significant step towards a fuller protection of the Antarctic environment generally.

R M Laws, CBE, FRS

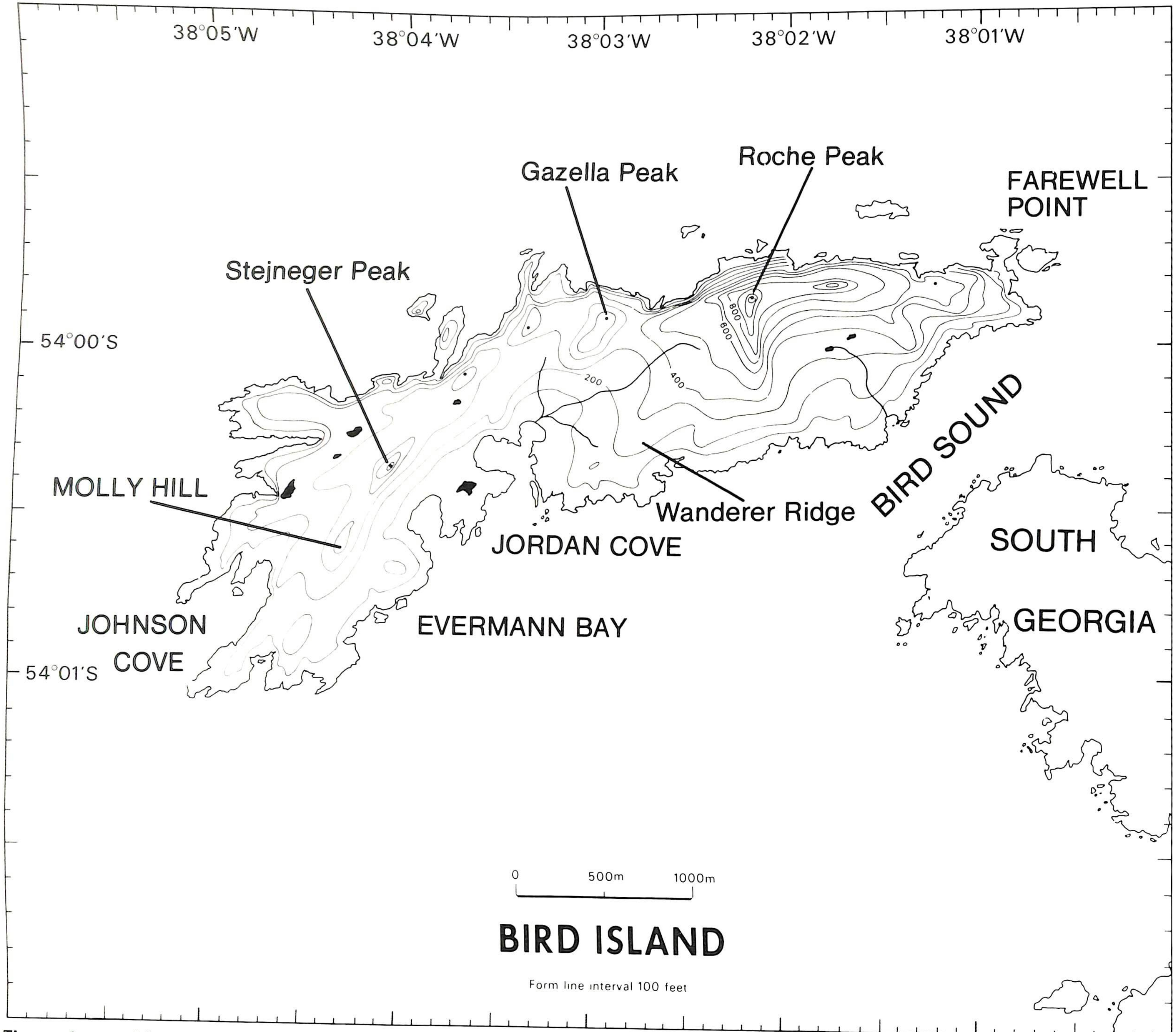


Figure 1. Map of Bird Island

AN ASSESSMENT OF ENVIRONMENTAL IMPACTS ARISING FROM SCIENTIFIC RESEARCH AND ITS LOGISTIC SUPPORT AT BIRD ISLAND, SOUTH GEORGIA

1. Description of Present Activities

The British Antarctic Survey (BAS) maintains a field research station at Bird Island where research into the population biology, trophodynamics, ecophysiology and behaviour of seabirds and seals is carried out. The station, which is self-contained, accommodates eight persons and is manned throughout the year, though wintering (April — October) parties do not normally exceed three persons.

The results of the research are important to biological science in general. The presence at Bird Island of large accessible populations of several species of seabirds and the Antarctic fur seal, some containing a high proportion of known-age, known-history individuals, makes possible at Bird Island work which could not be done elsewhere. Furthermore, studies at Bird Island, particularly those of trophodynamics, provide an insight into the ecology of the Southern Ocean in the region of South Georgia and form an important contribution to the BAS Offshore Biological Programme (OBP) and the international BIOMASS* programme. The presence of a research station with a long-term commitment to monitoring the abundance of several species at a single site provides a much better idea of the true nature and magnitude of effects induced by key changes in the environment, notably the availability of krill (Croxall and Prince, 1979, 1987; Croxall, 1987).

There are no alternative sites for the research station at Bird Island if the scientific research is to continue. Probably nowhere else in the world are the same variety and concentration of seabirds and fur seals to be found at such an accessible site.

2. Location and Physical Characteristics of Bird Island

Bird Island (lat. 54°00'S, long. 38°02'W) is a small island lying just off the north-west tip of South Georgia, from which it is separated by a strait (Bird Sound) at its narrowest only 500 m wide (Fig. 1). The island is 6.5 km long and up to 1.5 km wide with a superficial area of about 400 ha. The long axis of the island is oriented approximately east-west. The northern coast consists of high cliffs, rising to 365 m at Roché Peak near the eastern end. A high ridge divides the western half of the island and reaches 190 m at Stejneger Peak. The northern coast is precipitous and devoid of beaches but on the southern coast there are numerous small beaches and raised rock platforms, and two almost enclosed sea areas, Jordan Cove (where the research station is situated) and Evermann Bay. Another embayment is Johnson Cove in the south-west, but this is relatively unprotected, being wide open to south-westerly gales. Most of the gentler slopes below about 100 m are clothed with tussock grass, but in places relatively level swards of shorter grass and other plants occur. These are dotted with small pools and tarns. These meadows are particularly well developed in the area to the north-west of Stejneger Peak. Above about 100 m are areas of sparsely vegetated gravels and cryptogam-dominated scree and rock face.

Lying well to the south of the Antarctic Convergence the climate of South Georgia shares characteristics of the sub-Antarctic and maritime Antarctic. Extensive meteorological data are available for Grytviken,about 120 km to the west of Bird Island (Pepper, 1954; Smith and Walton, 1975), but the weather recorded there is colder, drier and sunnier than at Bird Island. There are no long series of meteorological data for Bird Island. The weather is predominantly damp and cloudy with frequent high winds. Temperatures vary from −2°C to 9°C in summer, and from −10°C to 3°C in winter (Richards and Tickell, 1968). Snow occurs in all months of the year but, although late snow patches may persist until January, there is no permanent snow or ice on the island.

3. Biota of Bird Island

(i) Terrestrial vegetation (by Dr R.I. Lewis Smith).

The vegetation of Bird Island is similar to that of mainland South Georgia (Greene, 1964; Smith and Walton, 1975), though fewer species are represented. A list of the vascular plants, and the principal mosses, lichens and fungi recorded from Bird Island is given in Appendix 1. The distribution and extent of the major vegetation types on the island have been illustrated by Hunter, Croxall and Prince (1982). The dominant plant is tussock grass, *Poa flabellata*, which, wherever it is influenced by fur seals or seabird colonies, is a deep green colour; elsewhere it is distinctly yellowish-green. This robust grass grows in clumps, or tussocks, up to a metre in diameter and 1 to 1.5 m high, the shoots radiating from a peaty stool composed of the dead and dying leaf bases with mineral inclusions. In places it has accumulated peat to a depth of up to 3 m. On seaward slopes up to about 100 m this tussock grass forms an almost pure continuous stand, the dense shade provided by the overhanging shoots preventing the growth of any other vascular plants between the clumps. However, where natural breaks occur in the cover, or where the tussock grows less luxuriantly, there may be an understorey of bryophytes or less commonly vascular plants, notably Antarctic starwort, *Callitriche antarctica*. In nitrogen-enriched situations the foliose alga *Prasiola crispa* may occur. Over large areas of low

* Biological Investigations of Marine Antarctic Systems and Stocks — a programme sponsored by SCAR, SCOR, IABO and the ACMRR of FAO.

altitude grassland on Bird Island there has been extensive damage by fur seals, resulting in the crowns of individual tussocks being killed leaving a fringe of flattened living tillers. More recently the most severely affected sites have been totally destroyed and seal erosion has left large areas of bare hummocky ground (Bonner, 1985). Clearings in tussock grassland may be occupied by more or less extensive swards (see below) or by banks of mosses, with variable amounts of the grass *Deschampsia antarctica, Callitriche antarctica*, the burnets *Acaena magellanica* and *A. tenera* or the pearlwort, *Colobanthus quitensis*.

On flat waterlogged areas, especially at Top and Bottom Meadows and Wanderer Valley, Antarctic hair grass, *Deschampsia antarctica*, forms closed meadow-like swards, with variable amounts of *Callitriche antarctica* and hydric mosses (*Calliergon sarmentosum* and *Drepanocladus uncinatus*), and rarely the rush *Rostkovia magellanica*. These overlie deep anaerobic peat of 2-3 m depth (Smith, 1981). These swards are commonly patterned with ridges of taller grass, on which *Colobanthus quitensis* and the mosses *Conostomum pentastichum* and *Polytrichum alpinum* commonly grow. However, the cause of these ridges is not known. These grass swards appear to be a sub-climax community of a hydrosere occupying former tarns; in some instances there is still a central or marginal pool of water. Stream margins are commonly lined with *Deschampsia, Callitriche, Acaena magellanica*, occasionally water blinks *Montia fontana*, Antarctic buttercup *Ranunculus biternatus* and various bryophytes (especially the mosses *Brachythecium* spp. and *Calliergon* and the liverwort *Marchantia berteroana*).

Moist slopes free of tussock grass often support small stands of an *Acaena magellanica-Tortula robusta* community with occasional plants of *A. tenera* and *Deschampsia*. The climate and substratum of Bird Island is too wet to permit the development of extensive *Acaena* herbfield with a closed canopy such as commonly occurs elsewhere on South Georgia.

All other major communities are dominated by cryptogams. The most prominent are banks of the turf-forming moss *Chorisodontium aciphyllum* on steep moist slopes, and in gaps amongst open tussock grassland. They are quite extensive on Molly Hill. These often have *Polytrichum alpinum* or, less frequently, *P. alpestre*, a variety of liverworts and several species of *Cladonia* associated. The relative scarcity of *P. alpestre* and the abundance of liverworts generally on Bird Island, compared with the mid-northern coast of South Georgia, is attributed to the wetter climate. *Acaena tenera* and *Deschampsia* are occasionally present. Immediately above much of the upper limit of the tussock zone there is an ecotonal community intermediate between the *Chorisodontium* dominated turves and various forms of fellfield. This is probably the most floristically diverse community on the island. *C. aciphyllum*, forming a shallow peat, is dominant but numerous other species are commonly associated, e.g. mosses (*Andreaea regularis, Polytrichum alpinum, Racomitrium* spp.), various liverworts, lichens (several species of *Cladonia, Cladia aggregata, Cetraria islandica, Hypogymnia lugubris, Ochrolechia frigida, Pseudocyphellaria freycinetii, Sphaerophorus globosus, Stereocaulon* spp., *Usnea antarctica*), and vascular plants (*Colobanthus, Deschampsia* and occasionally small *Poa* plants).

Between this ecotonal zone and the top of the precipitous cliffs along much of the northern backbone of the island are gently sloping gravel screes. These fellfield areas are extremely wind-swept and largely barren. Very isolated small plants of *Colobanthus* and *Deschampsia*, and cushions of *Andreaea, Dicranoweisia, Grimmia* and *Racomitrium* spp.; lichens (especially *Rhizocarpon geographicum*) occur only on the larger more stable stones. The floristic composition of this community is very similar to the fellfield vegetation of the northern maritime Antarctic.

Also above the tussock zone, occupying permanently moist rocky scree slopes below late lying snow patches, there are locally extensive closed stands of an *Andreaea* dominated community. This moss, and a species of the liverwort *Hygrolembidium*, give the vegetation a blackish appearance. Other prominent species include *Bartramia patens, C. aciphyllum, Dicranoloma harioti, Dicranoweisia* sp., *Polytrichum alpinum, P. juniperinum, Psilopilum trichodon, Racomitrium* spp., and numerous liverworts. Vascular plants are restricted to occasional *Deschampsia, Colobanthus, Acaena tenera* and *Poa*. A variant of this community extends onto wet rock faces, ledges and crevices, although locally *Andreaea fuegiana* is dominant and several chomophytes are restricted mainly to this habitat (*Lepyrodon lagurus, Pohlia cruda, Philonotis scabrifolia* and the filmy fern *Hymenophyllum falklandicum*). Elsewhere, dry exposed rock surfaces are almost totally covered by crustose lichens (mainly species of *Lecanora, Lecidea, Lecidella* and *Rhizocarpon*), with scattered moss cushions (mainly species of *Andreaea, Dicranoweisia* and *Grimmia*). The thalli of the predominant lichens are white which gives most of the higher rock exposures on the island (especially Roché and Gazella Peaks) the appearance of being composed of a very light coloured rock. Such extensive lichen cover is very rare on South Georgia and, unless lichen growth is extremely rapid in the prevailing climate, it must have taken several millenia to have developed to this extent, and may correlate with the establishment of the earliest vegetation on South Georgia about 10,000 – 12,000 years ago when the last glacial maximum ended (see Clapperton and Sugden, 1977; Smith 1981).

Another series of lichen-dominated communities occurs nearer sea level where rocks and cliffs are locally covered by colourful crustose nitrophilous and halophilous taxa of the genera *Buellia, Caloplaca, Verrucaria* and Xanthoria. The orange communities of *Caloplaca* and *Xanthoria* are associated particularly with seabird colonies.

Figure 2 (from Hunter *et al.*, 1982) shows the distribution of the major habitats at Bird Island and Table 1 their approximate extent.

Table 1. *Extent of major habitat types at Bird Island*

Habitat	Area (hectares)
Tussock	190
Meadows	9
Moss	19
Coarse Scree	26
Fine Scree	21
Lakes	1
Rocks	130

(ii) Invertebrates (by Dr W.C. Block).

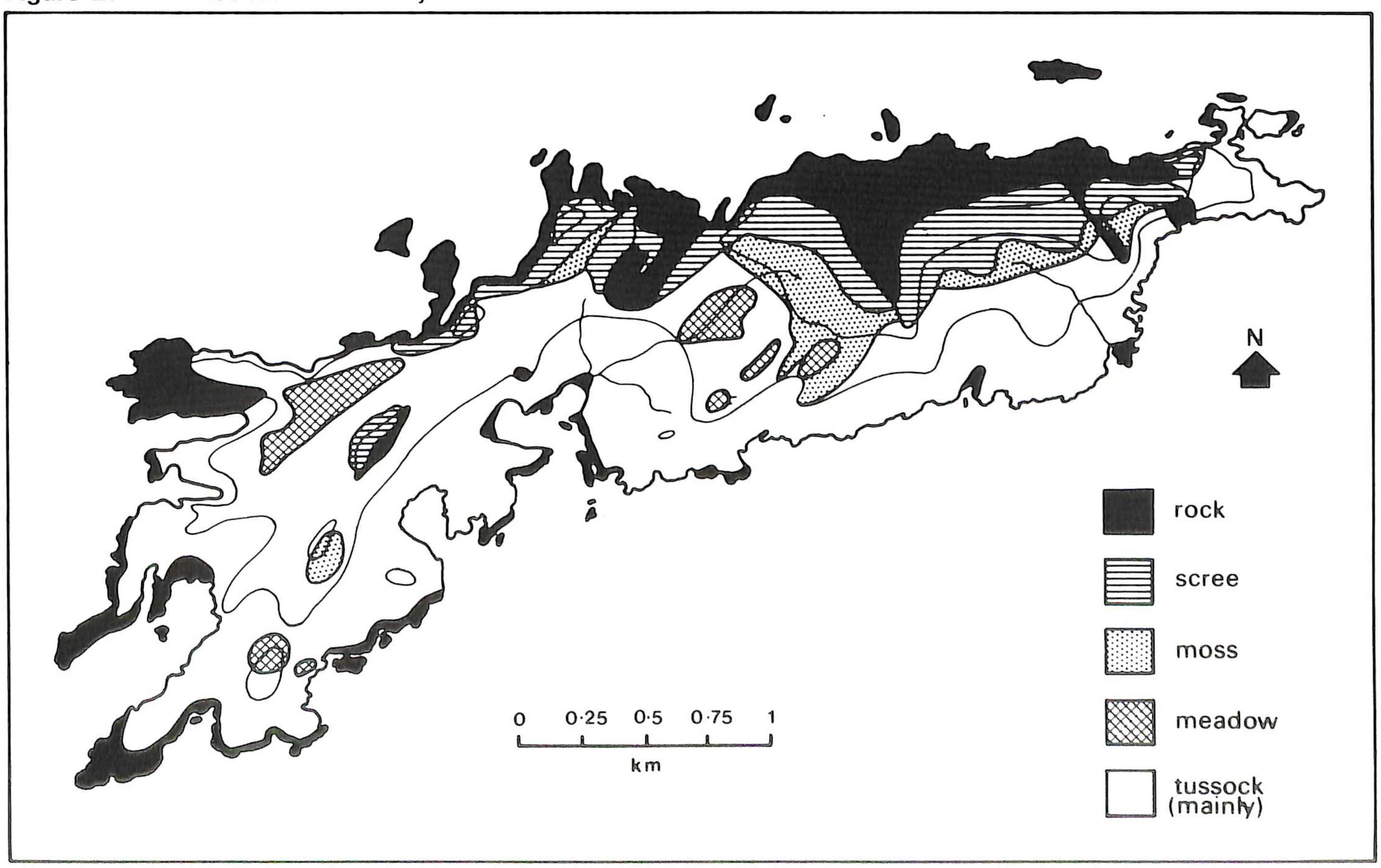
No thorough survey of terrestrial invertebrates at Bird Island has been made but the extensive insect collections made there by H.B. Clagg in 1962-1963 were reported on in detail in Gressitt's (1970) review of the entomology of South Georgia. Insects and arachnids hitherto recorded at Bird Island are listed in Appendix 2. The fauna is similar to that of mainland South Georgia, though as with the plants, fewer species appear to be present. The more obvious macroscopic forms include enchytraeid worms, an oligochaete (*Microscolex georgianus*), numerous mites, springtails, the spider (*Notiomaso australis*), four beetles (*Crymus antarcticus, Perimylops antarcticus, Hydromedion sparsutum* and *Halmaeusa atriceps*), and several flies including a sciarid (*Lycoriella caesar*), a large helcomyid kelp fly (*Paractora trichosterna*) and a brachypterous sphaerocerid, *Antrops truncipennis*, found along the shore. Bird Island is the type locality for ten species of mites (including one new genus) and for a monotypic genus of wingless chalcids (*Notomymar*).

The freshwater pools, tarns and streams at Bird Island do not appear to support an extensive invertebrate fauna (apart from larvae of the chironomid *Parochlus steineni* in the streams and the anostracan *Branchinecta gainii*), though copepods and a dytiscid beetle occur on mainland South Georgia .

(iii) Birds.

Bird Island supports a large and varied avifauna, a list of which, together with current estimates of breeding populations, forms Appendix 3. This also includes sightings of non-breeding visitors up to June 1987 (Prince and Croxall, 1983 and unpublished data).

Figure 2. Distribution of major habitats at Bird Island



(iv) Mammals.

By far the most conspicuous animal at Bird Island is the Antarctic fur seal, *Arctocephalus gazella*, which dominates all the available beaches during the breeding season and extends far inland. Some fur seals, mainly mature males, are present throughout the year, but numbers increase in the breeding season, bulls taking up their territories on the beaches in September/ October and the cows arriving in early December. Pupping is highly synchronised, with 90% of the pups being born between 1 and 24 December. Females bear their pups on the beaches and remain with them for about eight days, before going to sea to feed. On returning they usually suckle their pups at the back of the beaches or in the tussock behind. Juveniles are found in the tussock throughout the breeding season. By lying on the tops of the tussocks the seals eventually kill the plants, causing severe erosion (Bonner, 1985). By April most pups have been weaned and the females leave the island. Groups of immatures are abundant until about June, when the majority leave.

The total number of fur seals at Bird Island is hard to estimate. Payne (1977) estimated a production of about 36,000 pups in 1976 – 77. The Bird Island population is almost certainly larger than this today (see Section 4).

Subantarctic fur seals, *A. tropicalis*, have been recorded, usually singly, in most seasons since 1972 (Payne, 1979); adult males are readily identified but females and immatures may be overlooked. There is no indication at present of any increase in the frequency of sightings.

Elephant seals, *Mirounga leonina*, breed in small numbers at Bird Island, usually in Jordan Cove and Evermann Bay. In 1984, 14 pups were born (9 October — early November). Leopard seals, *Hydrurga leptonyx*, are regularly seen, particularly in the winter. Ten individuals were responsible for the bulk of the sightings in 1984. They haul out at Jordan Cove and Johnson Cove and probably elsewhere. Weddell seals, *Leptonychotes weddellii*, have been recorded occasionally. They may be stragglers from the relict breeding population centred at Larsen Harbour at the south-east end of South Georgia. There is one record of a crabeater seal, *Lobodon carcinophagus*.

Southern right whales, *Eubalaena glacialis*, and minke whales, *Balaenoptera acutorostrata*, are regularly seen feeding off Bird Island, mainly between December and March, occasionally as late as early June. In 1984, 15 separate sightings were recorded, perhaps involving twice as many individuals. Humpback whales, *Megaptera novaeangliae*, pilot whales *Globicephala melaena* and unidentified rorquals are recorded from time to time. Skeletal remains of a sperm whale, *Physeter catodon*, and of at least two rorquals have been found or are still present in Jordan Cove, Evermann Bay and Johnson Cove. A specimen of a beaked whale, possibly Arnoux's beaked whale, *Berardius arnuxii*, was stranded at Johnson Cove in 1975-76.

(v) Littoral fauna and flora. (by M.G. White)

No systematic study has been made of the intertidal and nearshore marine ecosystem at Bird Island. It is unlikely to differ from that of the rest of South Georgia. A conspicuous feature just offshore is the presence of banks of kelp, *Macrocystis pyrifera*. These occur on stony bottoms where there is some shelter from the full force of the sea and *Himantothallus grandifolius* forms an understorey beneath the kelp canopy. Other brown macroalgae include *Durvillea antarctica* and *Lessonia antarctica*. Both these are attached to rocks at the lower limit of the tides and just below. The former is found at the base of the North Cliffs which are exposed to very violent wave action. A red alga, *Gigartina apoda,* is found intertidally as is a green *Enteromorpha*-like species. Amphipods and isopods are abundant in the littoral and sublittoral. The most conspicuous mollusc is the limpet, *Nacella concinna*, often bearing spirorbid polychaetes on its shell. The byssate bivalves *Kidderia subquadratum* and *Gaimardia trapesina* occur in rock pools but the latter is more often found attached to *Macrocystis*. Various opisthobranch and gastropod molluscs are found intertidally.

Permanent communities occur in the intertidal, especially in rock-pools, and these are dominated by green algae, hydroids, littorinid and polyplacophoran molluscs, amphipod crustacea and polychaete annelids. The tidal range is normally less than 2 m and so zonation patterns are not especially obvious.

The kelp forests provide habitat for an extensive range of epifauna and epiflora. The holdfasts are colonised by invertebrates, mostly polychaetes, nemerteans, molluscs, sponges and crustaceans. The mid-water below the canopy is much utilised by shoals of postlarvae and juvenile stages of demersal fish. The fronds are colonised by hydroids, bryozoans, spirorbinids, byssate bivalves and isopods such as *Cassidinopsis emarginatus*.

Sediments below low tide are extensively colonised by bivalve and opisthobranch molluscs, lysianassid amphipods, sedentary polychaete annelids and isopods. The isopods *Serolis pagenstecheri* and *Glyptonotus antarcticus*, the decapod crustaceans *Chorismus antarcticus* and *Notocrangon antarcticus*, and eledonellid octopods are distinctive members of the nearshore benthos.

4. Trends in Biota

Conspicuous changes have taken place at Bird Island in the last three decades. The most important of these concern the fur seal population. Fur seals were all but exterminated at South Georgia by skin hunters in the course of the nineteenth century and the first decade of the present one. However, a remnant population, perhaps consisting of only a few tens of animals, remained. These were possibly located at the Willis Islands (Bonner, 1968), a very inaccessible group 10 km to the west of Bird Island. In the mid-1950s when the first scientific observations on Bird Island began annual pup production was probably below 5,000. Breeding fur seals were confined to the beaches and by no means all of these were occupied. The only classes of seals found in the tussock were juveniles, which occurred in small numbers, and lactating cows which fed their pups in the tussock immediately behind the beaches. Damage to the tussock was very restricted and was confined to a few localities.

The population at this time was undergoing a very rapid increase. Early annual rates were as high as 27% (in 1958 – 59), the greater part of this taking place on beaches which were being newly colonised (Bonner, 1968). As the beaches became more densely occupied the bulk of the expansion was concentrated on beaches on mainland South Georgia. The average yearly rate of increase at Bird Island between 1958 – 59 and 1972 – 73 was 11.4% (Payne, 1977). From 1972 – 73 to 1976 – 77 this fell to only about 3.9% (Croxall and Prince, 1979). The last recorded total for pup production at Bird Island was 36,000 in 1976 – 77. This was probably an undercount, as 38,000 had been recorded the previous year. Although further counts have not been made it seems likely that the number of pups born at Bird Island may have increased subsequently though the rate of increase has probably diminished.

The effect of this very large number of fur seals on the restricted and relatively fragile tussock grassland, as well as the even more fragile *Deschampsia* meadows and bryophyte stands has been extremely severe. The detailed vegetation survey of 1978-1981 (Hunter *et al.*, 1982) showed that fur seals had access to 60% of the tussock grassland, that signs of their presence were recorded in 47% of 469 quadrats distributed randomly over the whole island and that severe damage (including absence of occupied petrel burrows) was apparent in 60% of these (Croxall *et al.*, 1984). The situation has deteriorated since then, and will continue to do so, even with no increase in the number of seals breeding. Bonner (1985) described how the raised beach on which the research station now stands was in the 1950s covered with a continuous sward of *Deschampsia*. This has now been totally destroyed and a part of the material composing the beach has been eroded and washed out to sea. All low-level *Deschampsia* meadows and bryophyte stands have been destroyed and there has been extensive erosion of vegetation and peat along stream margins. The incidental effects of this habitat modification on birds which burrow or nest in the tussock has been described by Croxall *et al.* (1984) and Bonner (1985).

Probably associated with the increase in fur seals have been increases in the northern giant petrel and the brown skua. Both these species feed extensively on carrion. The increase in the former, possibly doubling between the 1960s and early 1980s (Hunter, 1984), is probably wholly attributable to the increase in food, in the form of carcases and placentae of fur seals (Croxall and Prince, 1979). Brown skuas have increased from 175 pairs in 1958 – 59 to over 400 pairs in 1980 (Prince and Croxall, 1983). Increased food availability will doubtless have had an effect on this species also, but Croxall and Prince (1979) suggested that tussock destruction by fur seals will have increased the extent of suitable breeding habitat.

In contrast, breeding populations of blue petrels and Antarctic prions are likely to be decreasing because of habitat destruction by fur seals and predation by the increased skua population. The wandering albatross breeding population has also decreased. Between the early 1960s and 1979 the overall decrease was 19% (Croxall, 1979). This trend has continued since with the decrease to 1985 amounting to 23% overall at an average annual reduction of 1.1% (Croxall *et al.*, in press), although there are signs that the population may be stabilizing now. The decline does not appear to be due to local influences (because breeding success has been consistently high) but rather to events in the albatrosses' wintering grounds, with mortality caused by entanglement with, or capture by, fishing gear being probably the most significant factor (Croxall *et al.*, 1984).

Breeding populations of penguins and other albatrosses have fluctuated considerably over the last decade, during which some colonies of each species have been counted annually. All species had high populations in the 1975 – 1977 period, declined over the next few years (especially during and after the 1977 – 78 season, which was one of extensive reproductive failure) and remained stable, or increased again, thereafter (Croxall *et al.*, in press).

5. Status of Bird Island

Bird Island is listed as a Site of Special Scientific Interest under the Falkland Islands Dependencies Conservation Ordinance 1975.

6. History of Occupation

Bird Island was discovered by Captain Cook in January 1775 and so named on account of the number of birds he saw in its vicinity. There are no records of landings in the era of eighteenth and nineteenth century sealing, but it is inconceivable that fur sealers did not visit its beaches. They left no recognisable traces, however.

There are records of landings by whalers in 1909 and 1919 and in 1933 and 1936 scientists of '*Discovery*' Investigations visited Bird Island briefly (Bonner, 1968).

In December 1956, W N Bonner visited Bird Island on the Grytviken sealer *Lille Karl* and this initiated a series of extended visits to study the biology of the fur seals there. Initially accommodation was under canvas, but in November 1958 a small (2.45 m × 1.84 m) hut was erected at Freshwater Inlet in Jordan Cove. The hut was occupied by parties of one to three for a few weeks before Christmas and a few weeks in January each year from 1958 – 59 to 1961 – 62, though briefer visits were made at other times of the year. This hut remained the sole permanent installation at Bird Island till 1963 when a larger hut was put up near the same site by W L N Tickell to accommodate an over-wintering party studying the breeding biology of albatrosses. This station closed in April 1964. When examined in March 1967 the hut was severely damaged by weather and seals.

Bird Island was reoccupied by BAS in the summer seasons 1971 – 72 to 1973 – 74 to resume the fur seal studies. After a break of one year the station opened again to resume bird and seal studies in 1975 – 76 and has been occupied every summer since then.

In the summer of 1981 – 82 a new and much larger building, designed to provide a high standard of accommodation for eight scientists, was erected. This was intended to provide year-round occupation but because of the Argentine invasion of South Georgia in 1982 the first continuous wintering party was not until 1983. The station has been occupied continuously by BAS personnel since 22 September 1982. A list of personnel resident at Bird Island since 1971, which illustrates the increase in scientific complement, forms Appendix 4.

7. Present base facilities

The present base (Figure 3) consists of two principal buildings and four smaller structures. The main living quarters are in a single-storied hut of composite plywood-insulation construction ('Structaply') faced with plastic-coated metal cladding. It measures 14.70 m × 5.08 m with a porch at the side 2.46 m × 2.61 m. All windows are fitted with blinds to eliminate the problem of bird-strikes at lighted windows on misty nights. The building provides living accommodation and office/laboratory space for up to eight persons. The normal complement is six to eight in the summer and three in the winter.

The other large structure (Figure 4), until 1982 the main base hut, measures 9.90 m × 3.75 m. It too is covered with plastic-coated metal cladding. At its northwest end it houses two Broadcrown 15 KVA diesel generators and associated fuel and water tanks and workshop area. At the opposite end is a food store.

The smaller buildings comprise four wooden huts (no. 1, 2.45 m × 1.84 m (seal laboratory); no. 2, 3.64 m × 3.04 m (carpenter's workshop); no. 3, 3.20 m × 2.50 m (travel and emergency store); old generator (now 'wet' laboratory) shed, 2.45 m × 1.84 m) used for storage and as workshops. Besides these there are a raised slatted platform 3.45 m × 3.05 m, used for storing food cases under a tarpaulin, and a timber store, 3.00 m × 2.50 m. A system of wooden duckboarding connects the buildings on base.

Immediately seaward of the base at the common mouth of the four small streams that drain into Freshwater Inlet a small plank-and-scaffolding jetty,

Figure 3. Base installation at Freshwater Inlet, Jordan Cove

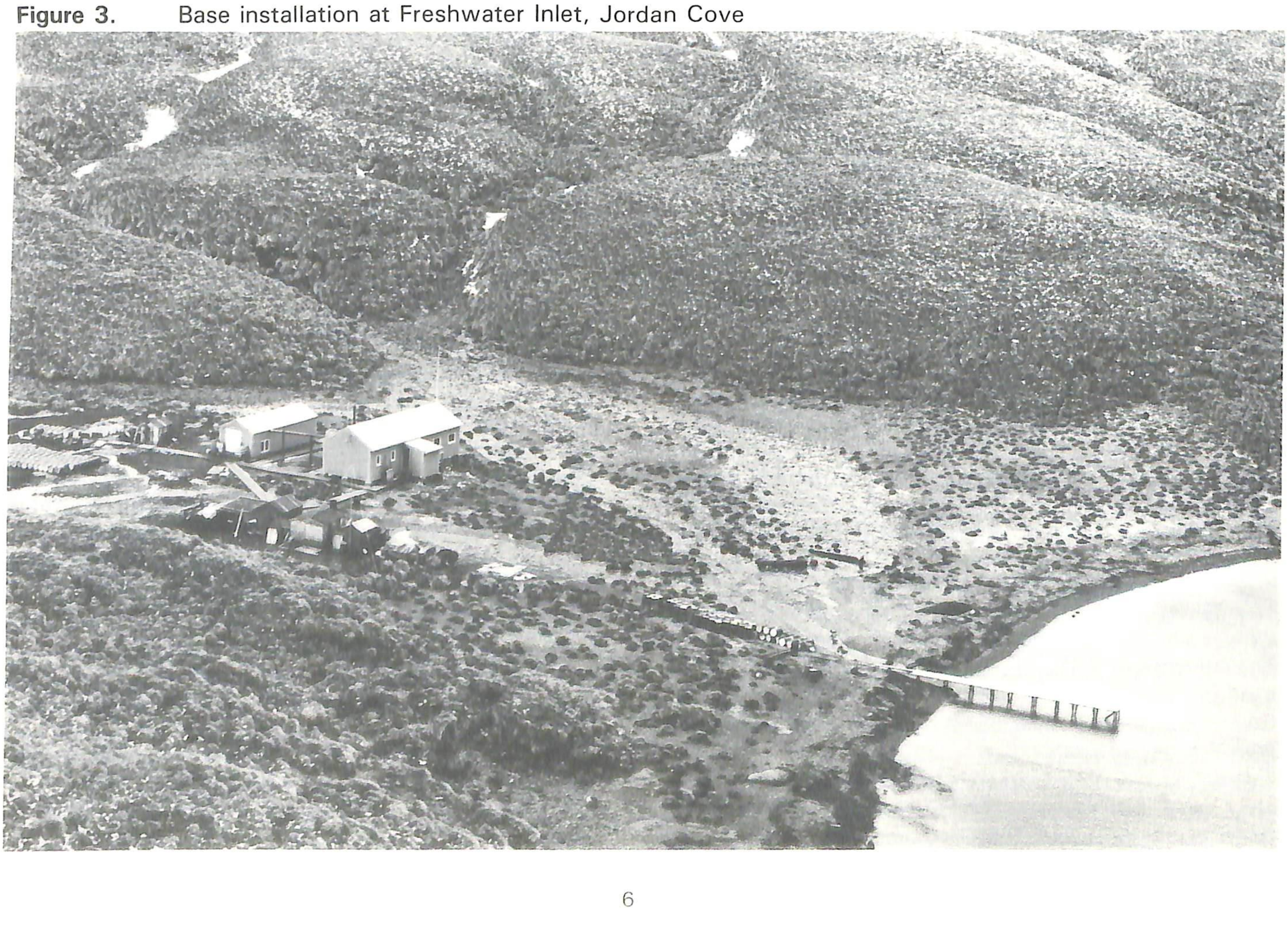


Figure 4. Base buildings and fuel dump

21 m long, has been built. There is about 1.5 m of water off the end of the jetty at high tide. No permanent path connects the jetty to the base buildings, but a corridor of empty fuel drums is erected for the period of base relief to protect personnel from the fur seals on the beach.

8. Field Facilities

Several minor facilities have been provided in the field at Bird Island to aid research programmes. These are detailed below.

(i) *Hibitane House* (Figure 5). This is the largest of the field facilities. It measures 2.56 m × 2.17 m and is 2.15 m high. It consists of a wooden hut with windows overlooking Payne Creek and a lean-to store at the back. It was erected in 1980-81 to provide an observation hide and instrument shelter for a programme on tropho-dynamics and chick growth in the grey-headed albatross. It is a permanent structure.

(ii) *Macaroni hide.* This is a wooden box hide, 1.4 m × 1.4 m and 1.75 m high built in 1984 and situated near the end of Fairy Point (below Hibitane House) whence it was transferred from Wanderer Ridge in 1986. It will be used for the programme on penguin reproductive biology and ecology until at least 1989. Adjacent is an instrument box, 1.03 m × 0.75 m and 1.14 m high, erected in October 1984 to house recording instruments used in programmes on penguin energetics and attendance behaviour.

(iii) *Johnson Cove hut.* This small hut on the north side of Johnson Cove measures 1.22 m × 1.26 m and is 1.86 m high. It provides shelter for recording instruments and for blood sampling procedures in the programme on penguin energetics and attendance behaviour noted above. It was erected in the winter of 1983 and will probably remain in position.

(iv) *Caboose.* This ruined timber structure (1.93 m × 2.23 m) in Wanderer Valley was erected in 1963 by Tickell as a hide for wandering albatross observations. It was subsequently abandoned and is scheduled for demolition.

(v) *'Special Study Beach'*. This small fur seal breeding beach immediately to the east of Jordan Cove was equipped in 1978 with a system of plank and scaffolding walkways at a height of about 1.5 m above the beach, to simplify observation of and recovery of specimens from the fur seals during the breeding season. A small observation hide (Figure 6) is included on the walkways. There are no plans to remove this structure.

9. Field programmes

A summary of all seabird and seal research programmes forms Appendix 5. Important aspects of programmes relevant to the present assessment are summarised below.

(a) *Seabirds*

Seabird research at Bird Island is directed to two main questions:

(i) what is the role of seabirds and seals as predators on Antarctic marine resources, especially krill?

(ii) at the population, cohort and individual level, how is reproductive behaviour, (lifetime) reproductive success and longevity affected by age, experience, mate quality and the availability of limiting resources (particularly food but also space)?

The first question has involved research on nearly all of the seabirds breeding at Bird Island to estimate population size, investigate basic breeding biology and determine the quantitative composition of their diet. More detailed work on feeding ecology at sea and bioenergetics has been confined chiefly to penguins and albatrosses.

Factors affecting reproductive performance and success are being studied on the three species of *Diomedea* albatrosses. For grey-headed and black-browed albatrosses one colony of each species is set aside exclusively for detailed demographic work and two or three other colonies are used for experimental studies. The main research on wandering albatrosses is carried out on the Wanderer Ridge population but detailed records are kept of the performance of known-age birds in many other areas of the island.

An important subsidiary programme is the investigation of the use of seabirds (and fur seals) as indicators of change in the marine environment, and especially to provide baseline data against which to evaluate changes that may arise following the advent of significant commercial exploitation of krill. The species under study are the three albatrosses listed above, plus gentoo and macaroni penguins. At present this study consists of recording annually breeding population size, eggs hatched and chicks fledged but other parameters may be measured in the future.

The published papers (see bibliography) give an excellent idea of the scope of the seabird research. Those aspects of the present programmes involving extensive handling of birds are noted briefly below. Nearly all programmes involve ringing birds and retrapping them (often without any physical contact) to read ring numbers. There is no evidence that this has any detrimental effect.

(i) **Diet studies** Obtaining stomach samples from Procellariiformes is not infrequently undertaken and is simplified by the ready regurgitation shown by most species on handling. Birds sampled in this way are colour-banded or given a paint mark to avoid recapture. Penguins do not readily regurgitate but the recent development of a technique known as 'water-off-loading' has enabled good samples to be obtained without causing more than temporary distress to the bird.

(ii) **Endocrine hormone studies** This research involved obtaining blood samples from albatrosses. It was essential to cause as little disturbance as possible to experimental birds and sampling techniques (Hector, 1984) were developed with this in mind. For smaller numbers of albatrosses, gonads were inspected by laparoscopy under a general anaesthetic. Because it was essential that experimental birds should commence normal behaviour (usually incubation or chick rearing), great care was taken with the experimental protocol. The birds were monitored for several months post-operatively and all survived.

(iii) **Bioenergetic studies** Several of these involve the use of radioisotopes to estimate body water flux in order to provide a measure of carbon dioxide production and oxygen consumption. This involves an injection into the blood stream and, subsequently, the withdrawal of blood samples at the start and end of the study period. Experimental birds are monitored carefully and we have no evidence of any ill-effects, beyond occasional mild haematoma.

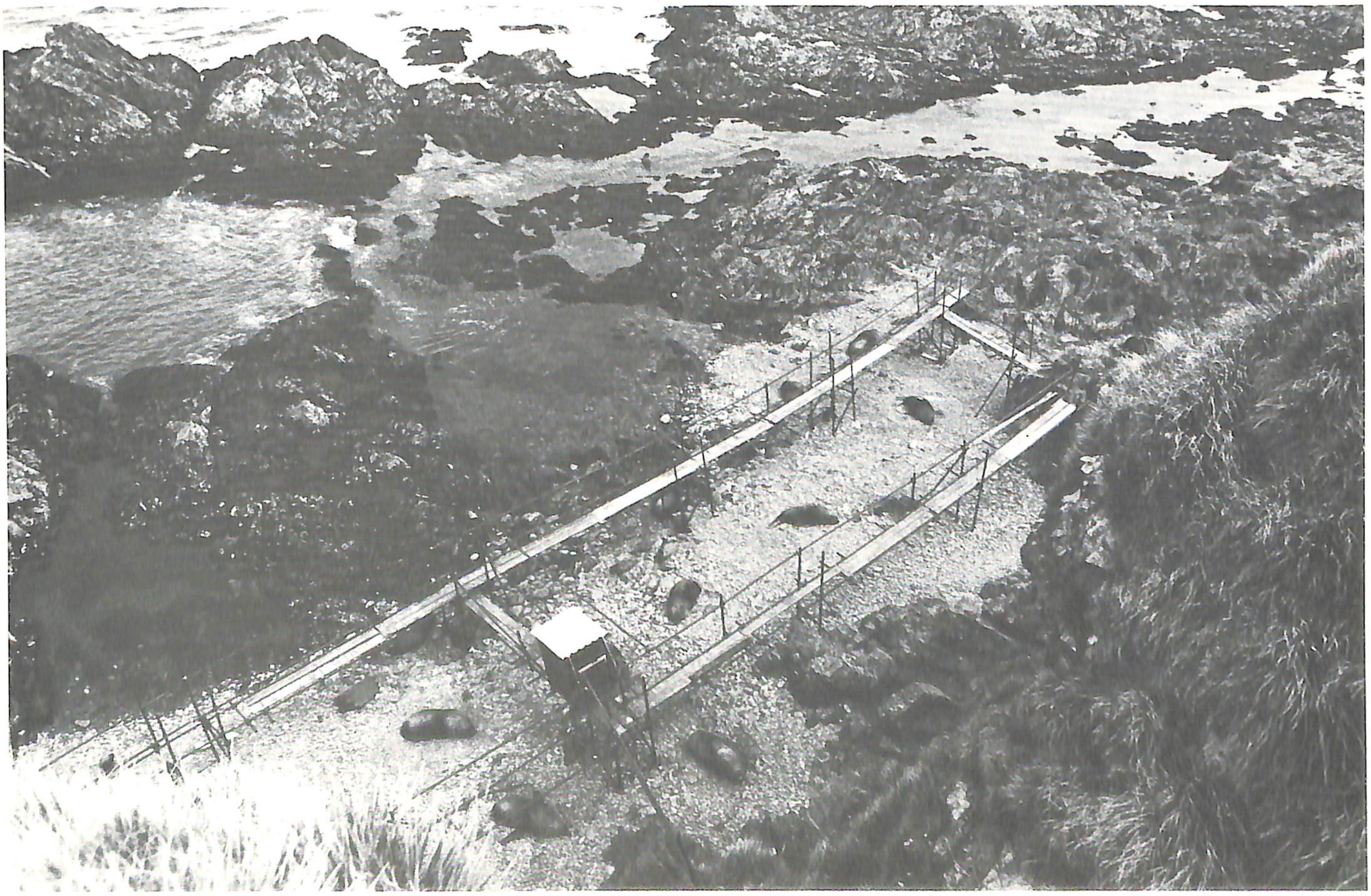
(iv) **Remote recording studies** Recorders to measure dive depths are attached to penguins, using epoxy adhesive and small clips. Devices to measure time spent on the sea are attached to colour rings on albatross legs. Radio transmitters are attached to penguins (glued to feathers mid-dorsally) and albatrosses (attached to colour-rings). All these devices are constructed so as to be as small, light and inconspicuous as possible and we have no evidence that they have any significant effect on bird behaviour.

(b) *Fur seals*

The research programmes on Antarctic fur seals concentrated initially on determining population size (to assess the nature and rate of the recovery from exploitation) and structure (Payne, 1977, 1978). From this developed investigations of the relationships between breeding density and reproductive success (Doidge, Croxall and Baker, 1984; Doidge, Croxall and Ricketts, 1984), leading to the present detailed studies concentrating on the individual over its lifetime. Other research has been investigating diet (Doidge and Croxall, 1985) and feeding ecology (Croxall *et al.*, 1985), including feeding attendance patterns, and the energy costs of foraging and milk transfer. Those aspects of the present programmes involving handling and marking animals are as follows:

Figure 5. Field hut ('Hibitane House') overlooking Payne Creek

Figure 6. Fur seal observation facilities on 'Special Study Beach', east of Jordan Cove



(i) **Social organisation and behaviour and reproductive success**

Females tagged as pups and some tagged as adults are observed each season. After tagging no further handling is required. Approximately 500 pups are tagged and weighed each year. From 1984 flippers were marked using ear punches to enable assignment of age in the event of tag loss. Some females are paint-marked each season, the marks being lost during the annual moult. Males are paint-marked and observed from scaffolding walkways. Immobilisation of males for tagging and weighing has been employed.

(ii) **Diet, diving behaviour and ecology and bioenergetics**

Diving behaviour and ecology have been studied with time-depth recorders. Recorders are attached to a harness which is removed when the females return to shore. Radio transmitters to study detailed onshore-offshore movements and to locate females are glued to the fur. These are removed after some weeks but would fall off during the annual moult if they were not recovered. Energy costs of foraging and onshore attendance patterns in females, milk transfer and pup growth have been estimated using radio-isotope techniques. For injection of isotopes and attachment of recorders females are caught and restrained on a board. Dietary work has involved analysis of stomach contents from animals shot for studies of population age structure and reproductive physiology. Current studies involve analysis of faecal samples and those obtained by ''water off-loading''.

(iii) **Reproductive history and feeding-attendance patterns from tooth sections**

The interpretation of the sub-annual incremental lines in fur seal tooth sections was studied in cows and pups using oxytetracycline injections to identify lines and detailed records of attendance patterns to interpret them. Some pups injected with oxytetracycline near weaning time were subsequently collected for the essential calibration of determining the accuracy of recognition of the 'weaning line'.

10. Impacts

(a) *Impacts associated with the station*

(i) **Habitat destruction or alteration** The station occupies a relatively small area (about 1600 m^2) of the raised beach behind Freshwater Inlet. When the first buildings were established this was well behind the area used by breeding seals. With the great expansion of the seal population, however, breeding territories are found over all of the raised beach. The two main buildings are raised on concrete piles and the spaces beneath are used for shelter by seals, particularly pups of the year. Very occasionally birds collide with wireless aerials or with buildings. The erosion of surface vegetation, other than the peaty stools of tussocks, is total, but this is caused by the fur seals, not the occupancy of the station.

(ii) **Energy generation** One of the two diesel generators is run for an average of 400 hours per month. There are no obvious effects from exhaust emissions. The main building is heated by an oil-fired boiler and cooking is done on an oil-fired stove. There are no obvious impacts from these though occasionally small quantities of smuts are emitted from the flues.

Fuel (light diesel and Avtur) is stored in 40 gallon steel drums on pallets (Figure 4). Fuel is hand-pumped into ready-use tanks as required. No major spillages have occurred but there are regular small spills near the refuelling points and occasionally small quantities (about 0.5 litres) of fuel remaining in used drums escape. There are several small areas (c. 1 m^2) and one larger (c. 6 m^2) area of oil-stained ground near the generator shed and elsewhere, but these appear to be localised.

(iii) **Waste disposal** All waste burnable material is incinerated in used 40 gallon fuel drums. Non-burnables are compacted if necessary by hammering or crushing, packed in empty fuel drums and removed for disposal in deep water at sea by the relief ship. Ash from the incinerator drums is treated similarly. Food wastes from the kitchen are dumped in the sea from the end of the jetty. The immediately edible parts are quickly eaten by scavenging birds. The remaining scraps seem to disappear quickly, since no accumulation can be detected. They are probably eaten by the very large concentrations of amphipods in the bay.

(iv) **Sewage** Waste from the kitchen and bathroom drains is discharged into one of the small streams running past the hut. A grease deposit is visible on the banks for about 3 m downstream from the discharge pipe. The bathroom is used also as a photographic darkroom. Used photographic chemicals from black and white processing are disposed of in the sink. The sea-shore (outside the fur seal season) or a stream about 100 m from the buildings, are used for lavatories. A good exchange or flow of water in both localities ensures that faecal matter is quickly dispersed. Although the system may appear primitive it is more acceptable to the occupants of the research station than other options (chemical closets, biodegradation closets) that have been tried. It should be put into the context of the use by several thousand fur seals of the same area.

(b) *Impacts associated with the scientific programmes*

(i) **Specimen marking** Because recognition of individuals is important for most of the programmes at Bird Island a relatively high proportion of individuals of several species bear identification marks. For birds these usually consist of BTO (British Trust for Ornithology) monel metal leg (or flipper) bands. Several thousand albatrosses and some other birds also bear coloured plastic (I.C.I. 'Darvic') rings. Birds bearing rings are checked regularly and rings causing abrasion (such incidents are very rare) are removed. Problems of abrasion are more prevalent with flipper bands (for penguins) and modifications of the shaping and application of these are being investigated. From time to time birds are marked by applying paint, dyes or bleaches to their plumage. The effects of these are temporary only. Nests of birds under study may be marked. This is done by inserting a piece of stout wire or a wooden stake bearing a numbered plastic tag into or near the nest. Such marks are removed when their purpose has been served.

Fur seals have been marked by tagging. In the past monel metal cattle ear tags (National Tag and Band Company or Dalton's) have been applied to the trailing edge of the foreflipper, the axilla, or more rarely to an interdigital web of a hindflipper. Metal tags rarely survive for many years *in situ*. Often seals are seen bearing tag scars where a tag has fallen out, usually by the erosion or tearing of the tissue posterior to it. Plastic cattle ear tags (Allflex) are now used. These are applied to the trailing edge of the fore flipper of fur seals or an interdigital hindflipper web of elephant seals. They seem more permanent than metal tags. Tattooing, using a modified pig marking device, has recently been tried on bull fur seals. Flipper edge marking by clipping has also been employed. Increasing use is being made of natural marks to identify fur seals individually. For short term recognition, paint marks or bleaches are applied to fur seals. These usually last for one season only, but some paint marks are visible the following year.

(ii) **Biological monitoring** Individually marked animals provide material for monitoring studies. These have been noted above. Besides simple marks other devices may be applied to sea birds or seals. These include radio transmitters, activity recorders, depth recorders, etc. Usually it is the intention to recover these instruments at a later stage in the investigation. Sometimes this is not possible, but attachments are designed to have a limited life, either by incorporating a corrodible link or by fixing to structures (hair, feathers) which will be subsequently moulted. One programme involves the substitution of artificial nests incorporating an automatic weighing device for the natural nests of albatrosses. These artificial nests are deployed during the breeding season only and collect large amounts of data without disturbing the birds at all.

(iii) **Specimen collection** Most of the scientific programmes involve the collection of specimens or terminal experiments from time to time. These specimens are taken on permits issued under the Falkland Islands Dependencies Conservation of Wildlife

Table 2. *Animals taken under permit at Bird Island, 1979-87*

Permit year	Antarctic fur seals	Penguins		Albatrosses		Fairy prion
		Macaroni	Gentoo	Black-browed	Grey-headed	
1979/80	3	10	10	–	–	–
1980/81	11	–	–	–	–	–
1981/82	–	–	–	–	–	–
1982/83	278	–	–	–	–	3
1983/84	–	–	–	15 (eggs)	15 (eggs)	–
1984/85	–	–	–	–	35	–
1985/86	–	–	–	1	35	–
1986/87	–	–	–	–	–	–
1987/88	10	–	–	–	–	–

Ordinance. In all cases numbers taken are very small in relation to the average annual recruitment of the species. Table 2 gives details of animals taken under permit at Bird Island since 1979. Occasionally, animals which are judged to be incurably injured are killed for humanitarian reasons. Some vagrant birds, not native to South Georgia, may be collected to provide voucher specimens. No wildlife is killed, nor are eggs collected, for food at Bird Island.

(b) **Tracks and paths** The passage of station personnel along frequently used routes has an obvious impact. Where peat deposits have built up under tussock, *Deschampsia* or moss cover, the vegetation is soon broken through and the peat tramped into mud. Rain or snow melt converts such tracks into drainage channels and further erosion ensues. Tracks are most marked in areas where topography restricts walkers to follow closely defined routes, as where paths from North Valley converge to cross the height of land before debouching into Top Meadow; or where a walker regularly follows the same route to some definite objective, e.g. the field hut 'Hibitane House' (Figure 7). The soft *Deschampsia* meadows and wet tussock flats of Bottom Meadow show considerable impact. As this impact is likely to be proportional to the number of journeys made, the increase in station complement and the extension of the field season by the provision of the over-wintering facility has resulted in an increase in this impact. The extent of such discernible tracks and the degree of erosion associated with them was very much greater in 1984 than in 1980.

11. Significance of impacts, mitigation procedures and monitoring

(a) *Impacts associated with the station*

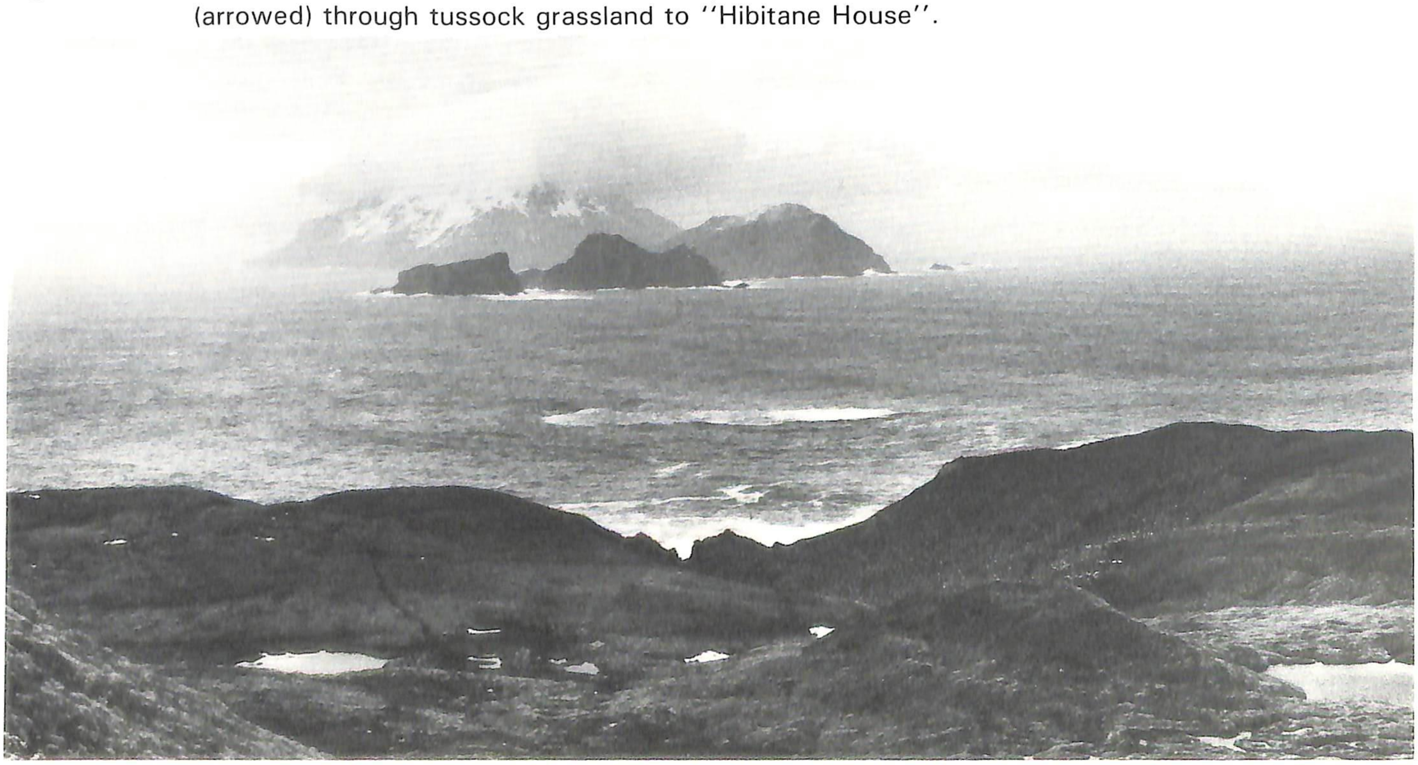
(i) **Habitat destruction or alteration** There is no significant impact in this category.

(ii) **Energy generation** There is no significant impact from the use of the diesel generators or heating and cooking stoves. However, oil spills are probably just significant in the locality of the station. More care should be taken in transferring fuel from drums to ready use tanks (e.g. minor spills resulting from the use of faulty pumps should be avoided). Clean-up techniques using oil absorbants should be introduced. Present conditions do not justify the use of chemical dispersants.

(iii) **Waste disposal** There are no significant impacts arising from this.

(iv) **Sewage** There are currently no significant impacts. However, should the volume of photographic processing increase, or should colour processing be undertaken, waste chemicals should be stored for disposal in deep water at sea or taken back to a proper waste disposal facility. Although the discharge of untreated sewage into a stream may seem aesthetically distasteful this has no significant impact

Figure 7. View over Bottom Meadows towards Payne Creek and the Willis Islands. Note track (arrowed) through tussock grassland to "Hibitane House".



whatever, particularly when the presence of several thousand fur seals using the same beach system is considered.

(b) *Impacts associated with the scientific programmes*

(i) **Specimen marking** There is no evidence that this has significant impact on the populations concerned. There is a very small possibility that some marked individuals may suffer a slight disadvantage as a result of the marks or the handling involved in marking. This is not thought to be significant.

(ii) **Biological monitoring** The same remarks apply as for specimen marking.

(iii) **Specimen collecting** For the very abundant species at Bird Island this clearly has no significant impact. The collection of rare vagrants causes no environmental impact, since these birds would in any case not survive to breed at Bird Island or to return to their own breeding grounds.

(iv) **Tracks and paths** These provide the most obvious sign of environmental impact away from the immediate vicinity of the station. Locally the impact is moderate to severe. This would be no cause for concern if the impact could be contained at its present level. However, there is no doubt that the area and degree of damage will spread as a result of increased complement and lengthened season at Bird Island. Although in general terms, erosion caused by station personnel is inconsequential compared with that caused by the fur seals, this is not so for the Meadows, west of Stejneger Peak or for parts of Wanderer Ridge. These areas are (so far) not occupied by fur seals, but contain large expanses of very fragile plant communities. Because of the scientific interest of these communities (few, if any other, examples occur in rat-free areas in South Georgia) it is desirable to limit the spread of erosion, so far as is possible.

Ideally, this would be achieved by placing some means of protection, such as plastic mesh, over the surface of the tracks. This should concentrate traffic onto the path and at the same time limit the erosion. This method is the one commonly used to protect fragile surfaces in Nature Reserves in the United Kingdom. However, it is probably not practicable at Bird Island because of the difficulty of installation. Failing this, it is recommended that, where practicable, travellers on Bird Island should be encouraged to follow marked paths, thus localising the damage and preventing the creation of large areas of low level damage. This will require a high measure of cooperation from station personnel, since it will restrict their movements and at times require them to move along exceedingly muddy tracks.

Because of the importance of this impact it is recommended that further examinations of the extent of erosion be made at intervals not exceeding two years.

12. Conclusions

The research station at Bird Island has contributed, and continues to contribute, significantly to our knowledge of the biology of seabirds and seals. It provides a unique research facility which should continue to be exploited. Environmental impacts resulting from the operation of the station and its scientific programmes are not severe, but two areas demand further attention. The first of these is the avoidance of further spills of oil and the cleaning up of existing spills. The second, and more important, is the prevention of further erosion caused by the passage of station personnel over areas of fragile vegetation. If these two objectives can be implemented there is no reason why the station should not continue to operate in its present style and at its present level of activity without significant environmental impact.

This assessment should be repeated in 1993.

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Appendix 1 — Flora of Bird Island (main references in parentheses)

VASCULAR PLANTS (Greene, 1964)
Acaena magellanica *
A. tenera
Callitriche antarctica *
Colobanthus quitensis
C. subulatus
Deschampsia antarctica * *
Hymenophyllum falklandicum
Montia fontana
Poa flabellata * *
Ranunculus biternatus
Rostkovia magellanica

MACROLICHENS (Lindsay, 1974)
Cetraria islandica
Cladia aggregata
Cladonia balfourii
C. bellidiflora
C. carneola
C. furcata *
C. gracilis *
C. phyllophora
C. pyxidata
C. squamosa
C. rangiferina
Cornicularia aculeata
C. epiphorella
Cystocoleus ebeneus
Hypogymnia lugubris
Leptogium menziesii
Mastodia tesselata
Massalongia carnosa
Platismatia glauca
Pseudocyphellaria endochrysa
P. freycinetii *
Psoroma hypnorum
Sphaerophorus globosus *
S. melanocarpus
Stereocaulon alpinum
S. glabrum *
Usnea antarctica *
U. fasciata *
Xanthoria elegans *

MICROLICHENS
A large number of undetermined crustose lichens occur on the island, mainly of the following genera:
Acarospora
Buellia *
Caloplaca *
Lecidea * (incl. *L. aspidophora, L. dicksonii*)
Lecidella
Lecanora *
Ochrolechia (incl. *O. frigida*)
Pertusaria *
Verrucaria

MOSSES (Greene (1974) and subsequent papers in the series, all appearing in British Antarctic Survey Bulletin)
Amblystegium sp.
Andreaea depressinervis *
A. nitida
A. fuegiana
A. regularis *
Barbula sp.
Bartramia patens
Brachythecium austro-salebrosum *
B. glaciale *
B. majusculum
B. subpilosum
Breutelia integrifolia
Bryum spp.
Calliergidium austro-stramineum
Calliergon sarmentosum *
Campylium polygamum
Catagonium politum
Ceratodon sp.
Chorisodontium aciphyllum * *
Conostomum pentastichum *
Dicranaceae spp.
Dicranoloma hariotii *
D. subimponens * *
Dicranoweisia cf. grimmiacea
Distichium capillaceum
Ditrichum sp.
Drepanocladus cf. uncinatus *
Funariaceae sp.
Holodontium inerme
Hygroamblystegium sp.
Hypnum sp.
Isopterygium sp.
Muelleriella crassifolia
Philonotis acicularis
P. scabrifolia
Plagiothecium falklandicum
Pohlia cruda
P. inflexa
P. nutans
P. wahlenbergii var. glacialis
Polytrichum alpestre * *
P. alpinum * *

* abundant
* * often achieves dominance

Appendix 1 *(continued)*

Pottia austro-georgica
Psilopilum trichodon
Racomitrium austro-georgicum *
R. crispulum var. crispulum
R. heterostichoides
R. lanuginosum *
R. pachydictyon
R. striatipilum
R. willii
Schistidium apocarpum
S. hyalino-cuspidatum
S. rivulare
S. syntrichiaceum
Sciaromium sp.
Skottsbergia paradoxa
Tortula filaris
T. geheebiaeopsis
T. robusta var. robusta * *

LIVERWORTS (Grolle, 1972; Hassell de Menendez, 1977)
Acrobollus ochrophyllus
Adelanthus integerrimus
A. lindbergianus
Allisonella sp.
Anastrophyllum sp.
Anthelia sp.
Barbilophozia hatcheri *
Blepharidophyllum densifolium
Cephalozia badia *
C. skottsbergii
Cephaloziella varians *
Clasmatscolea cookiana
C. gayana
C. vermicularis
Cryptochila sp.
Diplophyllum sp.
Evansianthus georgiensis
Herzogobryum atrocapillum
H. teres
H. vermiculare
Jamesoniella colorata *
Lepidozia cuspidata
L. fuegiensis
Leptoscyphus abditus
L. expansus
Lophocolea secundifolia
L. willii *
Lophozia propagulifera *
Marchantia beteroana *
M. polymorpha
Pachyglossa dissitifolia *
P. fissa
Plagiochila sp.
Riccardia georgiensis
R. granulata
R. papillosa
Roivainenia jacquinotii *
Schistochila aberrans

HIGHER FUNGI (Pegler, *et al.*, 1980)
Discomycetes
Hymenoscyphus chloophilus (type locality)

Basidiomycetes
Agrocybe semiorbicularis
Coprinus martinii
Galerina moelleri
Hypholoma elongatum
Phaeogalera stagnina
Psilocybe inquilina
Favolaschia antarctica
Omphalina antarctica

* abundant
* * often achieves dominance

Appendix 2 — Insects (and arachnids) recorded from Bird Island (Main reference: Gressitt (1970))

SPIDERS Araneae
  Micryphantidae
    Notiomaso australis

MITES Acarina
  Mesostigmata
    Parantennulidae
      Davacarus gressitti (type locality)
    Laelapidae
      Ayersacarus tilbrooki (type locality)
      Androlaelaps pachyptilae
      Stevacarus claggi (type locality)
      S. evansi
    Eviphididae
      Thinoseius hirschmanni
    Rhodacaridae
      Gamasellus rykei
      G. racovitzai
      G. antarcticus
      G. gressitti (type locality)
      Hydrogamasus watsoni
    Veigaiidae
      Cyrthydrolaelaps watsoni
      Veigaia claggi (type locality)
    Rhinonyssidae
      Rhinonyssus rhinolethrun
      R. schelli
    Ichthyostomatogasteridae
      Asternolaelaps sp. nov. (see West, 1984)
  Metastigmata
    Ixodidae
      Ixodes kerguelenensis
      I. uriae
  Prostigmata
    Eupodidae
      Eupodes minuties
      Stereotydeus reticulatus
      S. longipes (type locality)
    Rhagidiidae
      Rhagidia gerlachei
      R. leechi
    Ereynetidae
      Ereynetes macquarensis
    Bdellidae
      Bdellodes georgianensis
      B. rhachia
    Pyemotidae
      Bakerdania rugosa
      B. equisetosa
      B. sp. 1
    Astigmata
      Alloptinae
        Alloptes obtusolobus
        Echinacaruis rutidus
        E. petaliferus
        Brephosceles gressitti (type locality)
        B. marginiventris
        B. diomedei (type locality)
    Freyanidae
      Diomedaranus gigas
    Avenzoariidae
      Promegninia pedimana
      Zachvatkinia sp. aff *hydrobatidii*
      Scutomegninia phalacrocoracis
    Saproglypliidae
      Neocalvolia claggi (type locality of species and genus)

Appendix 2 *(continued)*

Cryptostigmata
Podacaridae
Halozetes marinus
H. littoralis (type locality)
H. belgicae
Alaskozetes antarcticus
Antarcticola georgiae
Podacarus auberti
Ceratozetidae
Edwardzetes elongatus
Magellozetes antarcticus
Porozetes polygonalis

FEATHER LICE Mallophaga

Material collected by Clagg at Bird Island was not reported on in sufficient detail to enable a definitive check-list for Bird Island to be drawn up. Below are listed the feather lice recorded from South Georgia from bird species that breed at Bird Island. Hosts are indicated in parentheses.

Menoponidae
Austromenopon affine (Diomedea spp*)*
A. ellioti (Pelecanoides urinatrix)
Piagetiella caputincisa (Phalacrocorax atriceps)
Philopteridae
Anaticola sp *(Anas georgica)*
Anatoecus sp *(Anas georgica)*
Austrogoniodes gressitti (Pygoscelis spp*; Eudyptes chrysolophus)* Type locality
A. macquariensis (Pygoscelis spp*; Eudyptes chrysolophus)*
Docophoroides brevis (Diomedea exulans)
D. simplex (Diomedea spp*; Procellaria aequinoctialis)*
D. murphyi (Phoebetria spp; *Macronectes* spp*)*
Episbates pederiformis (Diomedea exulans)
Haffneria grandis (Catharacta lonnbergi)
Harrisoniella hopkinsi (Diomedea exulans; Macronectes spp*)*
H. ferox (Diomedea melanophris)
H. grandis (Catharacta lonnbergi)
Naubates fuliginosus (Diomedea spp*; Phoebetria; Procellaria* spp*)*
N. prioni (Pachyptila desolata)
Paraclisis hyalina (Diomedea exulans)
P. diomedeae (Diomedea spp*; Phoebetria* spp*)*
P. obscura (Macronectes spp*)*
Pectinopygus turbinatus (Phalacrocorax atriceps)
Pelmatocerandra enderleini (Pelecanoides georgicus)
P. setosa (Pelecanoides urinatrix)
Perineus concinnoides (Diomedea exulans)
P. circumfasciatus (Diomedea spp*; Phoebetria* spp*; Macronectes* spp*)*
Pseudonirmus gurlti (Daption capense)
Quadraceps ornatus (Chionis alba, Larus dominicanus)
Saemundssonia gaini (Macronectes spp*)*
S. lari (Larus dominicanus)
S. lockleyi (Sterna vittata)
Trabeculus hexacon (Procellaria aequinoctialis)

SPRINGTAILS Collembola

None recorded in published literature but the following are almost certain to occur. Onychiuridae: *Tullbergia bisetosa;* Neanuridae: *Setanodosa steineni, Friesea grisea;* Isotomidae: *Cryptopygus antarcticus, Sorensia subflava, Setocerura georgiana, Parisotoma octooculata;* Smithuridae: *Smithurus jonesi.*

BEETLES Coleoptera
Staphylinidae
Crymus antarcticus
Halmaeusa atriceps
Perimylopidae
Perimylops antarcticus
Hydromedion sparsutum

Appendix 2 *(continued)*

FLIES Diptera
- Trichoceridae
  - *Trichocerca relegationis*
- Chironomidae
  - *Parochlus steineni*
- Sciaridae
  - *Lycoriella caesar*
- Helomyzidae
  - *Prosopantrum austrinum*
- Helcomyzidae
  - *Paractora trichosterna*
- Sphaeroceridae
  - *Antrops truncipennis*

FLEAS Siphonaptera
- Pygiopsyllidae
  - *Notiopsylla kerguelensis*
  - *N. enciari*
  - *Parapsyllus magellensis*

CHALCID WASPS Hymenoptera
- Mymaridae
  - *Notomymar aptenosoma* (type locality of species and genus)

MOTHS Lepidoptera
- *Agrotis ipsilon* (Bonner and Honey, 1987)

Appendix 3 — Avifauna of Bird Island
(Main references: Prince and Payne, 1979; Prince and Croxall, 1983)

SPECIES	STATUS	BREEDING PAIRS
King penguin *Aptenodytes patagonicus*	Regular visitor	
Adélie penguin *Pygoscelis adeliae*	One record	
Chinstrap penguin *P. antarctica*	Breeds	5-10 (-16)
Gentoo penguin *P. papua*	Breeds	(1000-)2000-4000(-6000)
Macaroni penguin *Eudyptes c. chrysolophus*	Breeds	60000—90000
Royal penguin *E. (c). schlegeli*	One record	
Rockhopper penguin *E. chrysocome*	Two records	
Magellanic penguin *Spheniscus magellanicus*	Three records	
Wandering albatross *Diomedea exulans*	Breeds	1200-1400
Black-browed albatross *D. melanophrys*	Breeds	13000
Grey-headed albatross *D. chrysostoma*	Breeds	9,000
White-capped albatross *D. cauta*	Two records	
Light-mantled sooty albatross *Phoebetria palpebrata*	Breeds	*c.* 300
Sooty albatross *P. fusca*	One record	
Southern giant petrel *Macronectes giganteus*	Breeds	600
Northern giant petrel *M. halli*	Breeds	1200
Antarctic fulmar *Fulmarus glacialoides*	Regular visitor	
Antarctic petrel *Thalassoica antarctica*	Rare winter visitor	
Cape pigeon *Daption capense*	Breeds	350-400
Snow petrel *Pagodroma nivea*	Regular; breeding Not proven	?1-2
Dove (Antarctic) prion *Pachyptila desolata*	Breeds	500000
Narrow-billed prion *P. belcheri*	A few records	
Fairy prion *P. turtur*	Breeds	100-500
Blue petrel *Halobaena caerulea*	Breeds	13000-17000
White-chinned petrel *Procellaria aequinoctialis*	Breeds	23000-36000
Kerguelen petrel *Pterodroma brevirostris*	One record	
Wilson's storm petrel *Oceanites oceanicus*	Breeds	44000-78000
Black-bellied storm petrel *Fregetta tropica*	Breeds	300-500
Grey-backed storm petrel *Garrodia nereis*	Breeds	Very small numbers
South Georgia diving petrel *Pelecanoides georgicus*	Breeds	4500
Common diving petrel *P. urinatrix*	Breeds	90000
Blue-eyed shag *Phalacrocorax atriceps*	Breeds	*c.* 100
Great egret *Egretta alba*	One record	
Snowy egret *Egretta thula*	Two records	
Cattle egret *Bubulcus ibis*	Annual vagrant	
South Georgia pintail *Anas georgica*	Breeds	?200-300
Speckled teal *A. flavirostris*	Four records	
Chiloe wigeon *A. sibilatrix*	Two records	
Solitary sandpiper *Tringa solitaria*	Two records	
White-rumped sandpiper *Calidris fuscicollis*	Regular vagrant	
Pectoral sandpiper *C. melanotos*	Four records	
Little stint *C. minuta*	One record	
Wilson's phalarope *Phalaropus tricolor*	One record	
Greater sheathbill *Chionis alba*	Breeds	?200-300
Brown skua *Catharacta lonnbergi*	Breeds	400
Dominican gull *Larus dominicanus*	Breeds	10-20
Brown-hooded gull *Larus maculipennis*	One record	
Antarctic tern *Sterna vittata*	Breeds	10-20
Swallow *Hirundo rustica*	Three records	
South Georgia pipit *Anthus antarcticus*	Breeds	?200-300

Appendix 4 — Personnel resident (for a continuous period of at least one month) at Bird Island, 1971-1987

(A: Assistant (biological); B: Builder (includes other technical support staff); S: (scientist); VA: (visiting assistant); VS: (visiting scientist); W: (overwintering))

1971-72	R.W. Burton (A), M.R. Payne (S), P.A. Prince (A)
1972-73	R. Berry (A), J.W.H. Conroy (S), M.R. Payne (S), P.A. Prince (A)
1973-74	M.R. Payne (S), P.A. Prince (A), D.A. Turner (A)
1974-75	—
1975-76	L. Kearsley (A), B. Pearson (A), P.A. Prince (S)
1976-77	J.P. Croxall (S), L. Kearsley (A), D.F. Parmelee (VS), B. Pearson (A), P.A. Prince (S)
1977-78	R.D. Bell (A), L. Kearsley (A), D. Orchard (A), P.A. Prince (S), G. Thomas (A)
1978-79	R.D. Bell (A), I. Hunter (A), S. Hunter (S), G. Thomas (A)
1979-80	J.P. Croxall (S), R.W. Davis (VS), I. Hunter (A), S. Hunter (S), G.L. Kooyman (VS), C.J. Pennycuick (VS)
1980-81	P.G. Copestake (A), D.W. Doidge (S), I. Hunter (A), S. Hunter (S), P.A. Prince (S), M.J. Whitehouse (A).
1981-82	R. Banner (B), P.G. Copestake (A), J.A.L. Hector (S), P. Humphries (B), M. Liddle (B), R. Phillips (B), P.A. Prince (S), C. Ricketts (S), R.E. Ricklefs (VS), D.D. Roby (VS), P. Sharples (B), N. Shaw (B), B. Wheeler (B), M.J. Whitehouse (A).
1982-83	J.L. Bengtson (VS), P.G. Copestake (A,W), J.P. Croxall (S), J.A.L. Hector (S), M. Liddle (B,W), B.C. Osborne (A,W), P.A. Prince (S), D. Schneider (VA)
1983-84	P.G. Copestake (A), D.P. Costa (VS), A.W. North (S), R. Lidstone-Scott (A,W), M. Liddle (B), T.S. McCann (S), M.J. O'Connell (A,W), B.C. Osborne (A), S.P.C. Pickering (S,W), P.A. Prince (S), P. Thorson (VA), D. Wallis (B)
1984-85	W.N. Bonner (S), D.P. Costa (VS), R.W. Davis (VS), C.D. Duck (S,W), J. Herpolsheimer (VA), R. Lidstone-Scott (A,W), T.S. McCann (S), M.J. O'Connell (A,W), S.P.C. Pickering (S), D. Sycamore (B)
1985-86	J.P. Croxall (S), S.N. Delany (A,W), C.D Duck (S,W), A.J. Hall (S), J.A.L. Hector (S), R. Lidstone-Scott (A), R.A. Morgan (A), M.J. O'Connell (A,W), S.P.C. Pickering (S), P.A. Prince (S).
1986-87	D. Davies-Hughes (A), S.N. Delany (A,W), C.D. Duck (S), D.W. Edwards (B,W), T.S. McCann (S), T.D. Williams (S,W).
1987-88	I.L. Boyd (S), S.N. Delany (A), C.D. Duck (S), D.W. Edwards (B,W), M. Jones (A,W), P.A. Prince (S), S. Rodwell (A,W), P. Rothery (S), T.D. Williams (S,W).

Appendix 5 — Seabird and Seal Research at Bird Island

Seabird Research

A. Role of seabirds as predators

The main elements of this programme are summarised below.

1. Population estimation

Breeding populations are assessed by surveys; non-breeding populations need life table data. Surveys of surface nesting species are fairly adequate at South Georgia (except that coverage of the Willis Islands is an urgent priority), patchy elsewhere and especially deficient at the South Sandwich Islands. Abundances of burrow-dwelling species have been studied only at Bird Island; it is important to refine the South Georgia estimates. It is unlikely that work away from Bird Island will be feasible without additional logistic facilities (e.g. an inshore trawler).

Basic data on minimum and average ages of first breeding, adult and juvenile survivorship are available for most species (macaroni and gentoo penguins and dove prions being notable exceptions; we are currently working on the first two of these). Age-specific data, adequate for constructing realistic life tables, are available only for three albatrosses. Such data are very time consuming to acquire and it is impossible to run more than one major project at a time.

2. Breeding biology

Basic work on the timing and duration of breeding activities, breeding success, etc. was a fundamental requirement. Now the main need is for information on attendance patterns ashore of non-breeding birds and of all birds outside the breeding season. This is very difficult to do for burrowing species but will be attempted for dove prions and white-chinned petrels.

3. Diet, feeding ecology and behaviour

Many studies of breeding season diets were done early in the programme. We now need research on diets in winter and are undertaking detailed analysis of summer diets, closely integrated with offshore sampling by OBP. Such studies are the key to interpreting predator-prey relationships both in terms of natural processes and also in respect of commercial exploitation. For the main prey types the following data are being recorded.

Krill: sex, reproductive status and multiple morphometric measurements; investigation of validity of relationships between, e.g. eyeball diameter and overall length.

Fish: from otoliths, species identity, age and weight (using standard relationships derived from live-caught specimens); also estimates of digestion rates and ideally of retention times and regurgitation behaviour.

Squid: from beaks, species identity, weight and investigation of use of laminae as indices of age; energy content determinations for Antarctic species.

Quantitative data, unique for pelagic seabirds, on feeding ecology and behaviour has been obtained recently using depth and activity recorders and on flight speeds and patterns using ornithodolites. We are expanding these studies. To assess foraging range and area we are using data from activity budgets, flight speeds and patterns, and duration of feeding trips to model possible foraging distributions. For penguins and fur seals these are probably fairly realistic and successful trials with radio transmitters suggested that their actual feeding grounds could be located given adequate ship support offshore. Flying birds pose problems that can probably only be solved by use of satellite telemetry and pilot studies are planned for 1988.

4. Bioenergetics
Early data were mainly from analysis of overall fasting weight losses. For albatrosses we are investigating the process in more detail using the automatic weighing nests. Labelled isotope studies provide further data on fasting costs and vital information on flight and swimming costs. We have started with albatrosses, because we can obtain realistic activity budgets for birds at sea using newly developed recorders and with penguins, because they are the key avian component of the ecosystem.

We have recently synthesized all available data and produced preliminary models of predator-prey interactions around South Georgia and in the Scotia Sea. Some conclusions are:

a) Food consumption by predators is high compared with estimates of stocks of krill and fish, though there are some obvious explanations, particularly with respect to present acoustic estimates of krill.

b) In the southern Scotia Sea penguins (and crabeater seals) take mature krill of broadly similar sizes to those caught by scientific (and commercial) net hauls. At South Georgia, however, birds and fur seals take much larger krill than reported in most net catches. There is a bias towards female krill (including gravid individuals), again at variance with most previous sampling from the area.

c) Seabirds eating fish species of commercial significance largely take immatures; male fur seals, however, mainly take adult ice fish (*Champsocephalus gunnari*). Although forming less than 5% of their summer diet, this represents 15,000 tons per annum and fish are likely to be more important in winter.

d) Birds and seals sample different (mainly larger) squid than nets and are probably presently the best index of relative abundance of Southern Ocean squid — and especially those of potential commercial significance.

Most of our comparisons and relationships, however, have been assembled from data collected in different months and years and often from outside the normal foraging range of breeding seabirds and seals. We are now comparing the detailed composition of predator diets with simultaneously collected prey samples taken within the vertical and horizontal feeding ranges of the main predators (penguins and fur seals). Fine scale acoustic estimates of prey stocks in similarly restricted areas were compared with predator requirements in collaboration with OBP in 1985/86. A comparison of the krill diet of seabirds and of fish caught by commercial trawls in the vicinity of Bird Island was carried out in 1984/85 in collaboration with the Sea Fisheries Institute, Hamburg.

B. Factors affecting reproductive performance and success of known-aged seabirds

Detailed studies of this nature have so far been confined to:

1. Black-browed and grey-headed albatrosses.

Although data on mate fidelity, breeding frequency and survivorship are being collected, the main aims at present are to compare feeding performance, provisioning rate, chick growth rates and rearing success between pairs, and the division of labour within pairs. Equipment has been devised and built to record the size and frequency of all meals delivered to the chick, the parent responsible, the detailed pattern of chick growth and the division of the adult foraging trip into time spent flying and time on the sea.

2. Wandering albatrosses.

Detailed study of mate fidelity, survival and breeding performance of c130 pairs annually (total population c220 pairs, 300 pre-breeding birds and 60 adults that have not bred in five years), divisible into three groups: old (35 years), middle-aged (20-25 years) and young (7-11 years) breeders.All individuals younger than age 10 are of known-age and a new project is using these to study how breeding territories are acquired (by males), how mates are selected (by females) and the effectiveness of partnerships in their first breeding attempts.

C. Use of seabirds (and seals) as indicators of change in the marine environment.

We have monitored breeding population size and breeding success for five species (two penguins, three albatrosses) at Bird Island since at least 1976. Attendance patterns of female fur seals and pup growth have been recorded at South Georgia since 1976. For all species, variation between seasons is substantial and significant trends would only be detected with many years' data, although very abnormal seasons are usually readily detectable — chiefly because several species are being studied simultaneously at a single site. Other parameters might be better indices of marine conditions (eg. weight of penguins on arrival at colony, length of foraging trips, sizes of meals delivered) but this is by no means certain and would require annual full scale research projects to collect the data required.

D. Competition and ecological isolating mechanisms in Antarctic seabirds

Where main objectives permit, we have tried to compare the ecological adaptations of related or similar species to see how they may avoid competition (and whether, indeed, it exists).

1. Northern and southern giant petrels
Significant similarity or overlap in everything except timing of breeding and, in some years, diet and juvenile survival which largely follow from this.

2. South Georgia and common diving petrels
Different breeding habitat, timing of breeding and differences in diet (not necessarily related to breeding time).

3. Dove prion, blue petrel
Different breeding timetable and some dietary differences, associated with feeding methods and bill morphology.

4. Black-browed and grey-headed albatrosses
Differences in diet are implicated in different chick growth rates, duration of rearing period and this contributes to black-browed albatrosses being

annual, grey-headed albatrosses biennial breeders. Factors influencing breeding frequency are the subject of current research. Endocrine studies show that of grey-headed albatrosses successful in rearing chicks, males, but not females, are able to return to active reproductive hormone condition by the next season; this has led to general hypotheses concerning reproductive refractoriness.

Seal Research

Present work is chiefly concerned with:

a) Population structure and dynamics, especially in comparison with that prevailing at the time of previous studies and other areas now. Such work aims to identify changes that may have resulted from the theoretically increased availability of prey consequent on the reduction of whale numbers and also to document the population response of species that were formerly significantly exploited by man.

b) The relationships between social behaviour and organisation, population structure, and reproductive success, with special reference to sex differences in fur seals.

c) Collection of data relevant to quantifying seal impact on marine resources.

A. Antarctic fur seals

1. Population size, age structure and demography

The project on these topics from 1972-1977 formed the basis of present research. Further population samples have been obtained (including some from lower density sites) in 1981 and 1983 and comparative analyses are underway.

2. Density, social organisation and behaviour and breeding success

The main research programme from 1978-1982 investigated differences in the nature and extent of pup mortality and its relation to male and female (especially mother-pup) behaviour at sites of high and low density. The reproductive history and performance of females from this study is being followed and augmented by further detailed studies of known individuals.

3. Diet, diving behaviour and ecology and bioenergetics

Diving behaviour and ecology have been studied with time-depth recorders in conjunction with detailed attendance records. Energy costs of foraging and of onshore attendance periods in females, milk transfer and pup growth have been estimated using radio-isotope techniques. Dietary work has involved analyses of the krill component and preliminary studies of the fish and squid elements.

4. Reproductive history and feeding-attendance cycles from tooth sections

The interpretation of the sub-annual lines in fur seal tooth sections was studied in cows and pups using oxytetracycline injections to identify lines and detailed records of attendance patterns to interpret them. The results suggest that it is feasible to determine for how long pups were reared in all previous breeding seasons. It may also be possible to use the number of feeding-attendance cycles for a cow in each year as an index of the prevailing marine conditions.

5. Male reproductive success

This new project (developing an early preliminary study) is examining the duration and location of territorial tenure and harem size in relation to reproductive success in various categories of individually marked male fur seals. We are assessing the costs and benefits to males of the different strategies that may be involved. Energy consumption of bulls while ashore is being assessed and activity budgets of adult and juvenile males monitored.

6. Natural mortality in males

Canine teeth from several hundred males which have died ashore of natural causes have been collected over the past decade and show the age structure of the animals involved. A study of the pathology of this mortality has been initiated, aspects of which will complement the study of competition and reproductive success described above.