Man and Nature in the Tristan da Cunha Islands

N. M. WACE and M. W. HOLDGATE

Published with the support of the World Wildlife Fund

IUCN MONOGRAPH NO. 6

INTERNATIONAL UNION FOR CONSERVATION OF NATURE
AND NATURAL RESOURCES, MORGES, SWITZERLAND, 1976

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Foreword

Since Charles Darwin's voyage in HMS *Beagle*, the life of remote islands has excited naturalists by its uniqueness and by its value to science. Just as no two remote islands have the same topography, so no two are identical in their flora and fauna. Built by volcanic eruptions in mid-ocean, these islands have provided natural experiments, testing the capacity of land plants and animals for dispersal across broad expanses of hostile ocean. Isolated behind these ocean barriers, the successful colonists have evolved distinctive 'endemic' species, genera or even families. Because many oceanic islands are small, and many of their peculiar species are adapted to habitats that cover only a part of the island's surface, some of these island endemics are among the rarest species in the world.

During the last three centuries, man has settled upon many remote islands. Deliberately or accidentally, he has imported the species that nature excluded—aggressive continental plants and insects, grazing mammals, and predators. He has cut down the natural forests, 'improved' the pastures, and cultivated the lowland soils. His livestock—like goats, pigs, or cats—have run wild. The world has already lost many unique life forms that are, as the saying goes, as dead as one of the greatest of all island endemics—the Dodo. The survivors include a high proportion of the world's most endangered species.

It is both natural and proper that conservationists have now begun to respond. The 'Islands for Science' project launched by Max Nicholson is being developed by IUCN as an inventory of the world's remote islands: a kind of stock-taking of their present condition. Before we can start to press for conservation, we need to know what is left to conserve. We know already that the Tristan da Cunha Islands in the South Atlantic are the only group in the whole southern temperate zone to retain their natural flora and fauna substantially intact. This Monograph is welcome accordingly. Its authors have visited Tristan several times, and studied its wild life for over twenty years. They have now provided a review of both the natural ecosystem and of the impact upon it of the human community. They recognize that conservation can only be secured with the good will of the Tristan Islanders, and under a Management Plan that respects the interests of that community, and in the final section of their work they show how this blend of conservation and development can be achieved. Indeed, they do more: they stress that in these islands, conservation in the sense of preserving the integrity of the ecosystems of ocean and land is an essential to the survival of the island people. Their work is directly along the lines proposed for island studies in UNESCO's Man and Biosphere Programme, to which it is being submitted as a case history.

As this Monograph goes to Press, IUCN is delighted to learn that, with the support of the Islanders, a new Conservation Ordinance has been enacted for Tristan, giving effect to the proposals in these pages. IUCN is equally pleased that it has been possible to include the text of the Ordinance in this volume, and trusts that other islands will soon follow the enlightened example of the Tristan da Cunha Islands in making proper legislative provision for conservation.

Contents

RECOMMENDATIONS: A MANAGEMENT PLAN FOR THE TRISTAN DA CUNHA ISLANDS

Introduction

1.1 This report has been written following a visit to the Tristan da Cunha Islands by Dr N. M. Wace (Research School of Pacific Studies, Australian National University), Mr C. C. H. Elliott (Percy Fitzpatrick Institute for African Ornithology, University of Cape Town) and Dr M. W. Holdgate* (Deputy Director (Research) The Nature Conservancy, London) during the period February-May, 1968.

1. 2 The visit was financed by grants from the Conservation Foundation, New York, and the Trustees of the Percy Sladen Fund. The Natural Environment Research Council, the University of Adelaide, and the University of Cape Town continued to support the participants during the period spent in the islands. This assistance is most gratefully acknowledged. We also thank the Conservation Foundation for allowing us to use the unspent part of their grant for the provision of extra Plates in this report.

We are most grateful to Den norske Amerikalinje, Oslo; Tristan Investments Ltd., Cape Town; the Department of Transport of the South African Government, Pretoria, and to Mr Harold Green of Tristan da Cunha, and the other members of his longboat crew, for their generous provision of transport to and between the islands. The Department of Transport also provided us with accommodation on Gough Island, and the Foreign and Commonwealth Office in London and their Administration on Tristan da Cunha helped in many ways. Mr Herbert Glass, Jnr., Mr Harold Green and Mr Ernest Repetto and other Tristan islanders provided valuable assistance ashore and afloat.

We are also most grateful to Mr Allan Crawford, Mr Peter Day, and Mrs M. K. Rowan in South Africa, to Mr A. J. Beintema, Mr Michael Swales and Sir Hugh Elliott in Europe; and to Mr E. K. Fisk, Dr Norma McArthur and Dr Donald Walker in Australia, for their advice and assistance.

Our particular thanks are due to Mr Clive Elliott of Cape Town University, † both for his companionship in the field and for ornithological information.

1.3 The present report describes the scientific interest of the Tristan da Cunha—Gough Island Group, summarizes current knowledge of the four main islands, outlines the history of human utilisation, analyses the impact of man upon the biota and sets out proposals for future management and conservation. Although not designed as a contribution to the UNESCO *Man and Biosphere* programme, it has been accepted as part of the UK contribution to Project 7 of that programme, on the ecology and rational use of island ecosystems. As such, it stands as a case study for that project.

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The Scientific Importance of Oceanic Islands

2.1 Oceanic islands are of particular interest to biologists because of their isolated situation, mode of origin and consequent biological peculiarities. Most of them arise by volcanic eruption from mid-oceanic ridges and associated crustal structures and are isolated from continental land masses by wide expanses of sea. Most oceanic islands are geologically young with rocks of Miocene or later age. Their native terrestrial floras and faunas have been gained by trans-oceanic dispersal, and because few species are adapted for such long range spread, they generally have an impoverished biota. The small size, restricted range of habitats, and climatic uniformity of many such islands further restricts their biota: only a small proportion of the species reaching them appear to be capable of establishing themselves. Insular ecological systems are also believed to be inherently less stable than those inhabiting larger land masses, and rates of biotic turnover are often high (MacArthur and Wilson 1967). Many major groups of plants and animals prominent in continental areas (including land mammals, amphibia, reptiles, such insect groups as Trichoptera, Plecoptera, Orthoptera, Megaloptera and Odonata, and most genera to which dominant forest trees on the continents belong) are unsuccessful in transoceanic dispersal or establishment and do not occur on remote islands.

Island floras and faunas are thus disharmonic: taxonomic groups which are of major importance on larger land masses are absent. By contrast, many species that do inhabit oceanic islands have an unusually wide ecological range there, living in habitats from which they are excluded on larger land masses where competition is more intense. Insular plant and animal communities as a whole are made up from unusually few species, and specialised ecological niches may remain unfilled. Because island populations are genetically isolated, derive initially from small founder stocks, and are exposed to different environments and selective pressures from their parental mainland populations, evolutionary divergence is general—culminating in the appearance of distinct endemic island species or complexes of species, which are found nowhere else.

For these reasons, the study of island biota has been of great importance in the formation and development of the concept of organic evolution, and continues to attract the interest of modern workers studying evolutionary processes (e.g. Stern 1971).

2. 2 In contrast to the restriction imposed by isolation on their terrestrial biota, remote islands generally support large populations of breeding seabirds and marine mammals, which are not confronted by the same dispersal problem as the truly terrestrial animals. Such marine creatures have ready access to extensive feeding grounds, and because of the lack of land mammals on oceanic islands, they are not exposed to destructive predators when ashore. Oceanic islands thus serve as breeding refuges for many marine vertebrates, and studies of the behaviour and population dynamics of large numbers of marine animals on islands have been of considerable value in the development of ideas on the biology of crowding, and social factors in the regulation of breeding (e.g. Wynne-Edwards 1962, Lack 1968).

2.3 These very peculiarities render oceanic island floras and faunas vulnerable when their isolation is broken down by man. Their vegetation, de-

veloped in the absence of herbivorous mammals, often has little resistance to grazing and may be catastropically modified if such animals as sheep, cattle, goats or rabbits are imported (Elton 1958, Holdgate and Wace 1961, Holdgate 1967). The large populations of breeding seabirds are particularly vulnerable to imported mammalian predators such as cats, rats, mink, mongoose and dogs. Continental plants, many of which are adapted to continual disturbance of their habitats, can invade and alter the character of oceanic island vegetation, especially if this is disturbed by fire, grazing, cutting, tillage or trampling etc. Some alien plants and invertebrates seem able to invade even undisturbed insular communities (Holdgate 1967, Wace 1967). Such changes, although themselves not without scientific interest, tend to reduce insular ecosystems to mere repetitions of those on the continents, with the loss of unique species and ecological situations.

2. 4 The oceanic islands of the world have suffered very greatly from human interference, especially over the past 300 years. Few temperate oceanic islands, even in the less accessible regions of the southern hemisphere, now remain in anything approaching their original condition (Wace 1966). The four islands of Tristan da Cunha, Inaccessible, Nightingale and Gough are now biologically unique as a group of extremely isolated oceanic volcanic islands with a temperate climate, a typically impoverished and disharmonic biota, a number of endemic species, large seabird and seal colonies and relatively little human interference. As such, they are recognized to be of international scientific importance and their conservation and study is of general concern (Wace 1965).

Such concern for the conservation of island biotas has found expression in the recent IUCN listing of all the oceanic islands of the world, together with indications of the current state of their biota, starting with those in the Pacific (Douglas 1969), and the related Islands for Science project (Nicholson 1971). The Man and the Biosphere programme of UNESCO includes a project (MAB 7) on the management of islands, because of general recognition of the particular ecological features of islands, their value for scientific study, and the need for special guidelines on their wise management.

2. 5 The scientific interest of oceanic islands does not lie solely in the study of their native ecosystems or environments in comparison to those of lands which are more accessible to (and therefore more affected by) man. The isolation and relative lack of industrial development on such islands also makes them attractive for 'background' or 'baseline' pollution monitoring stations. For example, recent proposals for a Global Environmental Monitoring System (Munn 1973), state in respect of global air pollution (p 40):

> 'Recommendation 9: It is recommended that Member States be encouraged to undertake pilot studies of the problems associated with obtaining precipitation chemistry samples on ships and on oceanic islands and coastlines.'

In considering marine pollution, the Report states (p. 43):

> '. . . island stations can play a role in monitoring relative levels of pollutant fluctuations, and in serving as sites for early detection of pollutant increases.'

The importance of the existing station at Mauna Loa, Hawaii, in monitoring atmospheric carbon dioxide levels has been widely recognized (e.g. SCEP, 1970, pp 192-200). Such use of oceanic islands for baseline monitoring is

likely to increase in future, as a consequence of world-wide concern about the environmental impact of world population growth and industrialization, and give a new scientific importance to remote islands such as the Tristan da Cunha Group.

The Physical Geography of the Tristan da Cunha Islands

3. 1 POSITION AND ORIGIN OF THE ISLANDS

The Tristan-Gough Island group consists of four islands. Three, Tristan, Inaccessible and Nightingale, lie close together in the central South Atlantic near 37 °S, 12 °W (Figure 1) and Gough Island lies about 350 km south-south-east of the others at 40 °S, 10 °W. The islands are about 2800 km from South Africa and some 3200 km from the nearest point of South America. They all lie somewhat east of the crest of the mid-Atlantic Ridge near its junction with the aseismic Walvis lateral ridge, and rise from water about 3500 m deep.

The three northern islands (referred to here as the 'Tristan Group') are the summits of separate volcanoes which differ in age, and therefore in erosional stage. Tristan, a young strato-volcano, has the highest, largest and least degraded cone; and the lowest lava flows dated (from near sea level) are about one million years old (Miller 1964). It has no extensive submarine platform surrounding its shores. Inaccessible and Nightingale, which are linked by shallower water than that between them and Tristan, both rise from platforms less than 300 m deep which far exceed in area the emergent parts of the islands (Fig. 2). Gass (1967) considers them to be the degraded remnants of former cones. Inaccessible has rocks up to about 6 (± 1) million years old and Middle Island (a sea stack near Nightingale) exceeding 18 (±4) million years. Gough Island, which is the summit of a completely separate volcanic mass, is intermediate in size and erosional state between Tristan and Inaccessible: its oldest dated rocks are some 6 (±2) million years old (Miller 1964).

Despite these widely differing ages of the oldest known rocks on the different islands, all four islands show evidence of recent volcanic activity such as effusive flows (Tristan), cinder cones (Tristan, Inaccessible and Gough), massive trachytic flows (Nightingale) and cumulo-domes (Gough). With the possible exception of those on Inaccessible Island, these have been formed within the last 40,000 years, and in most cases much more recently. None of the islands can therefore be regarded as volcanically extinct.

3. 2 CLIMATE OF THE ISLANDS

The islands have a cool temperate oceanic climate. Lying on the edge of the westerly wind belt, they are under the influence of both maritime tropical (mT) and maritime polar (mP) air masses from the western south Atlantic. The weather pattern is dominated by the passage of cyclonic storms generated by outbursts of mP air on the Polar Front. Since the mP air is cooler than the ocean, and many of the weather fronts are occluded by the time they reach the islands, the weather is mostly cloudy with frontal rain. The islands themselves also induce much orographic rainfall from the cool moist air. In summer, the Tristan group may come under the influence of the subtropical high pressure cell bringing mT air with orographic cloud on the Peak, fewer storms and less rain than in the winter. The Tristan group thus have some characteristics of a 'Mediterranean' climate, although summer droughts seldom exceed a few weeks and the Tristan-Gough group as a whole has a climate similar to that of maritime temperate west coasts.

Air temperatures and rainfall figures for coastal sites on Tristan and Gough are shown in Figure 3. The mean annual temperature at the Tristan settle-

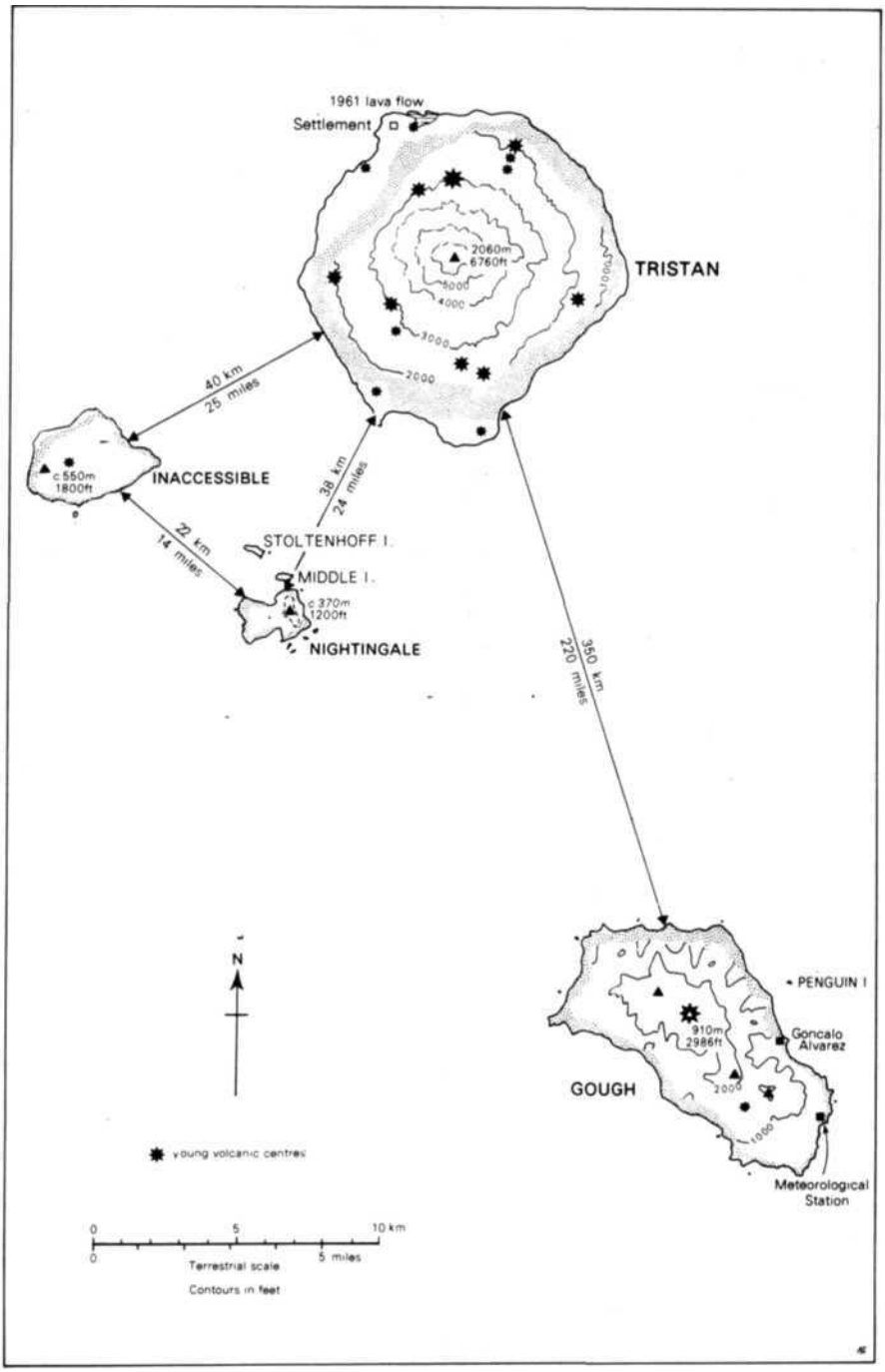

Figure 1.
Islands of the Tristan-Gough group drawn to the same scale. Distances between the islands are indicated, but *not* drawn to scale. Asterisks mark young volcanic cones and squares indicate the main points of human occupation.

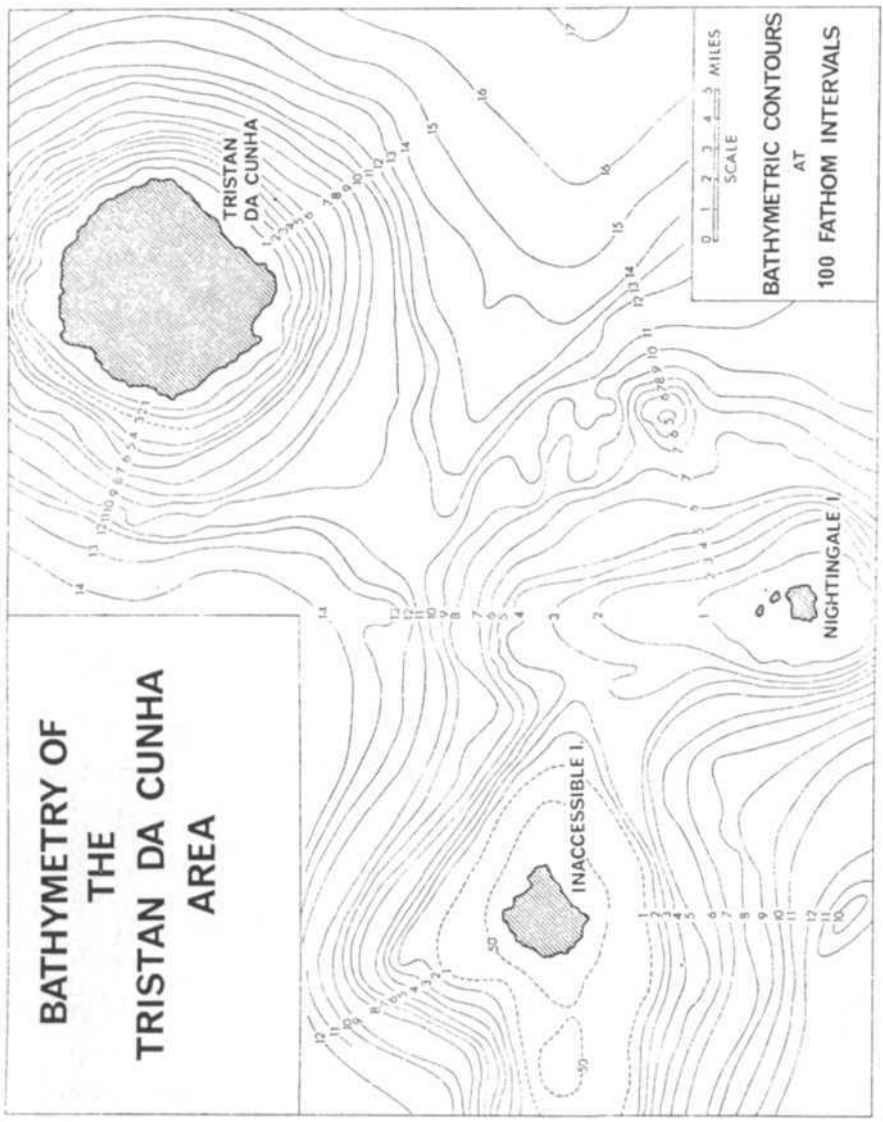

Figure 2.
Bathymetry of the Tristan group. From Baker *et al* (1964) by kind permission of The Royal Society.

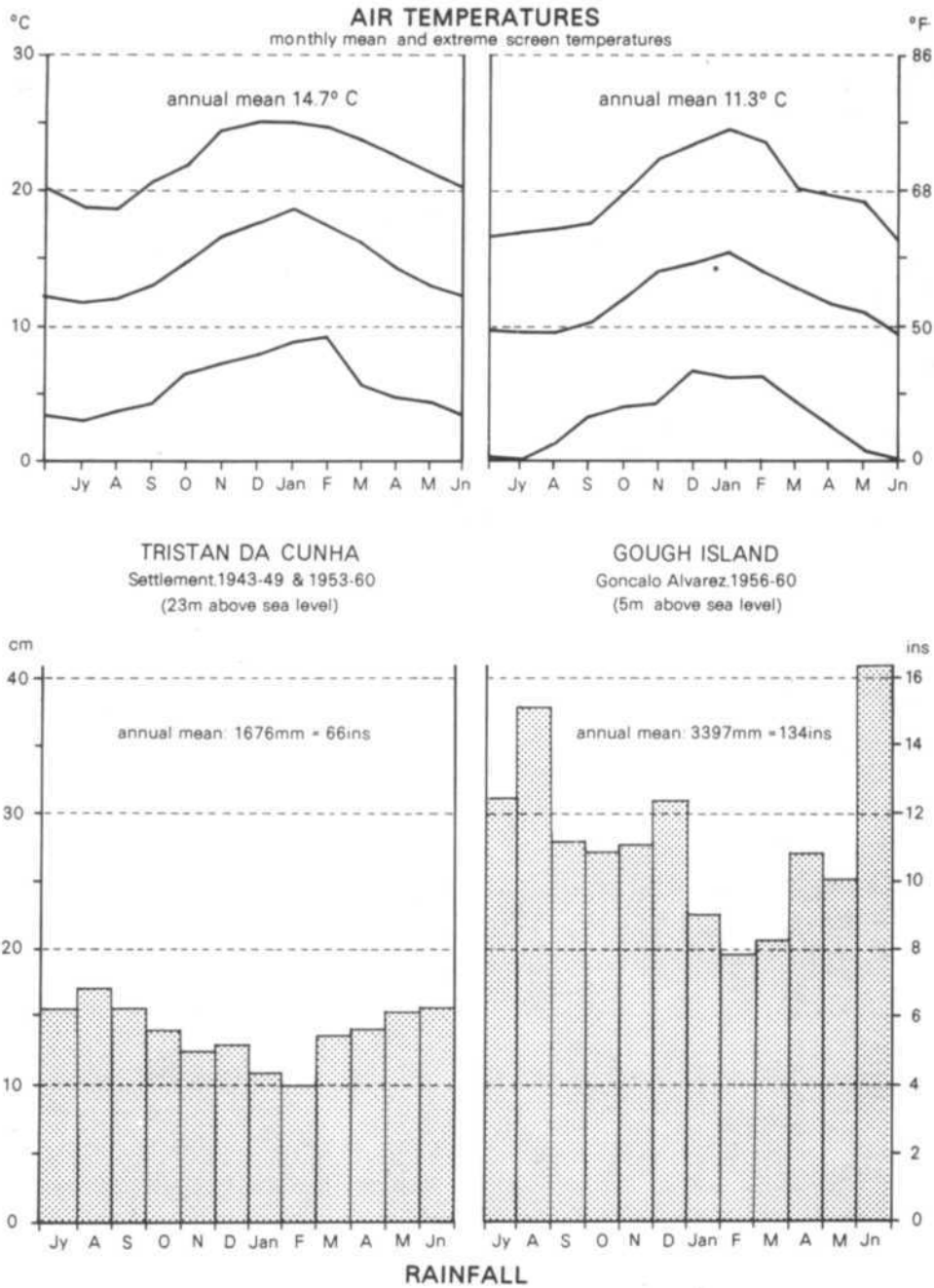

Figure 3.
Air temperatures (Stevenson screen) and rainfall on Tristan da Cunha and Gough Island. Data from S. African Weather Bureau, Pretoria.

ment is 14. 5 °C* and near sea level on the south-east coast of Gough 11. 3 °C. An important general feature of the island climates is their extreme oceanicity; both seasonal and diurnal temperature fluctuations are very small indeed, in common with those of the subantarctic islands (Troll 1964).

Tristan has a mean annual rainfall at sea level (Settlement, 1943-49 and 1953-60) of 1676 mm, with rain on 250 days of the year, and Gough (Goncalo Alvarez, 1956-60) of 3397 mm with rain on 296 days. These climatic data refer to sea level sites, where continuous records have been kept. Conditions elsewhere probably differ markedly from those quoted; for example Sandy Point on the east of Tristan is likely to be unusually well sheltered and possibly relatively dry. From the few comparative records (Christophersen and Schou 1946, Wace 1961), rainfall on the uplands of Tristan and Gough may be at least twice as heavy as that at sea level. Snow lies intermittently during the winter months above about 600 m on Tristan and above about 300 m on Gough, but frosts at sea level are almost unknown on either island. Few climatic data are available for Inaccessible or Nightingale Islands, and none for extended periods.

The prevailing westerly winds in the Southern Ocean impart an easterly set to the surface waters, and the islands lie within this West Wind Drift, which has an overall movement of some 13 km per day (Deacon 1960). The Subtropical Convergence lies near the Tristan Group, sometimes being between Tristan and Gough, and sometimes to the southward of all the islands (Knox 1960, Penrith 1967). Both subantarctic and cold temperate mixed water types therefore affect the islands. Mean sea temperatures are around 18 °C and 13 °C in summer and 13 °C and 11 °C in winter at Tristan and Gough Island respectively.

3. 3 TOPOGRAPHY AND STRUCTURE OF TRISTAN

The largest of the four islands is generally known locally as 'Tristan' and will be referred to thus in this report. The island is roughly circular in plan, with an average diameter of some 12 km (Figure 4). It consists of a conical central peak reaching a height above sea level of 2060 m. This cone, consisting largely of cinders and pyroclastics, culminates in an unbreached crater containing a shallow lake. The flanks of the Peak are steepest near the top, and gradients slacken to a more gently inclined area known as 'The Base', lying between 600 and 900 m above the sea. To seaward the Base is truncated by precipices and cliffs but a discontinuous ring of lowlands (the 'Lowland Plains' or 'Coastal Strips') lies between the cliffs and the sea. The three most important of these are the Settlement Plain in the north west, Sandy Point at the east, and Stony Hill and Cave Point in the south. Numerous parasitic cones, resulting from secondary eruptions, protrude from the flanks of the Peak, the Base, and some of the Coastal Strips.

The island is a strato-volcano made up of interbedded lavas (mainly basaltic) and pyroclastics (Baker *et al.* 1964). A main sequence of eruptions produced the greater part of the island, including the Base and the lower part of the Peak. In the most recent period, both explosive and effusive eruptions from secondary

* The published mean air temperature of 12. 2 °C in Pretoria Weather Bureau publication (3/1949) is in error due to transposition of figures. Published figures for mean air temperatures at Tristan Settlement apparently vary from 14. 3 °C for 1942-49, corrected Pretoria Weather Bureau data, copied in British Meteorological Office (1967) and U.S. Department of Commerce (1959), to 14.7 °C (U.S. Department of Commerce, 1968).

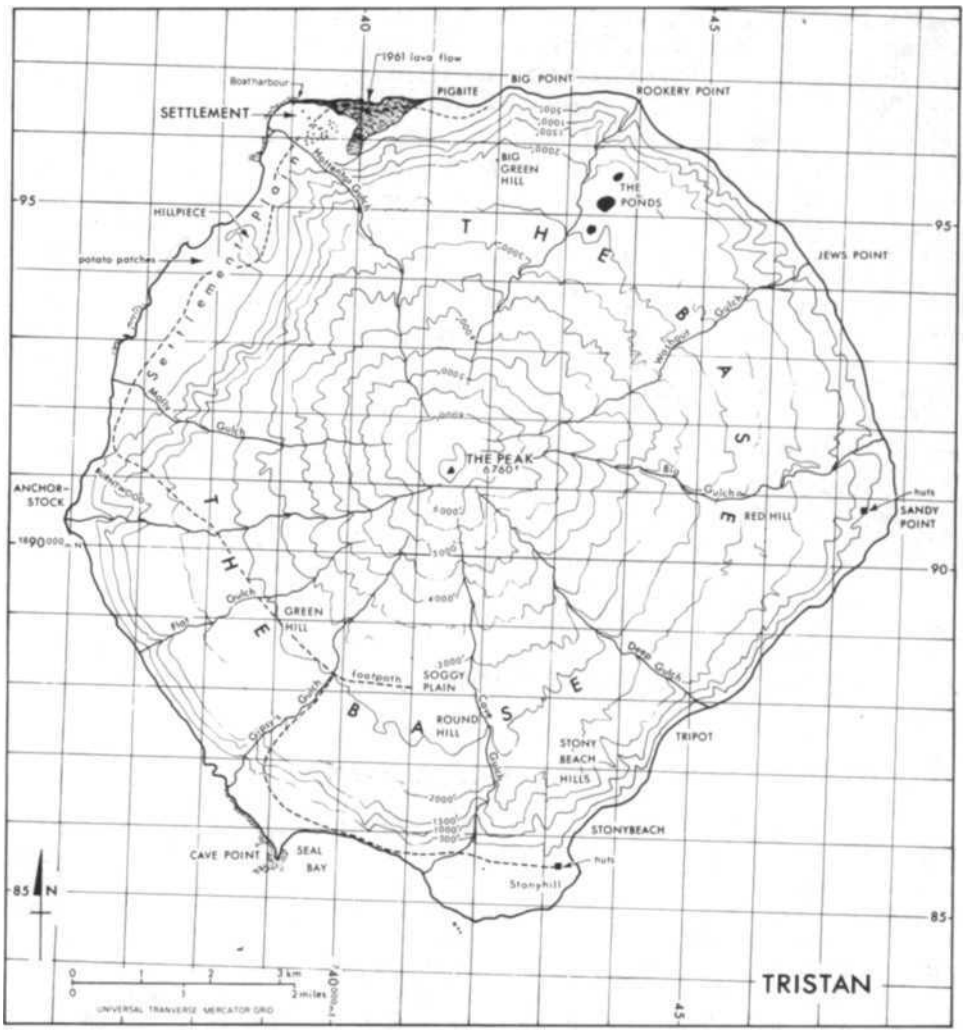

Figure 4.
Tristan da Cunha. Based on map by H. M. Directorate of Overseas Surveys.

centres have been a feature of the island. At least eight small parasitic cones on the Base are probably less than 25,000 years old (Gass 1967). Cinders from one such cone (Big Green Hill), overlie an organic silt dated at 10,600 to 11, 500 years B.P. (Wace and Dickson 1965). Younger centres have produced the lavas and pyroclastics that compose the bulk of the lowland plains. Much of the plain on which the Settlement stands seems to have originated from a centre that may be no more than 6, 000 years old, while the complex known as Stony Hill in the southeast of the island may be only a few hundred years old (Baker *et al.* 1964). Although no accounts of any seismic disturbances or volcanic activity on Tristan were recorded before the eruption of 1961 near the Settlement (Baker *et al.* 1964) it is now known that a violent earth tremor was experienced there in 1849 (MacGillivray 1852). The most recent activity (1961-62) added about 0. 5 km^2 of land, mostly as lava flows, at the eastern end of the Settlement Plain.

Plate I Tristan da Cunha, showing the new volcano and the Settlement (right), from the north, May 1968. The crater of the new volcano stands some 450 ft (137 m), and the edge of the precipices fronting The Base some 2000 ft (600 m) above the sea. The Peak (6760 ft, 2010 m) is obscured by cloud behind. Note the banked-up fan of alluvium where Hottentot Gulch debouches onto the coastal strip behind the Settlement (Photograph, N.M.W.).

Plate II Tristan Settlement from the edge of the precipice, some 2000 ft (600 m) above, April 1968. Hottentot Gulch to the left shows clear evidence of having overspilled its banks in the past, and deposited sediment and boulders where the houses now stand. The edge of the 1961 lava flow is seen to the right (Photograph, N.M.W.).

Seaward erosion of both the main flows and the coastal strips has produced a precipitous cliffed coastline fringed by narrow boulder beaches and rocky headlands. The island retains a youthful drainage system, with radially arranged flat-bottomed gorges ('gulches') deeply incised into the main sequence of lava flows on the Base. Most of the Base retains an undulating 'planeze' form (Oilier 1969) between the gulches, but the planezes are scored by narrow winding gullies ('fern slots') similar to those described from a young volcano in New Guinea (Oilier and Brown 1971). The coastal strips are largely veneered with outwash debris carried down the gulches and these often have substantial levees where they debouch onto the flatter ground from the cliffs above. (Plates I and II)

3. 4 TOPOGRAPHY AND STRUCTURE OF INACCESSIBLE ISLAND

Inaccessible Island, second in size of the Tristan Group, measures about 5 km from west to east and 4 km north-south and is trapezoid in plan (Figure 5). It is probably a planeze fragment of a massive cone whose summit lay to the west of the present island and most of which has been removed by marine erosion (Gass 1967). The highest point (about 600 m) rises above the western cliffs and the land dips eastwards at some 3° to 5° to cliffs about 200 m high above the sheer eastern coastline. The interior of the island probably contains two drainage systems divided by an eastward sloping ridge, but the whole terrain is much dissected by ravines and gullies (Stoltenhoff 1877, Christophersen 1940). Most of the island consists of thin basaltic lava flows interbedded with ash and cinders, similar to the main part of Tristan, but many intrusive features such as trachyte dykes, plugs and domes are exposed, especially towards the west of the island. There are four parasitic cinder cones of unknown age on the uplands of the island (Dunne 1941). Inaccessible Island is rightly named, for it is girdled by very steep cliffs on north, east and south sides. (Plate VII). On the west, where the slope is easier, landing is often impossible owing to the prevailing swell and a reef. The island is consequently the least known and least visited in the whole Tristan-Gough group.

3. 5 TOPOGRAPHY AND STRUCTURE OF NIGHTINGALE ISLAND

Nightingale Island is the smallest and oldest of the northern islands, measuring only 2. 5 km from east to west and 1. 5 km from north to south. It has the shape of a squat dumb-bell, with two hill masses separated by a broad waist (Figure 6). The highest hill, on the east, reaches about 400 m and that on the west 250 m. Much of the island is composed of trachyte lava flows and these extend northwards to the nearby small islands of Middle and Stoltenhoff, which are part of the same complex. Nightingale, with rocks up to 18 million years old, is only a volcanic skeleton (Kear 1957) and retains no trace of its original form. A wide, shallow submerged platform, to the north, may mark the former extent of the island. Despite its antiquity and advanced erosional stage, Nightingale Island shows signs of recent volcanicity, and a secondary centre near Ned's Cave on the south coast may have produced lavas and tuff there and at Seahen Rocks that overlie peaty deposits which have been tentatively dated at 36, 000 years B.P. (Baker *et at.* 1964).

3. 6 TOPOGRAPHY AND STRUCTURE OF GOUGH ISLAND

Gough Island, second in size of the Tristan-Gough group, is also the most complex in terrain and structure. It measures 13 km from north to south and

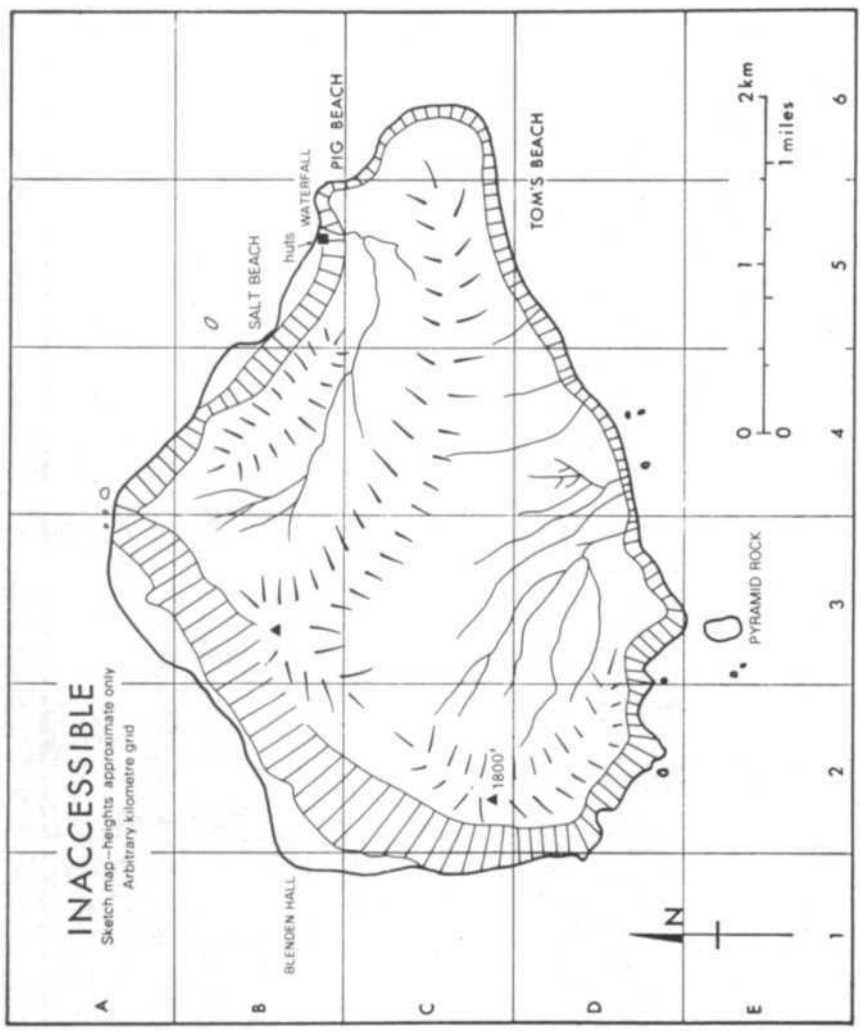

Figure 5.
Inaccessible Island. Sketch map, including detail drawn from incomplete aerial photography.

rather over 5 km from east to west at its widest point (Figure 7). The summit of the island, Edinburgh Peak, reaches 910 m and the second peak, Expedition Peak, 894 m. Both rise from a central upland of rounded hills and broad boggy plateaux (Plate XI). In striking contrast, the northern and eastern sides of the island form a deeply dissected landscape of narrow ridges and steep-sided valleys (Plate X). There are seven main valleys, ranging from 1. 2 km to 2. 5 km in length and the serrated ridges between them attain a rather uniform elevation of around 600 m. On the western side of the island, the upland

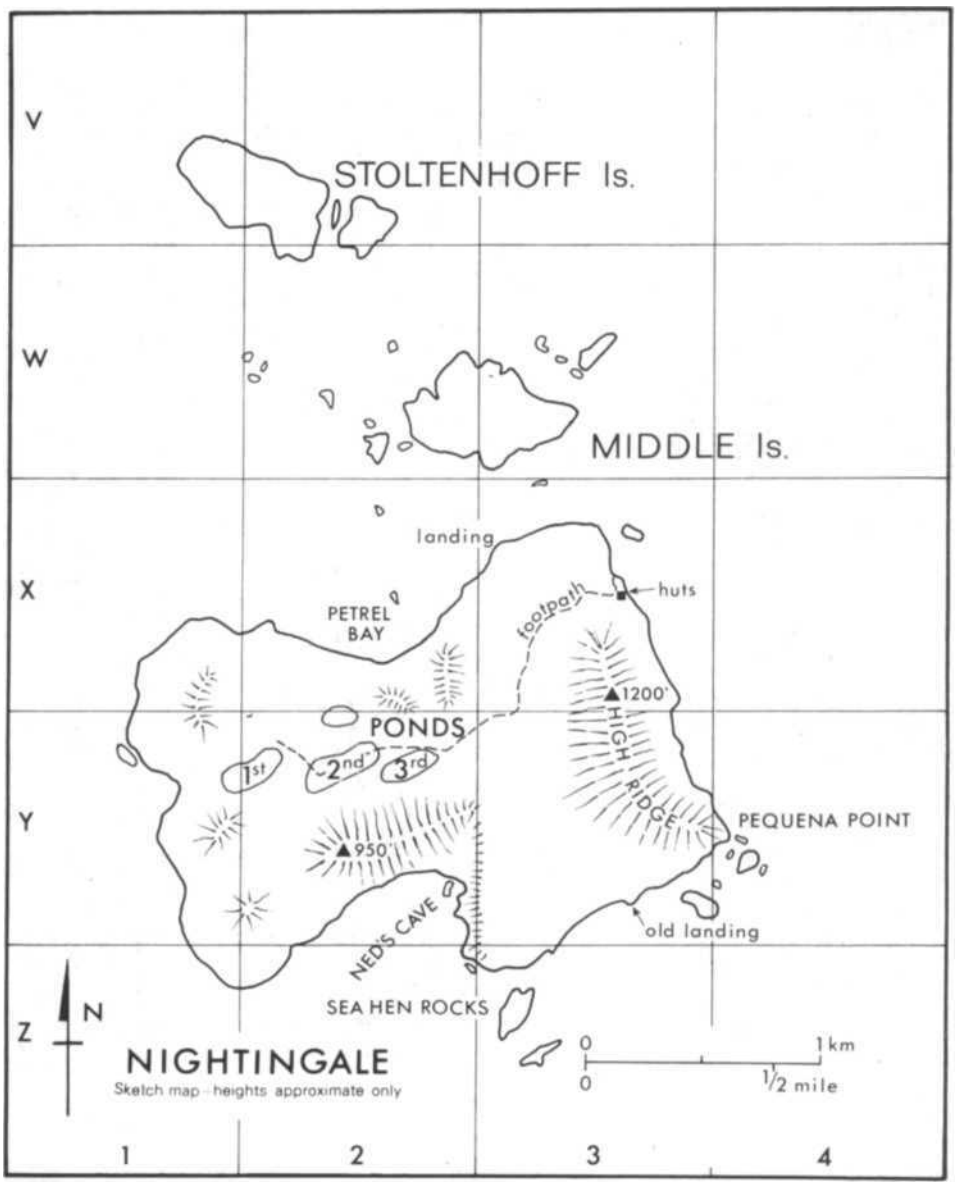

Figure 6.
Nightingale Island and its neighbours. Sketch map, including some detail from radar screen traces obtained by H.M.S. *Protector* in 1962.

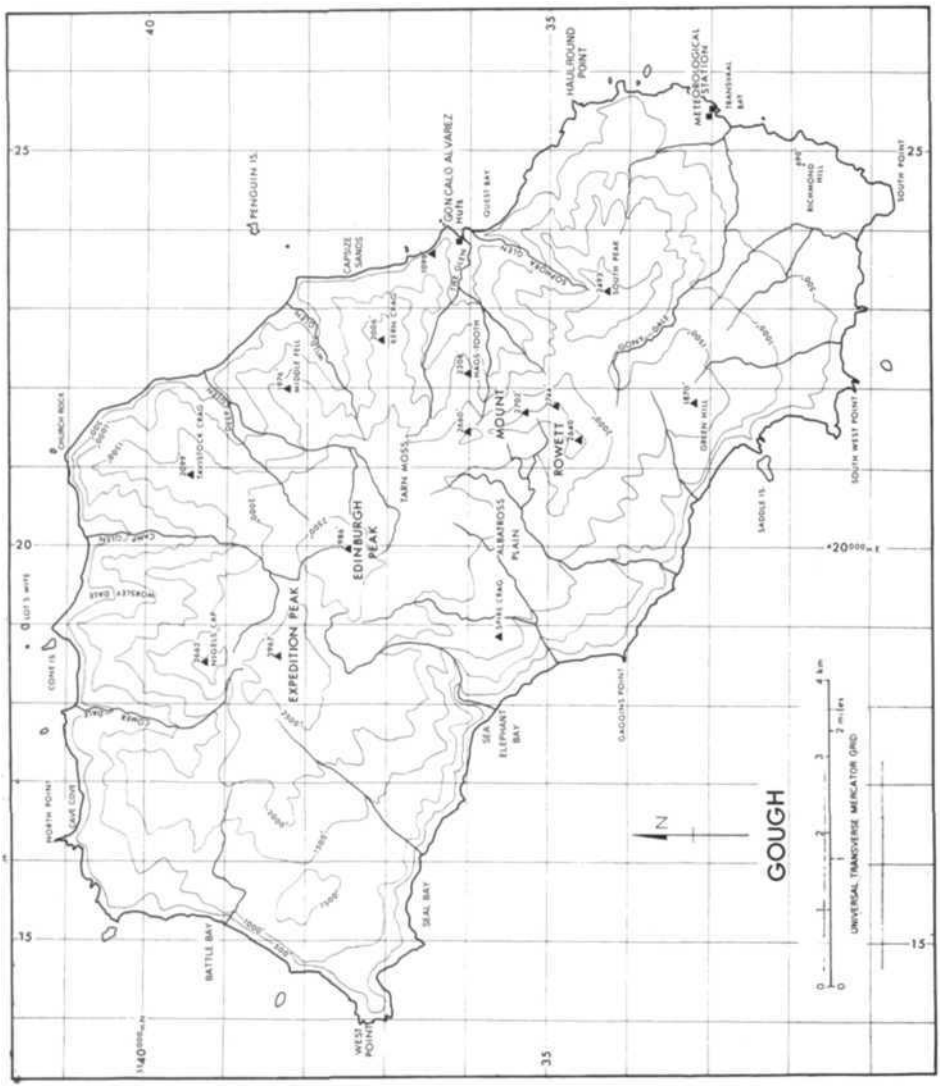

Figure 7.
Gough Island. Based on Survey by Gough Island Scientific Survey in 1955-56.

plateaux slope more gently to the tops of precipices which are here from 450 to 170 m high. Towards the south of the island there is an area of undulating, but thickly wooded, lowland much of which is drained by a meandering stream behind Transvaal Bay (Plate IX). The whole coastline is cliffed: of the numerous streams, only those draining The Glen (the largest of the deeply incised eastern valleys), its neighbour Sophora Glen, and that draining the southern slopes behind Transvaal Bay discharge their water at anything approaching present sea level. The other valleys are truncated by cliffs over which the streams draining them form picturesque cascades, or into which they have incised deep gullies. Access from the narrow boulder beaches to the interior of the island is possible at only a few places.

The eastern, deeply dissected portion of Gough Island is composed of basaltic lavas, up to 5 million years old. An initial phase of activity was probably followed by an explosive period, giving rise to thick tuffs, before trachyte lavas now forming much of the western side of the island were emitted. Later alternate basalt and trachyte phases built the higher plateaux and peaks, and Edinburgh Peak with its associated basalt flows and surrounding cumulodomes are probably youthful features (Le Maitre 1960). Other young secondary centres may be present in Gonydale and on the southern slopes. Ash bands in the peats on Albatross Plain probably result from local minor activity (possibly from the nearby crater of Edinburgh Peak). The most recent ash band in the Albatross Plain peats has been dated at 2345 (±120) years B.P. (Hafsten 1960a, 1960b).

3. 7 MAPS AND AIR PHOTOGRAPHS

Maps of Tristan, based on a 1937-38 ground survey (Crawford 1941) were printed by Christophersen and others in the Results of the Norwegian Scientific Expedition of 1937-38 (published 1946-68) and as part of the Admiralty Chart no. 1769. A more recent contoured map, based on 1961 air photography, was published in 1962 by the Directorate of Overseas Surveys (No. DOS (Misc.) 323). A stereo-pair of air photographs is reproduced in Baker *el al.* (1964).

Gough Island was surveyed in 1955-56 (Heaney 1957), and the resulting map published by the Royal Geographical Society, London (Heaney and Holdgate 1957), and subsequently incorporated into the South African Naval Chart no. 23. Air photographs covering most of the island, taken in 1961, are also available. The maps of Tristan and Gough included here (figures 4 and 7) are based on these sources, and therefore fairly accurate.

Inaccessible and Nightingale have not been accurately surveyed. Inaccessible was photographed from the air in 1961, but was largely obscured by cloud at the time. The maps of these islands (figures 5 and 6) include details from these air photographs, radar plots of the coastline from fishing vessels, and personal observations, but they are little better than plan sketches, and cannot be relied upon for scale or direction.

Discovery and Utilisation of the Islands

Brander (1940), Munch (1945) and McKay (1963) have published documented accounts of the history of the islands, and Wace (1969) has concentrated upon the events leading up to the British settlement of Tristan in 1816. Recent developments (since 1950) are outlined in successive Colonial and now Foreign and Commonwealth Office Reports on St. Helena.

4.1 DISCOVERERS (1505-1640)

The Tristan group was discovered by the Portuguese in 1506. Gough Island was discovered by Portuguese seamen, probably in 1505 (Wace 1969) and was originally named Gonçalo Alvarez, but the name was later corrupted to Diego Alvarez (probably through mis-reading of the abbreviation I. de Go. Alvarez). The Portuguese apparently showed little interest in the islands, and there are few known accounts of later Portuguese visits. All the islands were uninhabited when discovered and no clear evidence of any previous human visitors has ever been brought to light although Hafsten (1960a) postulates that some alien plants may have been introduced earlier than the first recorded discovery.

4. 2 RECONNAISSANCE BY EUROPEAN MARITIME POWERS (1640-1790)

The Dutch East India Company sent several expeditions to reconnoitre the Tristan Islands during the seventeenth century. The first known landing was on Tristan in 1643. Early visitors commented on the abundant marine life.

> 'they saw a number of Sea Lions, as large as Oxen, and abundance of Birds, as Penguins, and Sea Gulls which could be caught with the hand. There was likewise plenty of Sea Fish . .. but they did not see any animal'. (Dalrymple 1775).

This expedition recommended that the islands be explored for harbours or anchorages for the use of outward bound vessels from Europe to the East. Following the establishment of the Dutch colony at the Cape of Good Hope in 1652, Dutch expeditions were sent to the Tristan Islands in 1655, 1669 and 1696. The abundance of marine life was again noticed by several of the visitors: in 1690 a visitor off Tristan commented that:

> 'the sea was almost cover'd with Whales and Sea-wolfs which swam to the very Shoar of the isle playing with the water, and some of them ran against our Frigat'. (Oliver 1891).

However, no attempts were made at commercial exploitation of the wildlife, or the establishment of a strategic base or refreshment station. Human contact with the islands up to 1790 was limited to brief visits by passing vessels to obtain fresh water or other supplies. So far as is known, there were no attempts to settle ashore and there is no record of the introduction of any alien animals or plants, although goats and pigs were probably landed on Tristan before 1790.

4. 3 EXTRACTIVE COMMERCE AND THE FIRST SETTLEMENTS (1790-1830)

Sealing was the first activity in pursuit of which men lived ashore on the islands. American sealers were among the first to exploit furseals of the southern Atlantic and southern Indian Oceans (Roberts 1958, Stackpole 1953,

Kirker 1970, Wace and Lovett 1973) and their operations included plans for using the Tristan group as a sealing base where both pelts and oil could be collected and shipped to China and Mauritius or America (Wace 1969). In 1790, John Patton of the vessel INDUSTRY, probably from Philadelphia, spent nine months on Tristan, obtaining 5600 furseal pelts for the China market (Purdy 1816, Goode 1887, Allen 1899). Patton is also reported to have noted the abundance of sea elephants, from which much oil could be obtained.

The sealing gangs lived on the islands for considerable periods: a gang of ten men found by HMS NEREUS on Gough Island in 1811 had been there for eighteen months, taking fish, penguins and other seabirds and their eggs, and wild celery (and perhaps other herbs) as anti-scorbutics. Some of these gangs also cultivated potatoes to supplement their diet, and potatoes now growing wild on the north coast and in The Glen on Gough Island, and at Blenden Hall on Inaccessible were probably introduced by sealers. Mice (*Mus musculus*) which are now abundant on Gough Island were probably brought in by sealers also: they are now larger and darker in colour than wild British populations of this species, possibly as a result of evolutionary change over 150 years or so (Hill 1959).

The sealers clubbed and skinned the furseals, and salted the pelts for later collection by their company's vessels en route to the Northern Hemisphere markets in America, Europe and China. Elephant seals were also taken for blubber. Such a pattern of activity was typical of the period until about 1820, but fur sealing in the islands then declined due to the over-exploitation of stocks. Although furseals had been much reduced in numbers by this time, elephant sealing was still possible, but the islanders complained that visiting sealers shot more elephant seals than they could skin simply to deny the oil to the Tristan settlers (Gane 1933). There was a later resurgence of sealing in the islands between 1860 and 1890 (e.g. Verrill 1895), but a party who spent eighteen months on Gough Island in 1888-1890 took only 311 furseals and one elephant seal, and a second party there in 1891-1892 found that the seals were so reduced in numbers that the industry ended. It is not possible to make any estimate of the total numbers of seals taken from the islands during the course of these activities, although it is clear that the harvest was much less than the millions killed at South Georgia and the South Shetland Islands. However, ships' logbooks and other records reveal that furseals were taken from all the islands, and elephant seals from all except Nightingale.

This predominantly American sealing activity in the islands culminated in the first settlement, when Jonathan Lambert of Salem, Massachusetts, settled on Tristan in 1811. Feral goats and pigs were already established ashore before he landed (Tagart 1832) and he imported more pigs and some poultry. Lambert recorded that both pigs and men subsisted largely on the flesh of the elephant seals (Plate V), and that the Tristan rail (*Gallinula n. nesiotis*) was eaten also, proving 'very fat and delicate' (Im Thurn and Wharton 1925). Within a year he had some twelve acres on the northern coastal fringe enclosed, much of it under cultivation with potatoes, cabbage, maize, radish and pumpkin vines (Seaver, undated). Lambert intended to trade the produce of the islands with visiting ships but despite ambitious plans for its development as a sealing and victualling station, his settlement came to nothing when he was drowned in 1813, although a survivor of the venture continued to live on Tristan, growing vegetables and keeping some pigs. There were said to be 100 pigs around the huts in 1814, and potatoes, cabbages, carrots, turnips, radishes, onions and lettuce were grown (Theal 1902).

In 1816 the three northern islands were annexed by Britain and a garrison put

ashore on Tristan at the site of Lambert's settlement on the northern coastal strip. The garrison was withdrawn in 1817, but Corporal William Glass remained behind with his wife and family and two other men. The livestock at the time amounted to six horses, four cattle, fifteen sheep, about forty pigs and some ducks and turkeys, as well as the feral population of pigs and goats. Some castaways and other sailors joined the community and in 1825 five women were brought by a ship from St. Helena and paired off with the bachelors.

Although Inaccessible and Nightingale were visited by the islanders from Tristan and seals were taken from all the islands (including Gough) by sealers, no settlements were made on the smaller islands. The settlement on Tristan was confined to the northern coastal strip, and there are no records of cultivation or livestock elsewhere on Tristan before 1830, except for feral goats and pigs.

From these beginnings the human population grew by immigration and natural increase. Formal agreements made between the inhabitants in 1817 and 1821 show that they intended to trade the agricultural products of Tristan with visiting ships (Munch 1945), but ships were few during the first decade of settlement. A visitor stranded on Tristan in 1824 had to wait for eight months before he could get aboard a vessel to take him off the island (Earle 1832, McCormick 1966). Extractive commerce based on seals was by then already beginning to give way to trading as the islanders' main support. But trading was dependent upon a market for island-grown supplies. Ships voyaging to Australia and the Orient from Europe and North America, and American whalers operating in the surrounding waters soon began to provide such a market.

4. 4 DEEP SEA WHALING AND THE GROWTH OF A TRADING COMMUNITY (1830-1870)

American deep sea whalers were spreading into the South Atlantic soon after the Revolution, but it was not until the 1830s that Yankee whalers began to visit Tristan in numbers. The island was conveniently situated for vessels sailing eastwards on the fringe of the westerly wind belt in the summer right- and sperm-whaling grounds (Townsend 1935, Wace 1969). Tristan soon became an important provisioning station for whalers voyaging to the Indian and Pacific Oceans (Wace and Lovett 1973) while China traders, East Indiamen and other traders, and trading and emigrant ships bound for Australia also began to call. Some idea of the numbers of vessels involved in this trade can be obtained from logbooks and other manuscript material. The New Bedford whaleship EMERALD, whaling on the Tristan ground in 1830-31, sighted other vessels on fifty out of 100 days—up to eight sail being in sight at any one time (Norton 1830). She called at Tristan for supplies, but found that

> 'the hes ben So menny Ships here that they Stard all thare potatoes'.

Similarly, the brig HENRY, bound from England to Australia, called at Tristan in February 1836, but found that no beef or mutton was available, the island having recently supplied two vessels voyaging to India (Whiting 1836).

Potatoes were the staple of the community, but logbooks and trading records show that the following were also grown on Tristan between 1830 and 1870:

cabbages	strawberries
onions	apples
turnips	pears
carrots	peaches.

Plate III Tristan da Cunha, the potato patches and coastal strip from about 300 m on the precipices to the south-west, April 1968. Pastures and tillage on the young alluvial soils of this part of the coastal strip are the principal agricultural resource of the islanders (Photograph, N.M.W.).

Plate IV Tristan da Cunha, 1824, settler about to kill wandering albatross, which then nested on the upper part of The Base. (Water-colour by Augustus Earle,now in the Rex Nan Kivell Collection (NK 12/15) National Library of Australia, Canberra. Reproduced by permission of the National Librarian).

Livestock was also traded, notably pigs, cattle, sheep and geese, as well as eggs, butter and cheese. In 1837 there were 100 head of cattle, 100 sheep, fifty pigs, numerous poultry, potatoes, apples, strawberries, onions, cabbages and other vegetables on Tristan (Mort 1837). By 1842 nearly 150 acres on the Settlement Plain had been cleared and there were then ten families on the island, totalling seventy-three people. The annual yield of potatoes was said to average ten tons per family and of the 100 tons thus raised, some seventy tons were sold, bringing in annual income of about £600 to the island (Brierly 1842).

In the fifty years between 1825 and 1875 the whole economy of the islanders thus became geared to supplying visiting ships. Many islanders joined whaling crews, and seamen settled on Tristan, marrying island girls. There was a considerable movement of people, especially between Tristan and New England so that different estimates of population size on the island in any one year vary considerably. This trading economy had a great impact on the native biota of Tristan and it is likely that the main influx of alien plants can be dated to this period. But its effects were probably very small away from the coastal strips, since almost all the products traded were domesticated species kept near the Settlement.

By 1856 the islanders' stock amounted to more than 200 head of cattle, 300 sheep, 100 pigs and 500 poultry, all kept on the Settlement Plain. Already there was concern about the declining fertility of the soil, and apprehension because of the reliance of the islanders on trading with passing vessels: 'should anything occur to tempt the American whale-ships—upon which they are dependent for flour and clothes, and their communication with the rest of the world—to more promising fields of speculation (which has already been to some extent the case), they might be reduced to great extremities' (Gray 1856).

The islanders and seamen from whaleships continued to visit the smaller islands (as well as the remoter shores of Tristan itself) for water and to take penguins and seals and to collect potatoes from the sealers' plantings. Whaleships frequently sent boats to fish inshore and one account of a landing on Inaccessible in 1870 remarks that a goat was killed (Davis 1870). There are records of casual predation on seals by visitors to all the islands at least until 1880. A logbook record for 1857 even records landing a goat on Tristan (Slocum 1857) but it is not known if such animals were landed on the other islands. Other introductions may have been made to the islands during this period, but no alien vertebrates other than those listed (Table **III,** p. 42) seem to have established themselves as a result of these activities.

4. 5 SUBSISTENCE CROFTING (1870-1950)

From around 1870, the numbers of vessels visiting Tristan began to decline sharply. The increasing replacement of whaling products by mineral oils, and the destruction of the American whaling fleet during and after the Civil War, together with the replacement of sail by steamships and the opening of the Suez Canal (1869) all had the effect of removing vessels from Tristan waters and thus taking away the market for her agricultural produce. The islanders therefore became increasingly isolated from the outside world. From a prosperous farming and trading community, they were forced to revert to subsistence crofting, supplemented by fishing and by hunting the native and feral animals.

Potatoes continued to be their main support, but agriculture declined. Fewer types of domesticated plants were grown, and livestock which grazed the com-

mon pastures of the Settlement Plain increased their numbers beyond the carrying capacity of the swards. Beetham (1968: personal communication to N. M. W.) recalls that cattle, sheep, goats, donkeys and chickens were all kept on Tristan in about 1885. In the winter of 1906-07, some 400 cattle out of a total herd of about 700 died of starvation (Barrow 1910). Figure 8 gives estimates of the numbers of domestic animals kept on Tristan at various times. Most of these were kept on the Settlement Plain until about 1900 when small herds of cattle were established on the other coastal strips at Stony Hill and Cave Point on the south side of the island.

Fish remained an important part of the islanders' diet, but were not exported. Visiting whalers and other vessels often fished in local waters, but there were no facilities for the islanders to transport such perishable materials to distant markets. A commercial farming and fishing venture started with outside capital in 1907 was not a success, largely because of the lack of a harbour (Barrow 1910).

In Lambert's time, Tristan itself abounded with seabirds and seals, and there was no need for the settlers to crop the wildlife on the smaller islands. Seabirds were still abundant on Tristan before the introduction of the rats (1882); wandering albatross were collected on the Peak in the 1880s, when fires were lit at the Settlement to attract nocturnal seabirds nesting on the island, whose eggs formed an important food for the islanders (Beetham, 1968: personal communication). But by the late nineteenth century the wildlife of Tristan was becoming depleted, especially near the Settlement. It is likely that regular seasonal visits of the islanders to Nightingale and Inaccessible started around 1870, especially to obtain fat and eggs from the seabirds and pelts and blubber from the few remaining seals. Beetham also recalls that pigs (which were not then present on Tristan) were hunted on Inaccessible Island. As the resources of Tristan diminished, the opportunities for trade also declined, and the islanders increased their pressure on the wildlife of the smaller islands—although Gough was beyond the range of their longboats. Inaccessible was visited more frequently than Nightingale in 1923-25 (Rogers 1926), but this situation was reversed by the late 1930s.

Two German brothers settled on Inaccessible Island in 1871, staying for two years and living off feral pigs and goats and taking seals, penguins and other seabirds. They cleared some land at Salt Beach and accidently fired the tussock grass on the cliffs (Stoltenhoff 1877), but seem to have had little permanent effect on the biota. There were no attempts by Tristan Islanders or outsiders to settle on the other islands. Some sealing and trading ventures were mounted from Cape Town: at least ten voyages were made by the schooner THEMIS between 1871 and 1881, in the course of which she traded with the Tristan islanders, carried some of them to Inaccessible Island (Stoltenhoff 1877), and took guano, penguin eggs and sealskins from Gough Island (Cape Argus 1881). Such visits, and the short periods of residence by sealers there from 1888-90 and 1891-92, and of diamond prospectors who spent a few abortive months panning the gravels in The Glen in 1919 (Holdgate 1958) probably had only minor and local effects on the biota. No parties of outsiders are known to have lived ashore on Nightingale Island during this period, although sealers may have done so.

From 1851-57 the first missionary lived on Tristan (Taylor 1856) and others were appointed intermittently thereafter. An important part of the missionaries' work became the distribution of food and other supplies collected by charitable organisations in England. As the islands became more isolated, with the almost total disappearance of sailing vessels, these supplies assumed a

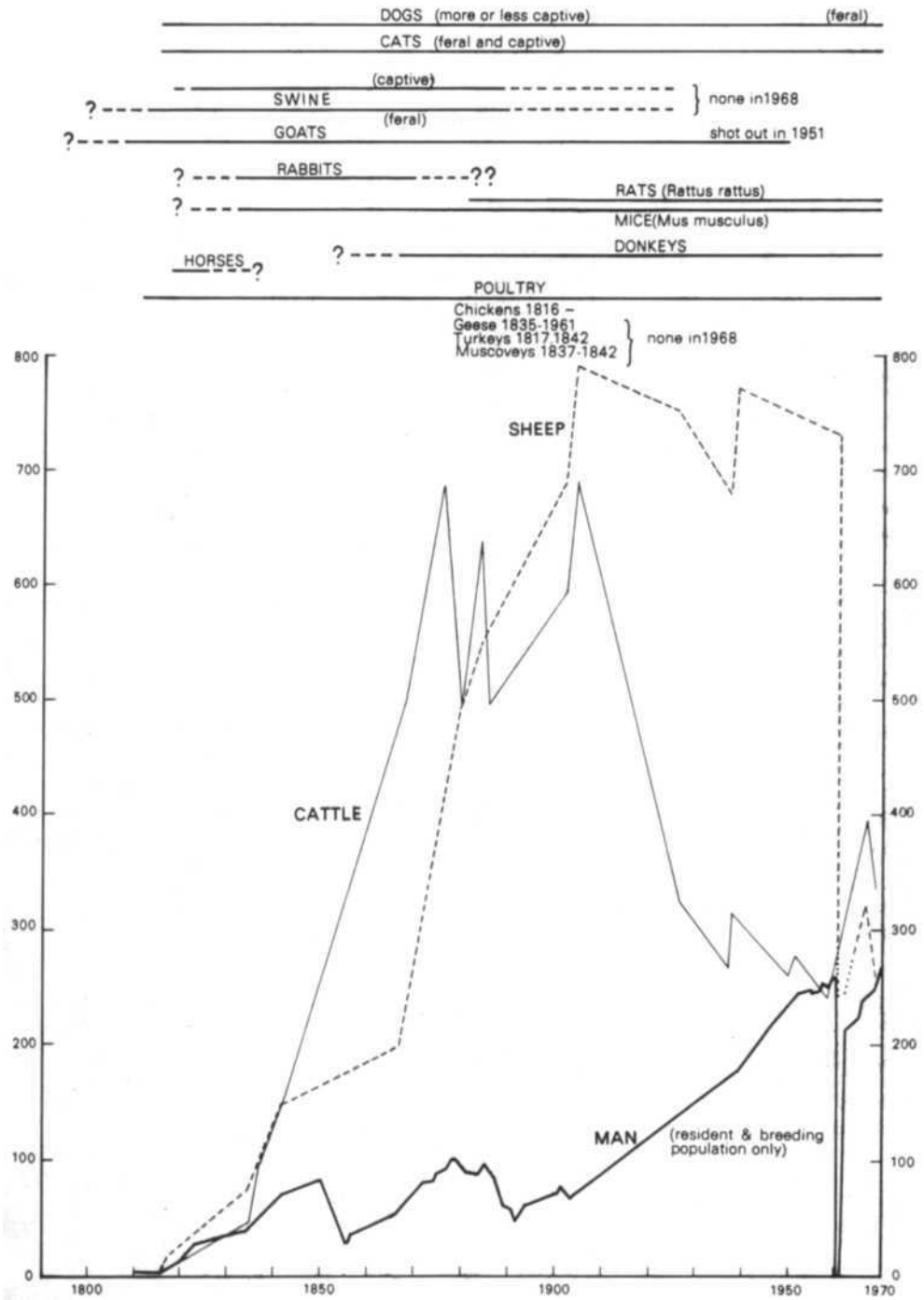

Figure 8.
Introduced vertebrate animals on Tristan da Cunha from 1800 to 1970. Only goats (and possibly pigs) were introduced and feral before 1800. Data from various ms. and printed sources.

greater importance to the islanders, and evacuation was discussed. After the loss at sea of a longboat with fifteen men in 1885, and the establishment of rats ashore following a shipwreck in 1882, many islanders left for New England and South Africa. By 1892 the population was down to fifty but from that date it grew steadily, although the opportunities for trade continued to decline. Between 1911 and 1927, less than a dozen vessels visited Tristan each year, and in several years there were no recorded visits (Munch 1945).

The subsistence economy of the islanders, supplemented by charity, persisted until 1948. Missionaries were sent to Tristan more or less continuously from 1922 and, under their guidance, some attempts were made to improve the economic conditions by importing new seed and livestock etc. Attempts were made to establish a farm at Salt Beach on the north coast of Inaccessible Island in 1937-38, but the venture failed.

The activities of the islanders and the scale of their predation on seabirds towards the end of the period of subsistence crofting, is described in various papers resulting from the Norwegian Scientific Expedition to Tristan of 1937-38 (see especially Christopherson 1940, Munch 1945, Henriksen and Oeding 1940,Hagen 1952).

4. 6 COMMERCIAL FISHERY AND OUTSIDE ADMINISTRATION (1950-1961)

In 1942 a small naval garrison was put on Tristan and an administration set up, with more or less regular radio and ship communications linking the islands to Cape Town. The naval station, housed in a system of interconnected wooden huts, was by far the largest building complex built on Tristan up to that time. It included a canteen and recreation hut (with dance hall). A medical officer established a clinic. The impact of all these developments on the life of the island was considerable. Islanders were employed by the garrison and were able to purchase imported goods in the naval canteen. These increased links with the outside world continued in 1949 with the appointment of an Administrator and the establishment of commercial crayfishing in Tristan waters by a South African company (inspired by a former naval chaplain on Tristan who had noted the abundance of crayfish around the islands). Islanders were employed, along with ship's crew from the Cape, as fishermen, and a canning factory was built in 1950 near the Settlement employing island men and women ashore.

This re-establishment of extractive commerce in the island waters led to more frequent ship visits to Tristan, and eventually tended to reduce the number of landings on smaller islands. Payment of the islanders enabled them to buy imported food in the canteen and thus relieved the pressure on the terrestrial biota. But, despite protective regulations, some penguins were taken for crayfish bait, some furseals taken from the coasts, and fires started in the coastal vegetation by fisherman. After 1955 the fishing company built or took over huts for the storage of fuel, boxwood etc. on Inaccessible and Gough Islands. Overall, however, the human impact on the small islands has remained negligible, especially away from the coasts.

With the appointment of an outside Administration, efforts were made to improve the agriculture of the islanders by importing better livestock and fencing the pastures on the Settlement Plain. Pines, willows, populars, wattles, eucalypts, apples and some other trees were planted at Sandy Point, and attempts made to establish a market garden there. Sheep were released on the lower slopes of the Peak before 1950, but were never numerous enough to produce

a heavy grazing pressure. Herds of semi-wild cattle remained at Stonybeach and at Cave Point on the south coast of Tristan. Apart from the sheep on the Peak, continued predation by the islanders on albatrosses and other breeding seabirds, and regular 'wooding' parties to cut fuel, there was little human impact above the narrow coastal strips. On Inaccessible and Nightingale Islands no attempts were made to cultivate land, and the few cattle at Salt Beach, Inaccessible, surviving from the attempts to establish a farm there in 1937-38, were slaughtered or removed in the 1950s, as were the sheep on the plateau there. The regular annual visits of the islanders to Nightingale for petrels, penguin eggs and feathers, guano (see 5. 4. 5) and beachcombing made the only persistent human impact on the smaller islands near Tristan. The establishment of an expedition base and weather station on Gough Island in 1955 led to the erection of huts at the bottom of the Glen (Heaney and Holdgate 1957, Holdgate 1958), and the cultivation of a few small plots for vegetables nearby. A small number of sheep were grazed at The Glen and above Capsize Sands in 1956-58, but all were destroyed at the end of this period. An enlarged weather station was established in 1958 at the top of the cliffs in Transvaal Bay, and the huts in The Glen were used thereafter by the fishing company, who also built a pipe from higher up The Glen stream terminating near the Huts for the supply of fresh water to vessels offshore. Some cultivation of vegetable plots was begun near the new weather station, but apart from poultry no livestock or any other domestic animals have been allowed ashore on Gough Island, and the weather station personnel have relied on imported supplies.

4. 7 EVACUATION, RETURN AND THE PRESENT ECONOMY (1961-1972)

The volcanic eruption of 1961 near the Tristan Settlement which drove the islanders away had little permanent direct effect on the island biota (Dickson 1965). The effect of temporary human de-control of domestic animals has been described by Baird (1965). Dogs, abandoned to a feral existence, exterminated the geese and very greatly reduced the numbers of sheep. Nesting albatross on the Base were probably reduced also, and the successful rearing of calves and donkey foals on the Settlement Plain was prevented by the marauding dogs. The temporary ending of direct human predation on seabirds and seals may have been of some importance, but apart from reports that some furseals returned to form a breeding colony at Cave Point on Tristan during the evacuation period, no data comparing the numbers or the range of species before and after the evacuation are available. Almost the entire human population returned to Tristan in November 1963, two years after the evacuation, although an advance party of islanders had returned in September 1962, so that the island was without a resident human population for only about eleven months. The island community that re-established itself after the eruption in 1963 has evolved in steady and relatively smooth progression from the pre-eruption situation. The commercial exploitation of crayfish has remained the staple industry, and a new freezing plant was built to replace the cannery destroyed by the new lava. A small boat harbour, with two curving, converging arms built of boulders contained within coarse wire gabions, has been built close to the Settlement to which it is linked by a new road. The road and trackway network has been extended and the stock of tractors, cranes, generating plant and powered equipment greatly expanded. Motor boats with glass fibre hulls have come into use for shore-based fishing. The fishing Company and Administration have become more specialised employers, with pools of permanent labour and higher wage levels. Housing and public amenity standards have improved and there has been a steady improve-

ment in agriculture. The islands are now economically self-supporting, although receiving grants in aid for capital development from the British Foreign and Commonwealth Office (St. Helena Reports, 1952 onwards).

Revenue is derived almost entirely from the sale of postage stamps and the crayfish industry. These activities and the inter-relationship between the modern community and the wildlife of the islands are considered later (6. 2. 2.).

4. 8 HUMAN POPULATION GROWTH

Initial growth of the human population, up to 1850, was rapid—reflecting the economic prosperity resulting from maritime trading. Subsequent fluctuations from 1850 to 1890 were the result of emigration, and the loss of a boat and crew, referred to below, but numbers grew steadily from about 1890 until the evacuation of 1961 at which time there was a peak population of 278 islanders and some thirty outsiders. Since the return of most of the islanders in 1963, the population has again grown to some 250 islanders with about thirty outsiders (Fig. 9). Emigration of a few families to Britain has been compensated for by the return of others, and the natural increase of the Tristan population.

Birdsell (1957), basing his analyses on the population figures of Munch (1945), pointed out that the intrinsic rate of increase of the Tristan population appeared to be more or less logistic during three discrete periods between the first permanent settlement of the island in 1816, and 1938. These three periods are separated by the two major emigrations, following the death of Corporal Glass in 1857, and the arrival of rats and the loss of a longboat with a high proportion of the most able-bodied men aboard (1882 and 1885 respectively). Birdsell considered that during these three periods, the Tristan population appeared to double its numbers during one generation (which he took to be twenty-two to twenty-five years), and that Tristan was similar in this respect to the comparable hybrid immigrant populations on Pitcairn Island and the Furneaux Group (Bass Strait), which were similarly isolated and in economically simple situations involving only hunting and gathering, together with subsistence agriculture.

The figures on which Birdsell's analyses for Tristan were based are few, and subject to considerable uncertainty regarding supposedly intrinsic rates of increase of an isolated population. This uncertainty is especially true for the period 1830-1890, when emigration and the movement of people between Tristan and North America, and the temporary absence of island men working aboard whaleships were important factors influencing the numbers of people on the island at any one time. Some family sizes were certainly very large during this period.

MacGillivray in his journal of 1852 remarked:

> '...the Swains too, with their 15 children, are no less determined anti-Malthusians than the Glasses' (who had 16 children)

The only period during which Tristan might be said to be a closed system depending almost entirely on its own resources, and with little or no external trade or movement of people to or from the island, is the period of subsistence crofting which followed the emigrations of the 1880s and until the establishment of a British naval base during the Second World War. During this period, the Tristan population grew from fifty-nine in 1893 (Bull 1896) to 188 in 1938 (Munch 1945): its overall rate of increase was therefore 2.6 per cent per year, and its doubling time some twenty-six years. Figures for total popula-

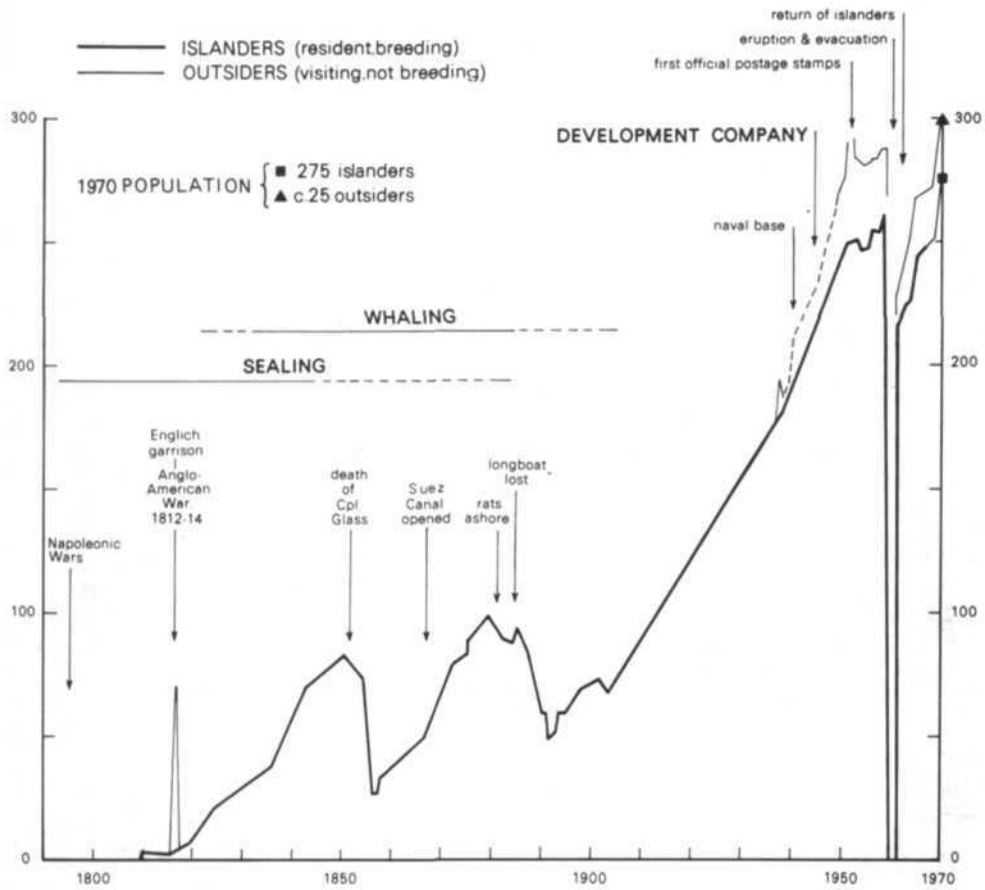

Figure 9.
Numbers of people resident on Tristan da Cunha with some important historical events. Data on population size from various sources, but using Colonial/ Commonwealth Office Reports since 1952.

tion sizes on Tristan during the period between 1890 and 1938 give growth rates approximately the same as those quoted above covering the whole period, although suggesting a slowing down in the rate of population increase in the 1930s. Unfortunately, few data are available upon which to base a more thorough demographic analysis of the population during this period of rapid growth.

Between 1951 (when commercial crayfishing was firmly established as the economic base of the islanders' life) and 1961 (when the volcanic eruption on Tristan forced the temporary evacuation of the inhabitants) the permanent resident population grew from 242 to 264. This represents a rate of increase of only 0. 87 per cent per year, and a doubling time of some eighty years. The period since the return of the islanders in 1963 until the present seems to provide rates of increase similar to those obtaining between 1951 and the evacuation to Britain in 1961, but intrinsic reproduction rates for this period are confused by the movement of islanders to and from Britain and South Africa. Birth control has been practised on an increasing scale and using

TABLE I. SYNOPSIS OF BIOLOGICAL COLLECTING IN THE TRISTAN DA CUNHA-GOUGH ISLAND GROUP (EXCLUDING MARINE FAUNA), WITH REFERENCES TO RESULTING PUBLICATIONS, MANUSCRIPTS, OR UNWORKED COLLECTIONS.

Number	*Date*	*Occasion:* Collectors	*Islands Studied* T	I	N	G	*Organisms Studied*	*Resulting Publications or Manuscript Accounts*
1	Jan 1793	FRENCH VOYAGE: Aubert Dupetit Thouars	+				vascular plants, cryptogams	Dupetit Thouars 1811, Mitten 1875
2	Nov-May 1816-17	BRITISH GARRISON: D. Carmichael	+				vascular plants, birds	Carmichael 1819
		D.Carmichael	+				Mollusca, Diptera, Lepidoptera	Gray 1824, Walker 1849, 1857-62
3	Nov 1852	HMS HERALD: J. MacGillivray &H.G.Milne	+				vascular plants	MacGillivray 1852
4	Mar 1842	RYS WANDERER: B. Boyd	+				birds	Brierly 1842,Sclater 1861, Beintema 1972
5	Oct 1873	HMS CHALLENGER: H. N. Moseley	+	+	+		vascular plants, cryptogams	Moseley 1875, 1892; Hemsley 1885; Dickie 1874
		H. N. Moseley	+	+	+		birds	Moseley 1879, Sclater 1861, 1878, Beintema 1972
		H. N. Moseley	+	+	+		Coleoptera	Waterhouse 1884
		H. N. Moseley	+	+	+		Myriapoda	Pocock 1893
6	1888-89	SEALING EXPEDITION: G. Comer				+	birds	Allen 1892,Verrill 1895
7	Apl. 1904	S.Y.SCOTIA: R.N.Rudmose Brown				+	vascular plants	Rudmose Brown 1905, 1912
		R.N. Rudmose Brown				+	cryptogams	Rudmose Brown 1905, 1912
8	1907-09	FISHING VENTURE: P.C.Keytel					vascular plants	Philips 1913
			+				birds	Mathews 1932: Beintema 1972
9	June 1922	RYS QUEST: G.H.Wilkins	+			+	vascular plants, cryptogams	Wilkins 1925
		G.H.Wilkins	+	+		+	birds	Lowe 1923; Beintema 1972
		G.H.Wilkins	+	+			Lepidoptera	Viette 1952
10	1922-26	TRISTAN RESIDENTS: H. M.Rogers and D. Glass	+	+	+		vascular plants	Rogers 1926
			+	+	+		birds	Lowe 1928, Mathews 1932
11	June 1927	WILLIAM SCORESBY: E.R.Gunther				+	vascular plants	Gunther 1928
12	1928	TRISTAN RESIDENT: P. Lindsay	+	+	+		birds	Rothschild 1928; Rand 1955
13	Feb 1933	WHALER: THORSHAVN: L. Christensen				+	vascular plants, cryptogams	Christophersen 1934, Christensea 1935
14	Nov 1934	WHALER: THORSHAMMER: E.Siggeson	+				vascular plants, cryptogams	Christophersen 1937
15	Mar 1937	H.M.S.CARLISLE: R. A. Dyer	+				vascular plants, cryptogams	Dyer 1939
16	Dec-Mar 1937-38	NORWEGIAN SCIENTIFIC EXPEDITION E. Christophensen	+	+	+		flowering plants	Christophersen 1939, 1940, 1944, 1968; Hooper 1968
			+	+	+		pteridophytes	Christensen 1940
			+	+	+		bryophytes	Dixon 1960, Arnell 1958
			+	+	+		non-vascular cryptogams	Christophersen, E. (Editor) 1940-1968; many papers listed and taxa reviewed, Wace & Dickson 1965

		E. Baardseth	+	+	+		seaweeds	Baardseth 1946
			+			+	rodents	Hill 1959
		E. Sivertsen	+	+	+		fish	Sivertsen 1945
		Y. Hagen	+	+	+		birds	Hagen 1952
			+	+	+		invertebrates	Christophersen, E. (Editor) 1940-1968: many papers listed and taxa reviewed, Holdgate 1965
17	1946	J. Kirby	+	+	+		birds	Roberts 1948
18	1947	Rev. M. Handley	+				birds	Broekhuysen & Macnae 1949
19	1948-49	FISHING COMPANY: M. K. Rowan	+	+	+	+	birds and fish	Rowan 1951, 1952, 1965, Broekhuysen & Macnae 1949
20	1950-51	AGRICULTURAL OFFICER: R. Upton	+	+	+		birds	Ripley 1954, Rand 1955
21	1950-52	ADMINISTRATOR: H. F. I. Elliott	+	+	+		birds, invertebrates	Elliott, 1953, 1957, Rand 1955 (Invertebrates listed at Commonwealth Institute of Entomology, London)
22	1953-63	AGRICULTURAL OFFICER: H.G.Stableford	+	+	+		vascular plants, invertebrates	(plant collections at Kew)
23	Oct-May 1955-56	GOUGH ISLAND SCIENTIFIC SURVEY N.M.Wace	+			+	vascular plants, bryophytes and cryptogams	Wace & Holdgate 1958, Wace 1961, Hafsten 1960, Manton & Vida 1968
		N.M.Wace				+	seaweeds	Chamberlain 1965, Chamberlain, Holdgate & Wace (in preparation)
		M.W.Holdgate				+	invertebrates	Holdgate 1960, 1961
		M.K.Swales				+	birds	Wilson & Swales 1958, Swales 1965
24	1956-58	S.AFRICAN WEATHER STATION: J. J. van der Merve				+	vascular plants, birds	Paclt 1959
25	Feb 1961	H.M.S. OWEN: R. McKinnon				+	vascular plants, bryophytes	(collections at Kew, London)
26	Jan-Mar 1962	ROYAL SOCIETY EXPEDITION: J. Dickson	+	+	+		land plants	Dickson 1965, Wace & Dickson 1965
		D.E. Baird	+	+	+		land-breeding animals	Baird 1965, Holdgate 1965
27	1966	H.M.S. PROTECTOR: J.Dickson	+	+	+		vascular plants, bryophytes	Manton & Vida 1968, Dickson 1967
28	1966	TRISTAN SCHOOL TEACHER: J.Flint	+	+	+		birds	Flint 1967
29	1966	RODENT CONTROL: E.Taylor	+				rodents	
30	Feb-June 1968	CONSERVATION SURVEY: N.M.Wace	+	+	+	+	vascular plants	(plant collections at DSIR Botany) Division, Christchurch, New Zealand) Wace 1968
		M.W.Holdgate	+			+	invertebrates	
	May 1968	C.C.H.Elliott				+	birds	Elliott 1969, 1970a, b

increasingly effective contraceptive methods since the mid-1950s and has undoubtedly been the major cause of the diminished rate of population increase.

From these meagre data, it appears that the replacement of subsistence by a commercial economy, together with improved education and greater material expectations brought about by increased contact with the outside world, has had a marked effect in depressing the intrinsic growth rate of the Tristan population. Although a thorough demographic analysis of all the data may alter these figures somewhat, it is clear that a major change took place in the growth characteristics of the island population with the introduction of new ideas, imported foods and other goods which had hitherto been almost inaccessible to the islanders. On current trends, and with the maintenance of today's medical services and levels of nutrition (and assuming no emigration, or lowering of fertility or other checks on reproduction due to the effects of continued inbreeding), the Tristan population may be expected to double its present size in about eighty years. It thus compares to rates of increase of developed countries such as the USA, USSR and France (Ehrlich and Ehrlich 1970) which have passed their 'demographic transition' into a state of slowly increasing population levels.

Nightingale and Inaccessible Islands remain uninhabited and about eight men (but no women) live in the meteorological station on Gough Island.

4. 9 SCIENTIFIC INTEREST AND INVESTIGATION OF THE ISLANDS

Scientific interest in the islands began in 1700 with the visit of the astronomer Edmund Halley (Dalrymple 1775) and with subsequent attempts to fix the positions of the different islands (Wace 1969).

The first scientific descriptions and collections of plant and animal life were made on Tristan in 1793 (Dupetit Thouars 1811) and 1816 (Carmicnael 1819). No systematic descriptions or collections were made on Nightingale or Inaccessible until 1873 (Moseley 1875, 1892; Hemsley 1885). Shore-based expeditions worked in the Tristan Group in 1937-38 (Christophersen *et al.* 1940), in 1955 (Wace and Holdgate 1958), and in 1962 (Baker *et al.* 1964), Baird *et al.* 1965). Shore-based scientific work on Gough Island did not start until 1955-56 (Heaney and Holdgate 1957). Geological and geomorphological knowledge of the Tristan Group up to the time of the 1961 eruption is summarized by Baker *et al.* (1964), with later papers on geochronology by Gass (1967), while LeMaitre (1960) summarized geological knowledge of Gough Island. Biological work (excluding medicine) on all the islands up to 1963 is summarised by Wace and Dickson (1965) and by Holdgate (1965). Table 1 is a chronological summary of all scientific work involving studies on vascular plants and land breeding vertebrates (other than man), up to the time of the Authors' visits of 1968.

Medical and sociological studies of the Tristan islanders were initiated by members of the Norwegian Expedition of 1937-38 (Henriksen & Oeding 1940, Munch 1945). Such scientific interest in the islanders greatly increased as a result of their evacuation to Britain in 1961: medical studies of the islanders (both in Britain and after their return to Tristan) were reported by Lewis 1963 & 1969, by Lewis *et al.* (1963), and in many specialist papers; and sociological work by Munch (1970, 1971).

Some climatic records have been kept on Tristan since 1942, and five years of these data have been published (Pretoria Weather Bureau 1949). A weather

station has been maintained on Gough Island since 1955, and much fuller data than for Tristan are available for Gough Island for the period 1955-60 (Pretoria Weather Bureau 1961). These data are summarised in Figure 3, p. 16, and include climatic summaries published anonymously by the Meteorological Office of Great Britain (1967) and the US Department of Commerce (1959 and 1968).

Native and Alien Biota of the Tristan Islands

5.1 Apart from the presence of some subantarctic plants and their associated vegetation types on Gough Island which are lacking in the Tristan Group, and detailed differences in the numbers and ranges of endemic species, the native land floras and faunas of all four islands are very similar to one another. Their marine floras and faunas differ more markedly—probably because of a much more pronounced subantarctic influence at Gough Island, which lies south of the mean position of the subtropical convergence. The greatest biotic differences between the islands are due to the differential effects of man.

The general state of the native and alien biota in each island is considered separately below. The numbers of species recorded from the different islands are summarized in Table II, and the birds and mammals in Table III. Figure 10 compares the vertical zonation of the vegetation on the four islands.

5. 2 Tristan da Cunha

5. 2. 1 Vegetation. Tristan supports five native vegetation types which are clearly zoned according to altitude and topography (Fig. 10). Some of the coastal strips, especially where penguins and seals breed, originally had a thick cover of tall tussock grass (*Spartina arundinacea*), but most of the lower ground and some of the cliffs and the Base below about 600 m altitude were covered with thickets of the island tree (*Phylica arborea*) growing amongst a dense mass of various ferns. All the extensive stands of tussock and most of the fern bush have now been cleared to make pasturage for cattle on the coastal strips, and much of the cliffs (especially near the Settlement) has been denuded of *Phylica* by cutting and firing. Although individual plants of *Spartina* are abundant on the Base up to an altitude of about 900 m, there are probably no extensive tussock-dominated communities left on Tristan. Dense undisturbed fern bush, with few or no alien plants, still occurs on the Base above Sandy Point, in the southern half of the island and in most of the gulches.

The dwarf tree-fern *Blechnum palmiforme* dominates an altitudinal belt between 600 m and 750 m but also extends well down into the fern bush in many places. Having no value as fuel or fodder, or for constructional purposes, it has been less affected by man or by his animals than the tussock or *Phylica*-dominated communities. Above an altitude of 750 m to about 900 m, around the bottom of the Peak, the tree ferns are replaced by mats of *Blechnum penna-marina* and the alien species *Rumex acetosella* and *Holcus lanatus.* The native plant cover of this zone probably consisted of small scattered tussock-forming grasses (*Agrostis* spp. and *Deschampsia* spp.) which have not withstood the grazing of alien herbivores (Moore 1954). Above an altitude of 900 to 1000 m, this alien-dominated community is replaced by extensive mats of *Empetrum rubrum* and *Rhacomitrium lannginosum,* growing with scattered sedges and *Acaena stangii.* Vegetation is very sparse above about 1500 m on the loose cinders of the Peak, but patches of *Empetrum* and bryophytes grow in the main crater at some 2000 m altitude. There are no higher plants in the shallow crater lake, which is frozen over in winter.

5. 2. 2 Native and Alien Flora. Some forty species of flowering plants and thirty species of pteridophytes are native to Tristan (Table II). So far as is known, no native vascular plants have become extinct on Tristan since botanical study started, except perhaps *Atriplex plebeia* on the shores. It is now

TABLE II. NUMBERS OF SPECIES OF TERRESTRIAL VASCULAR PLANTS AND VERTEBRATE ANIMALS RECORDED IN THE TRISTAN DA CUNHA-GOUGH ISLAND GROUP UP TO 1968

Numbers include only those species known to breed ashore. Some species formerly present, but not now found in the various islands are bracketed.

	Tristan	*Inaccessible*	*Nightingale*	*Gough*	*Whole Group*
PLANTS					
Native: Pteridophytes	30	27	15	27	33
Angiosperms	39 (+1)	26	18 (+1)	35	45 (+1)
Naturalized: Angiosperms	c.97	20 (+3)	5 (+1?)	11 (+3)	c.100
ANIMALS					
Native: Seabirds	c.13 (+2)	16	14	21	21
Landbirds	2 (+1)	4	3	2	6
Sea Mammals	(2)	2	2	2	2
Feral: Land Mammals	3 (+3?)	?1 (+3)	0	1	3 (+3)

TABLE III. LAND-BREEDING VERTEBRATE ANIMALS RECORDED ASHORE IN THE TRISTAN DA CUNHA-GOUGH ISLAND GROUP

Species formerly recorded, but not now present on the various islands, are bracketed. Data from Swales (1965), Holdgate (1965), Flint (1967 and personal communication), and observations by C. C. H. Elliott and Wace on vagrant landbirds in the islands in 1968.

	Tristan	*Inaccessible*	*Nightingale*	*Gough*	*English name*	*Local name*
SEABIRDS BREEDING ASHORE						
Eudyptes crestatus	+	+	+	+	rockhopper penguin	pinnamin
Diomedea exulans	(+)	+		+	wandering albatross	gony
Diomedea chlororhynchos	+	+	+	+	yellow-nosed albatross	mollymauk, molly
Phoebetria fusca	+	+	+	+	sooty albatross	peeoo
Macronectes giganteus	(+)			+	giant petrel, nellie	stinker
Adamastor cinereus	+			+	grey or brown petrel	pediunker
Pachyptila vittata	+	+	+	+	broad-billed prion	night-bird
Procellaria aequinoctialis		+		?	white-chinned petrel	shoemaker, ringeye
Pterodroma incerta	+			+	Schlegel's petrel	white breasted black haglet
Pterodroma lugens	+	?		+	Kerguelen petrel	night-hawk
Pterodroma macropteea	+			+	great-winged petrel	black haglet
Pterodroma moHis	+	+	+	+	soft-plumaged petrel	night-hawk
Puffinus assimilis	+	+	+	+	little or dusky shearwater	whistler
Puffinus gravis	?	+	+	+	great shearwater	petrel
Pelecanoides urinatrix		+	+	+	Tristan diving petrel	flying pinnamin
Fregetta grallaria	+	+	+	+	white-bellied storm petrel	storm-pigeon
Garrodia nereis					grey-backed storm petrel	
Pelagodroma marina		+	+	+	white-faced storm petrel	skipjack
Catharacta skua	+	+	+	+	great skua	seahen
Sterna vittata	+	+	+	+	Antarctic or swallow-tailed tern	kingbird
Anous stolidus	+	+	+	+	noddy tern	wood pigeon
LANDBIRDS BREEDING ASHORE						
Nesocichla eremita	+	+	+		Tristan thrush	starchy
Nesospiza acunhae	(+)	+	+		Tristan bunting	canary
Nesospiza wilkinsi		+	+		Tristan large-billed bunting, grosbeak	big canary
Rowettia goughensis				+	Gough Island bunting	
Atlantisia rogersi		+			Inaccessible rail	island cock
Gallinula nesiotis	+			+	Gough Island rail, moorhen	island cock
					Tristan rail, moorhen	island cock

VISITING SEABIRDS SEEN ASHORE						
Aptenodytes patagonicus				+	king penguin	
Eudyptes chrysolophus			+		macaroni penguin	
Oceanites oceanicus				+	Wilson's petrel	
Larus dominicanus	+			+	kelp gull	
Larus pipixcan	+				Franklin's gull	
VAGRANT LANDBIRDS SEEN ASHORE						
Ardea cocoi				+	white-necked heron	
Egretta thula	+		+		snowy egret	
Egretta sp.	+		+	+	egret (species uncertain)	whitebirds
Actitis macularia	+				spotted sandpiper	
Bartramia longicauda	+				upland sandpiper	
Charadrius modestus	+				rufous-chested dotterel	
Calidris acuminata	+				sharp-tailed sandpiper	
Calidris fuscicollis	+				white-rumped sandpiper	
Calidris melanotos	+				pectoral sandpiper	
Hirundo rustica	+				barn swallow	
Porphyrula martinica	+				American purple gallinule	guttersnake
Anas flavirostris				+	yellow-billed teal	
SEA MAMMALS BREEDING ASHORE						
Arctocephalus tropicalis	?		+	+	furseal	
Mirounga leonina	(+)		+	?	elephant seal	
	Settle-ment Plain	*Base Peak*				
INTRODUCED MAMMALS & BIRDS						
Felis domesticus	+	+			cat	
Canis familiaris	+	+		(+)	dog	
Rattus rattus	+	+			ship-rat	
Mus musculus	+	+		+	house mouse	
Oryctolagus Cuniculus	(?)	(?)			rabbit	
Equus caballus	(+)				horse	
Equus asinus	+				donkey	
Sus scrofa	+	(?)	(+)		Pig	
Bos taurus	+		(+)		cattle	
Capra hircus	(+)	(+)	(+)	(+)	goat	
Ovis aries	+	+	(+)	(+)	sheep	
Gallus gallus				+	fowls	
Anser anser	(+)				geese	
Anas spp.	(+)				ducks	

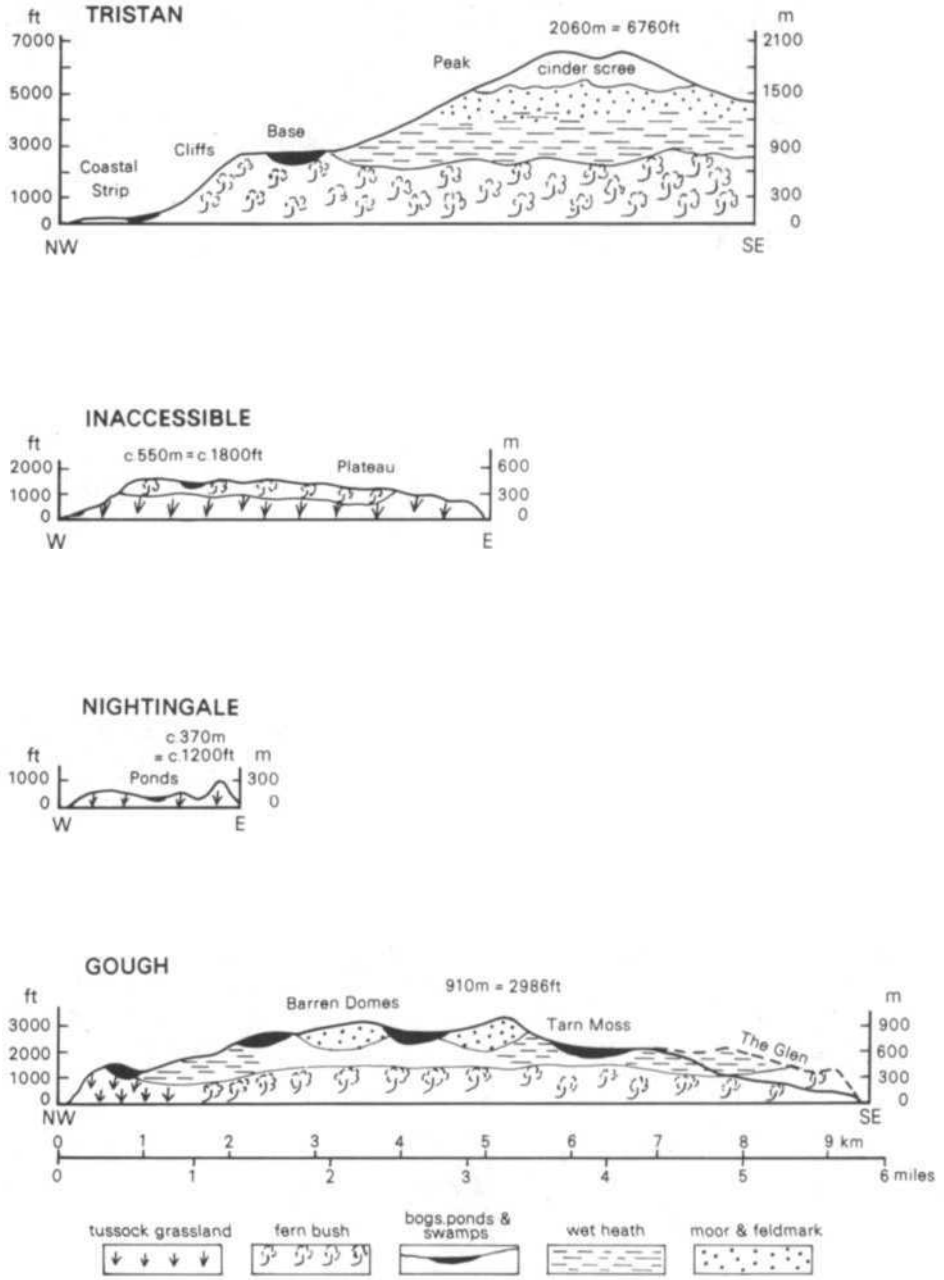

Figure 10.
Topographic sections of the Tristan-Gough Islands, drawn with similar vertical and horizontal scales, and showing zonation of native vegetation. Data from Wace & Holdgate (1958), Wace (1961) and personal observations in 1968.

thought unlikely that *Poa flabellata* (which is so prominent on Gough Island) ever inhabited the Tristan group (cf. Wace and Dickson 1965). Although most native species have now disappeared from the coastal plains, some maintain themselves in the pasture swards (notably *Blechnum penna-marina* and *Chevreulia sarmentosa)* and the prominent colonists of the new lava near the Settlement include the native species *Blechnum penna-marina, Scirpus thouarsii* and *Spartina arundinacea.* But alien species are far the most frequent in both situations.

About 100 species of alien vascular plants had been recorded as more or less naturalized up to 1968: this includes a few species which are only found as weeds of cultivation, but does not include cultigens which are confined to gardens. Most of the alien species are confined to the coastal plains which are themselves subjected to heavy grazing pressure and some tillage and other human disturbances (Wace 1967). A few alien herbs are naturalized almost all over the island in suitable habitats, but mostly in situations which have been disturbed by man-induced or natural processes:

Cerastium fontanum	*Juncus macer*
Chrysanthemum leucanthemum	*Poa annua*
Veronica serpyllifolia	*Anthoxanthum odoratum*
Holcus lanatus	*Rutnex acetosella*

Other alien species are more restricted in their range. Conspicuous and aggressive weeds of cultivation include:

Agrostis stolonifera	*Anagallis arvensis*
Poa pratensis	*Gnaphalium luteo-album*
Cyperus congestus	*Senecio vulgaris*
Coronopus didymus	*Sonchus oleraceus*

Pastures on the coastal strips are dominated by *Cynodon dactylon* (Dyer 1939), but the volunteer species *Plantago lanceolata, Centella asiatica* and *Trifolium subterraneum* which was introduced as an impurity amongst grass seed for the playing field, at the Settlement (to which it was confined in 1968), may in future play an important part in the islanders' economy by increasing the productivity of the pastures, as in temperate Australia (Donald 1965).

In addition to many of the widespread aliens noted previously, a few species are characteristic of waste ground in and around the Settlement, but have not so far shown much sign of spreading away from this area:

Conyza bonariensis	*Verbascum virgatum*
Juncus bufonius	*Gnaphalium candidissimum*

Rumex obtusifolius which is a conspicuous alien in waste places has spread widely, especially round the coasts.

There are no woody alien plants which are naturalized and spreading outside plantations or gardens. Barrow (1910) planted blackberries (*Rubus fruticosus*) and gorse (*Ulex europaeus*), both of which are extremely aggressive in comparable climates elsewhere (e.g. Healy 1969) but on Tristan they have not spread, probably due to the scarcity of frugivorous birds or burning where they were planted. Rogers (1926) comments on the failure of eucalypts and many imported garden plants to grow on Tristan, but said that willows and apples grew well. None of these plants is naturalized on Tristan today, although willows, apples and blackberries all grow quite well more particularly at Sandy Point. Apples have been widely planted around the island at low altitudes, but do not appear to be spreading. *Eucalyptus viminalis* thrives near the pine plantation at Sandy Point, but no eucalypt and few pine seedlings were seen there in 1968.

5. 2. 3. Native fauna. Two species of sea mammals, about fifteen species of seabirds and three species of land birds are (or were) native to Tristan. Of these, about eleven seabird and two land bird species still breed on the island.

Fur seals ('sea wolfs') and elephant seals ('sea lions as large as oxen') were noted in abundance on Tristan by early visitors (see 4.2). About 1000 elephant seal pups were said to have been born on Tristan in 1810-11 (Lambert, in Im Thurn and Wharton 1925). Both species were hunted from about 1790, but by the years preceding the 1961 eruption neither came ashore regularly to breed, although hauling out occasionally on the beaches. Elliott (1953) reported that both had increased in numbers on the Tristan beaches in 1950-52, and five furseal pups were born in a small colony at Cave Point in 1962 when the islanders were in England (Wace 1966). None bred there in 1967-68, but in 1973/4 seals were reported as numerous at Cave Point and pups may have been present (personal communication to M.W.H. from G.Jack). It is unlikely that seals breed ashore elsewhere on Tristan, except possibly on the inaccessible beaches near Tripot.

Rockhopper penguin (*Endyptes crestatus*) rookeries, which were formerly very extensive on the coastal strips, are now confined to the southeastern coast, from Stonybeach to Sandy Point. Elliott (1957) estimated the total population of all Tristan rookeries at 5000 pairs. Present numbers are not known but islanders no longer take the birds (for feathers and scalps) or eggs (for food) as in the past, although dogs kill birds and some are taken for fish bait.

The smaller subspecies of the wandering albatross (*Diomedea exulans dabbenenn*) breeds only in the Tristan-Gough group. It once nested in numbers on the Base and at the bottom of the main cinder cone (Carmichael 1819, Earle 1832 & Plate IV), but is now extinct on Tristan as a breeding species, although common in surrounding waters and occasionally seen ashore (Elliott 1953). Gonies nested on the Tristan Peak in 1852 (MacGillivray 1852) and at least until the 1880s (Beetham, personal communication), but they were extinct as a nesting species on Tristan by 1907 (Barrow 1910, Mathews 1932).

Rowan (1951) discussed the status of the yellow-nosed albatross or 'molly' (*Diomedea chlororhynchos*) in the islands. This species still breeds on Tristan, usually building solitary nests on densely vegetated slopes between altitudes of about 200 and 800m (700 to 2300 ft) above sea level. Elliott (1957) estimated the Tristan breeding population to be some 3000 pairs in 1950-52. Perhaps half that number nested on Tristan in 1968, and although some nests are still found around the northern part of the Base, most are now confined to the southeastern slopes (Flint 1967). The sooty albatross or peeoo (*Phoebetria fusca)* nests on cliffs and in other inaccessible places at a similar altitudinal range to the molly. Elliott (1957) estimated that some 1200 pairs nested on Tristan in 1952 and considered that they had increased in numbers since Hagen (1952) remarked on their scarcity compared to the molly in 1937-38.

The giant fulmer or 'stinker' (*Macronectes giganteus*) formerly nested on Tristan, when plenty of carrion was available from the slaughter and afterbirth of breeding elephant seals (Hagen 1952). It is thought to have nested near Stonybeach up to about 1870, and is still occasionally found ashore. Elliott (1957) thought that its extinction as a breeding species on Tristan was connected with the decline in food supplies as the seals were driven away and that it was not due to predation on the species by man or alien animals. However, this is a species which, by comparison with most Antarctic and subantarctic birds, is liable to abandon its breeding grounds where there is regular human disturbance. At Signy Island (S. Orkney Islands), a substantial

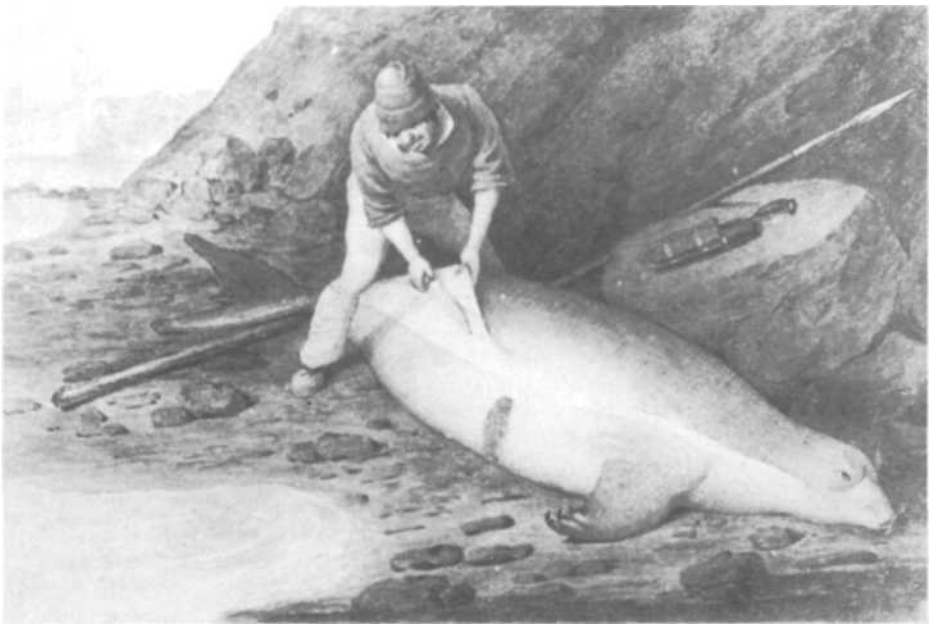

Plate V Tristan da Cunha, 1824, settler skinning a young elephant seal. (Water colour by Augustus Earle, now in the Rex Nan Kivell Collection (NK 12/9), National Library of Australia, Canberra. Reproduced by permission of the National Librarian).

Plate VI Tristan da Cunha, 1824, settlers hunting goats on the mountain. (Water colour by Augustus Earle, now in the Rex Nan Kivell Collection (NK 12/14), National Library of Australia, Canberra. Reproduced by permission of the National Librarian).

breeding colony was progressively abandoned when a scientific base was established nearby, and banding returns confirmed that disturbed birds had moved to more secluded sites elsewhere. Disturbance may likewise have played a part in the abandonment of the Tristan colony.

Little is known of the numbers of smaller seabirds still breeding on Tristan. Flint (1967) noted *Pachyptila vittata* nesting in a cave below the Hillpiece (a colony that has been exploited by the islanders, at least since 1950), and *Pterodroma macroptera* and *P. incerta* were still nesting on the Base during the winter of 1965. *Adamastor cinereus, Pterodroma mollis, Pterodroma lugens,* and probably *Pelagodroma marina* were all taken in numbers by the islanders, at least until 1950 (Elliott, personal communication). Small numbers of great shearwaters (*Puffinus gravis*), no doubt an overspill from Nightingale and Inaccessible, have been suspected of breeding on the steep Western slopes. Skuas (*Catharacta skua*), terns (*Sterna vittata*) and noddies (*Anous stolidus*) are commonly seen around the island, and nest ashore in places quite close to the Settlement. Skuas are the only breeding birds frequently seen near the houses (Flint 1967).

The commoner surviving species of the three original land birds on Tristan, the thrush or 'starchy' (*Nesocichla eremita*) is most frequently encountered to the east and south of the island away from the Settlement. Its present numbers are not known, but Elliott (1953) estimated that there were probably only a few hundred pairs on Tristan in 1952. In 1955 we often encountered starchies in the fernbush above Sandy Point and on the Base between Burntwood and Gipsy's Gulch. The species was said to be fairly common on the Base in 1964 although no estimates of its numbers were made.

The flightless Tristan moorhen (*Gallinula nesiotis nesiotis*) was first noted there by Patton in 1790 (Purdy 1816) and also by Lambert in about 1811 (Im Thurn and Wharton 1925). It is therefore almost certainly native on Tristan (Beintema 1972), and not taken there from Gough Island, nor attributed to Tristan although the specimens were actually taken from Gough as alleged by Eber (1961). Specimens were collected on Tristan in 1816 (Carmichael 1819), in 1842 (Brierly 1842), about 1860 (Sclater 1861), and apparently in 1908 (Mathews 1932). The bird was said to be 'still abundant away from cleared ground' in 1852 (Macgillivray 1852), but was 'almost extinct' on Tristan by 1873 (Thomson 1877), and was not collected by the naturalists from HMS CHALLENGER in that year (Sclater 1878). It was not remembered by the Tristan islanders in 1950 (Elliott 1953). Beintema (1972), after a careful study of the history of the bird on Tristan, concluded that it was probably extinct there by 1906. However, in 1973 a population of moorhens estimated to be as large as 200 pairs was found in dense, relatively inaccessible and little visited fern-bush at Longwood on the north-east side of Tristan (Elliott and Richardson, in preparation). Careful comparison of specimens with the handful of authentic skins and bones still remaining from those collected on Tristan over a century ago suggests that the newly discovered population may be of the Gough Island sub-species, *Gallinula nesiotis comeri.* A number of the latter are known to have been released at the Settlement in the late 1950s and improbable though it may seem that they have escaped the attentions of dogs, cats, rats and boys and made their way to remote Longwood, the possibility exists. Alternatively, there may have been unrecorded releases of Gough Island birds near Jews Point or the criteria whereby Gough Island and Tristan moorhens have hitherto been separated may have been mistaken. Much further work has to be done before the problem is resolved.

Little is known of the Tristan form of the finch (*Nesospiza acunhae*) which was

observed in 1793 (Dupetit Thouars 1811) and collected on Tristan in 1816 (Carmichael 1819), and in 1842 (Brierly 1842). Later collections of this species described by Rogers (1926) probably came from Inaccessible or Nightingale. Today there is only one specimen of the Tristan bird that is known to have been collected on Tristan itself (H.F.I. Elliott, personal communication). The bird was said to be 'not common' in 1852 (MacGillivray 1852), and it was not observed by naturalists from HMS CHALLENGER in 1873. It was possibly extinct on Tristan by then, as stated by Fisher, Simon and Vincent (1969). Hagen (1952) thought that the species had disappeared from Tristan 'a long time ago'.

Although incomplete collecting and imperfect taxonomic study of the collections hamper authoritative statements it is clear that the native invertebrate fauna of the Tristan-Gough group is strikingly impoverished and disharmonic (Holdgate 1965). There are probably no native lumbricid worms, chilopods, diplopods, slugs or insects of the Orders Dermaptera, Dictyoptera, Plecoptera, Odonata, Ephemeroptera, Trichoptera, Neuroptera or Mecoptera. Many other major groups are represented only by one or two species: for example there are only two certainly native Hemiptera. The fauna as a whole shows strong relationships with temperate South America, upwind in the prevailing westerlies, and a number of specimens believed to be vagrants carried to the islands by storms have been collected. About sixty per cent of the species of native land fauna are endemic, but the island group shows little of the spectacular radiation of endemic forms typical of older and warmer archipelagoes like Hawaii.

Tristan has more recorded land invertebrates than any other island in the group (119 species) and of these fifty-seven are aliens - by far the highest total of any of the islands. It also has the lowest number of endemic species strictly confined to it (4). These features probably arise because it is the largest and youngest island, and also that most studied and most modified by man.

5. 2.4 Alien fauna and its effects. Alien vertebrates which have been present on Tristan at various times are listed in Table III and Figure 8. Only cats, mice (*Mus musculus*) and ship-rats (*Rattus rattus*) now maintain permanent populations living in native vegetation, although goats, pigs, and possibly rabbits have done so in the past. Both pigs and rabbits are said to have been present on Tristan away from the Settlement in the mid 1800s, but the existence of rabbits on the island at any time is doubtful, despite reports by Morrell (1832) and Hemsley (1885). No specimens of rabbits or their skeletal remains are known from the island, and they are not mentioned by MacGillivray (1852), or in any ships' papers of the period. Wild goats, said to have been introduced by earlier navigators, were shot by the sealer Patton on Tristan in 1790 (Purdy 1816). Feral goats were present before Lambert's settlement in 1811 (Tagart 1832) and were hunted by the inhabitants in 1824 (Plate VI) and in 1852 (MacGillivray 1852). Feral pigs were also present before 1811 (Tagart 1832). Both died out later, and were said to be extinct on Tristan in 1873 (Moseley 1892). Goats were reintroduced in 1942, but were shot out by 1951 (H. F. I. Elliott 1953, and personal communication). The reasons why goats, pigs and possibly rabbits (which have built up large and destructive feral populations elsewhere) did not do so on Tristan remain obscure. Dogs maintained a small population subsisting mostly on sheep and poultry after the human evacuation of 1961 (Baird 1965), but this feral stock was destroyed before the reoccupation of the islands by man. Dog numbers are now controlled by culling female pups: in 1968, there were two bitches and some sixty dogs kept as pets and for working sheep and cattle.

Horses were imported to Tristan in 1816, but died out shortly after. Donkeys were present by 1870 and are still used for transport. Their hybrid, the mule (which would be an invaluable pack animal on the island and whose numbers could easily be controlled) has never been present. Both horses and donkeys and various poultry, have probably always been confined to the Settlement Plain. Estimates of the numbers of cattle and sheep kept on Tristan at various times are shown in Fig. 8. Almost all of these except sheep have been confined to the Settlement Plain, where many died from starvation on the severely overgrazed pastures in the early 1900s (Barrow 1910). Cattle were not taken to the Stony Hill area until after 1890 (Munch 1971). In 1968 there were some 280 head of cattle and about 250 sheep on the Settlement Plain and about fifty cattle at the Stony Hill and Cave Point pastures and twelve sheep on the Peak.

There can be no doubt that on Tristan, as elsewhere, the alien vertebrates have had the greatest effects both in exterminating or reducing some native animals and in altering the native vegetation, and thus the habitats, of the native fauna (Holdgate 1967). The extent of lowland grassland, itself dominated by alien plants, is clearly related to accessibility by stock; and the *Rumex acetosella—Holcus lanatus* belt of alien-dominated vegetation around the bottom of the Peak may also be related to the grazing of goats and sheep, as it is in New Zealand (Moore 1954).

The extinction of the 'canary' (*Nesopiza acunhae*) the near-extinction (or probably the actual extinction) of the original race of the moorhen *Gallinula n. nesiotis,* on Tristan and the great reduction in the numbers of the smaller nesting seabirds can probably be attributed directly to the presence of cats and rats. Dogs have undoubtedly been responsible for the reduction of penguins and albatrosses, although direct human predation has also affected these species.

No introduced birds (other than poultry), and no reptiles, amphibia or freshwater fish have ever been recorded from Tristan or the other islands in the group. Vagrant landbirds such as swallows, egrets, waders and gallinules have been recorded from Tristan, but these are part of the naturally occurring, but non-breeding, fauna (Elliott and Wace, in preparation). No bats (which are vagrant or breeding species in other remote islands) have ever been recorded from the Tristan-Gough Group.

Many of the alien invertebrates found on Tristan are restricted to the Settlement, or to cultivated ground and imported plants. Some, however, have successfully invaded native vegetation and are found in unmodified fernbush or grasslands. This is true for several lumbricid worms, the common millipede *Cylindroiulus latestriatus,* the woodlouse *Porcellio scaber* and the 'garlic snail' *Oxychilus alliarius.* These species also occur on the other islands, including Gough. There are other species, known to have been imported recently to the Settlement area, whose spread can be expected: among them the Carabid beetle *Harpalus agilis* which fills a niche hitherto vacant on the island.

The dates of introduction of some alien invertebrates are known. The willow aphid *Tuberalachnus salignus,* for example, appeared in 1956 after young trees of its food plant had been imported. The weevil *Pantomorus cervinus* was seen in 1955 in the boats and in the Settlement after hay had been landed. No ants were known on Tristan up to 1962 but plagues are said to have infested the Settlement from time to time after the return of the islanders in 1963. A plague of cockroaches was reported at the same period and H. F. I. Elliott (personal communication to M. W. H.) recalls finding many of these insects when turning out an old naval store in 1950. They were not recorded previously or between the

late 1950s and the eruption. Both ants and cockroaches have now declined in numbers or disappeared, suggesting failure to establish themselves in natural habitats. Some attempt is now made to impose quarantine regulations to keep out unwanted species, but they did not prevent the importation of venomous Australian red-backed spiders (*Lactrodectus hasseltii*) in 1968 (Wace 1968), or a moss in 1966 (Dickson 1967).

5. 2. 5. Human Activities, Vulnerable Species, Summary. Tristan is the only island in the group in which man has so far established a permanent breeding and self-supporting colony. As a result of his activities, there have been substantial changes in the vegetation, the commercially valuable seals have long been almost extinct as breeding species, and the most vulnerable land birds (rail, finch) and seabirds (wandering albatross, giant petrel and probably others) exterminated or greatly reduced as breeding species on the island.

These changes are summarised in Figure 11, which distinguishes 9 major 'land use' and 'human impact' zones. The boundaries shown are highly approximate, for no mapping of these zones has been carried out on the ground. That between types 7 & 8 on the one hand and 9 on the other is particularly arbitrary, for even in zone 9, man and alien mammals have had a significant effect on the avifauna. Broadly, however, Figure 11 does indicate the distribution of human activities and the concentration of substantial habitat alteration in the lowland strips and the girdling *Holcus-Rumex* pasture low down on the Peak. It also indicates the concentration of human impact on the native woodland and bird fauna in the regions nearest to the Settlement. Table IV provides a crude numerical index of these types of impact.

Some native species other than those noted above may also be in danger due to the present activities of the islanders or introduced animals. There were

TABLE IV. HUMAN IMPACT ON THE FLORA AND FAUNA OF TRISTAN

Type of land use	Number of 1 km grid squares in which this type of land use occurs.
1 New, largely barren lava	3
2 Grassland or stony pasture dominated by alien plants	65
3 Experimental forestry plots	2
4 Potato patch and vegetable garden	4
5 Settlement and outlying huts	4
6 Areas of cliff, largely bearing native plants but denuded of wood	21
7 Largely natural vegetation on the Cliffs and Base, but with reduced bird faunas	65
8 Largely natural vegetation on The Peak probably with reduced bird faunas	28
9 Relatively unaltered vegetation with the least reduced bird faunas	25

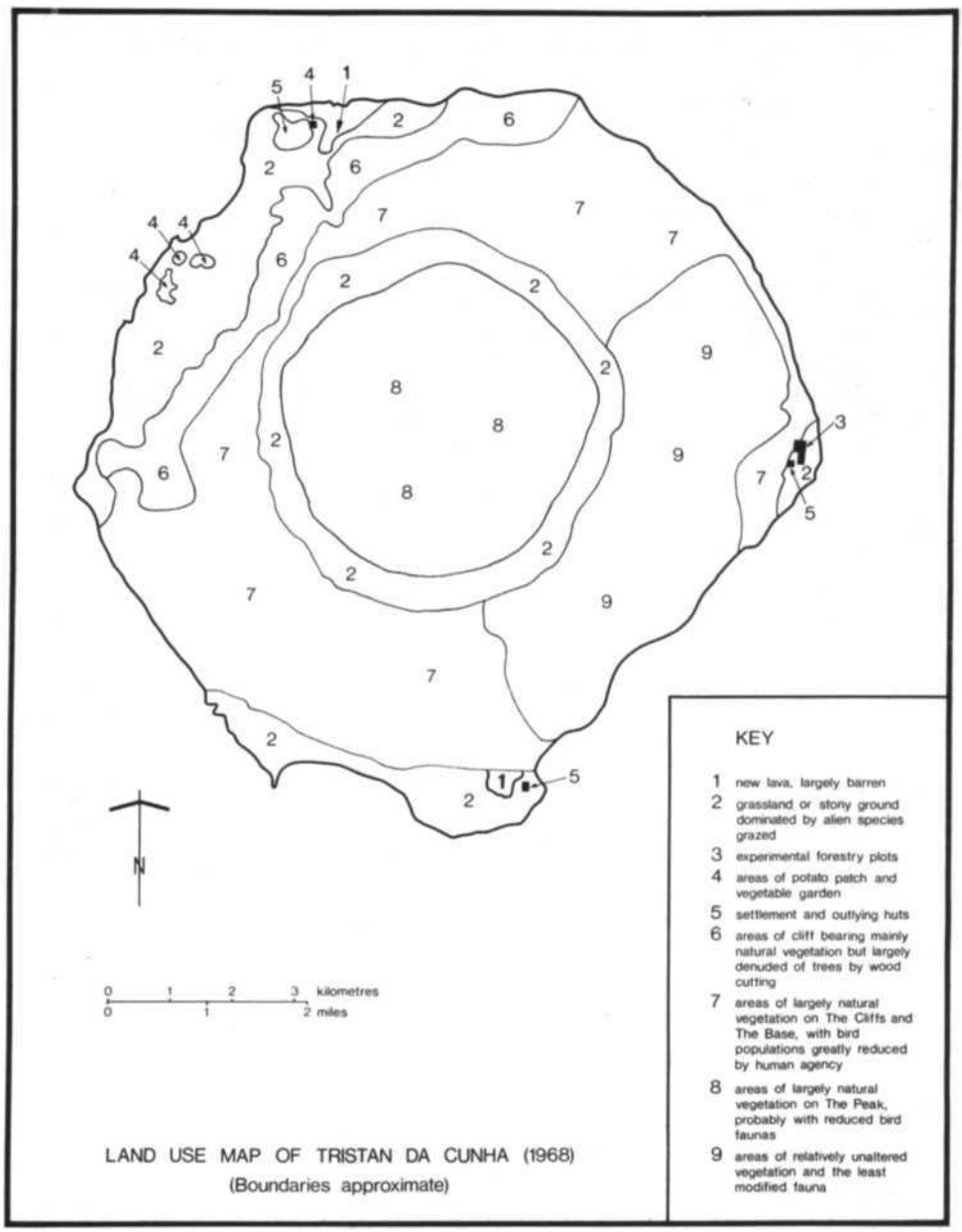

Figure 11.
Land use map of Tristan. Based on aerial photographs and field observations: boundaries highly approximate.

probably between one and two thousand pairs of yellow-nosed albatross (*Diomedea chlororhynchos*) nesting on the island in March to April, 1968, but far fewer occupied nests with chicks were seen in the northern and western sectors of the Base than at similar altitudes away from the Settlement. This difference is undoubtedly due to continued human predation. The islanders now take only chicks and not eggs or adult birds as in the past. They are supposed to obtain the permission of the Administrator before taking any, apart from an allowance of one chick for each man, woman and child at Easter.

Flint (1967) noted that a limit was imposed on the numbers of mollies taken for food but that enforcement was difficult, and the quota rarely observed: in 1965 some 400 birds were taken on Tristan. In 1968, between 100 and 150 chicks were taken on Tristan over the Easter period, and some fifty birds at other times during the season. In the absence of any reliable estimate of the size of the population, or whether the adult birds raise a chick every year, it remains uncertain whether the present takings would exceed the sustainable yield. The number of mollies taken now is very much less than in 1923-27 and in 1938, when thousands of chicks were taken annually in addition to large numbers of eggs (Rogers 1926, Mathews 1932, Hagen 1952). The total population of mollies has certainly declined very greatly since the settlement of Tristan. Rowan (1951), citing Rev. C. P. Lawrence, states that the molly had almost deserted Tristan as a breeding station in 1942-45, but that as a result of the ban then placed upon all fowling on the main island, they were again breeding in fairly large numbers by 1949-1950. Further research is urgently needed on the population size, distribution and breeding frequency of this species, which should remain a valuable resource for the islanders if sensibly managed by a rational limitation of cropping.

The sooty albatross or peeoo (*Phoebetria fusca*) also breeds on Tristan within similar altitudinal limits to the molly, but most often on cliffs and other inaccessible places. Its present numbers are not known, but they have probably always been smaller than those of the molly. In 1952 Elliott (1953) estimated a population of 1500 pairs with about 750 chicks harvested. A few peeoo chicks are still taken by the islanders, along with the mollies, but the numbers (included in the rough 1968 estimate for mollies, above) are unknown. The species is probably not endangered, due to its preference for cliff nesting sites where it is too much trouble for the islanders to take them. Hagen (1952) supposed that the peeoos had suffered a large decline in numbers since the first records made by Carmichael in 1816, who spoke of 'upwards of a hundred nests in an area of half an acre (Carmichael 1819).

A few penguin eggs are still taken each year from the rookery near Sandy Point, but there is now no organised collection of eggs or birds as in the past. The penguins have been eliminated from the northern shores of the island, but still breed at Sandy Point, Stonybeach and other points on the southeast coasts, and in smaller colonies on the sides of many of the gulches away from the Settlement (Hagen 1952). None of the smaller seabirds except the winter-breeding *Pterodroma macroptera* is now systematically exploited on Tristan by the islanders, but many species have probably been exterminated from the nearer and more accessible parts of the island: even in their present haunts they are occasionally sought by individual islanders. An islander fell to his death from the cliffs near the Hillpiece in 1969, while attempting to take seabirds: this event may possibly discourage other attempts to venture into such places and thus serve to protect the remaining species. Cats and rats have probably exterminated or at least very greatly reduced the numbers of the smallest species on Tristan, such as the storm and diving petrels which still

nest on the small islands where these feral predators have not established themselves.

Examples of the effects of introduced mammals and birds on insular breeding colonies of seabirds are perhaps best documented from New Zealand and its nearby islands, some of which present ecological situations similar to those on Tristan. Atkinson (1973), Atkinson and Bell (1973) and Gibb and Flux (1973) have analysed the effects of mustelids, rodents and other introductions there, including the catastrophic effects of the establishment of ship rats and land-birds on small islands near Stewart Island.

Despite more than 159 years of human occupation, much of Tristan away from the coastal strips shows little sign of man's impact. This is because of its rugged nature, and the extreme difficulty of access to man or his animals. None of the native flora is of sufficient practical or commercial value to have led to the extermination of any exploited species, as has occurred in many islands with sandalwood (Shineberg 1967). The naturalised plants are all herbs. Where domestic animals have been introduced to island areas on Tristan (such as sheep on the Peak), it is difficult for the islanders to catch them and there is therefore little incentive under present conditions to keep larger numbers of animals away from the more accessible coastal strips. This, too, has been an influence for the protection of the native biota.

If the native ecosystem is, as far as possible, to be conserved it is important rigidly to exclude from the island such woody alien plants as *Acacia dealbata, A.melanoxylon,Chrysanthemoides monilifera, Crataegus* spp., *Cytisus* spp., *Fuchsia magellanica, Lantana* spp., *Lycium ferocissimum, Rosa rubiginosa, Rubus cuneifolius, Rubus fructicosus* and *Ulex europaeus* which are all aggressive in comparable climatic conditions elsewhere (Allan 1961, Henderson and Anderson 1966, Madden and Healy 1959, Mason 1969, Healy 1969, Praeger 1934). Although the improvement of the lowland pastures on Tristan is of the first importance for the welfare of the islanders, the utmost care should be taken in the introduction of new plant and animal species, so that aggressive, poisonous, diseased or otherwise undesirable species are not brought in. The costs of control, and the damage to the native biota arising from such introductions could be very great, as it has been in New Zealand (Howard 1967, Fordham and Ogden 1974), Australia (Rolls 1969) and other isolated lands. It is also important not to move alien species already on Tristan which are known to be aggressive in particular situations (such as *Phormium tenax* in swamps and *Acacia mearnsii* on outwash gravels) from the sites where they are at present grown on the coastal strips or in the plantations above Sandy Point.

Similarly, it is important to confine grazing mammals to the lowland areas where they at present range (and where the potential for agriculture is in any event concentrated). The construction of a road up the cliffs at Burntwood on to the Base and over to Stonybeach (which was under consideration in 1968) would radically alter this situation, by rendering the uplands accessible to stock. If cattle were to be grazed on the Base and around the bottom of the Peak, the native vegetation would probably be devastated, as has happened in similar circumstances on Hawaii (Warner 1960). The protective cover of peat which retains and slowly releases large quantities of water above the highly porous lavas, would be broken up by the trampling of stock, and this eroding peat with its vegetation would probably be burnt to 'improve' the pastures. In these circumstances, conditions influencing erosion of the cone might be very greatly altered. It is likely that the rates of runoff down the gulches would be greatly increased, and the whole water balance of the island irreversibly changed if the upland peat cover were to be seriously disturbed.

The constant flow of water from springs near the Settlement, and elsewhere at the bottom of the cliffs, could thus be endangered by substantial changes in the plant cover or peat on the Base, and enormous quantities of outwash debris deposited on the pastures of the coastal strips after storms. It is evident from the levees, and the scattered boulders on the flanks of Hottentot Gulch (Plates I & III) and the other large gulches where they debouch on to the coastal strips that they have occasionally overspilt their banks during storm surges from the Peak. If the plant cover on the Base were to be disrupted by grazing, it is likely that surface wash from the upper lava flows into Hottentot Gulch during heavy storms might even overwhelm the Settlement itself. The southeastern sector of the island, which remains the largest refuge area for native species and is rarely visited by the islanders, would also be subjected to irreversible changes as any stock on the Base extended their range to this part of the island. We consider that a thorough geomorphological and hydrological survey should be made on Tristan before any road is constructed on to the Base, for the consequences of such construction might in the long run be catastrophic for the human community on Tristan.

5.3 INACCESSIBLE ISLAND

Inaccessible is the least well known of all the islands in the Tristan-Gough group. Its vegetation has never been described or mapped, and, even its vascular flora may not be completely collected. Nowadays the island is seldom visited by the Tristan islanders, and neither of the authors has been on to the plateau. The following notes must therefore be regarded as less securely based than those for the other islands (in all of which we have personal experience of both coastal and inland regions).

5. 3. 1. Vegetation. There are three native vegetation types, little affected by human activities apart from the local occurrence of a few alien plants. High *Spartina arundinacea* tussock grass, much of which is occupied by penguin rookeries, covers the uneven rocky ground on the west and northeast coasts, and all but the steepest cliffs (Plate VII). Fern bush with thickets of *Phylica arborea* in the gullies covers most of the wet peaty plateau, but there are a few areas of *Empetrum* and mossy *Scirpus* heath at the highest altitudes to the west of the plateau. A few freshwater swamps in the tussock on the coastal lowlands near Blenden Hall contain *Azolla filiculoides.*

5. 3. 2. Native and Alien Flora. The known native flora consists of 26 species of flowering plants and 27 pteridophytes. It includes several species which are unknown and almost certainly absent in the other islands: notably *Peperomia tristanensis* and *Azolla filiculoides.* Further species may yet remain to be discovered on Inaccessible, especially on the plateau.

The alien flora consists of some twenty species of flowering plants, but probably few of these ascend to the plateau and only *Poa annua, Rumex obtusifolius, Sonchus oleraceus, Agrostis stolonifera* and *Holcus lanatus* appear to be widespread around the shores and aggressive in entering the native vegetation. The agressive alien *Rumex acetosella* was collected near Salt Beach in 1873 (specimen at Kew), but could not be found there or on the southern cliffs in 1968. Most of the alien plants are confined to the areas behind Salt Beach and Waterfall Beach on the northeast coast, where some tillage and cattle raising was attempted in the past. *Brassica rapa* is very abundant on formerly tilled ground and potatoes are occasionally found there. Willows, pines (*Pinus carribea*) and some apple trees have all been planted in this area, but none appears

Plate VII Inaccessible Island, showing Salt Beach and the northeast coast from the precipice near the Waterfall. February 1968. The cliffs and the lower slopes are largely mantled by *Spartina arundinacea* tussock grass (Photograph, N.M.W.).

to be spreading and no seedlings could be found in 1968. *Phormium tenax,* which is aggressive in similar native vegetation on Nightingale, formerly grew above Waterfall Beach, but was eaten out by cattle (Green, personal communication) and is not known to be established elsewhere on Inaccessible. No sign could be found in February 1968, of two species of clover introduced in this area, which were said to be spreading rapidly in October 1873 (Moseley 1875).

5. 3. 3. Native fauna. A few fur seals were seen on the south coast of Inaccessible Island in February 1968, and elephant seals probably haul out on the island in small numbers also. Both species were hunted there in the past (MacGillivray 1852, Furlong 1821, Lockhart 1930), but are not now taken.

Sixteen species of seabirds are known to breed on the island and others which breed elsewhere in the Tristan group will probably be found to breed on Inaccessible also (e.g. *Adamastor cinereus, Pterodroma incerta* and *P. macroptera*). *A* few pairs of wandering albatross or gony (*Diomedea exulans dabbenena)* nested at the western end of the plateau on Inaccessible in 1937-38 (Hagen 1952) and up to 1952 (H. F. I. Elliott, personal communication) Hagen (1952) implied that the Inaccessible gonies had been reduced to two or four breeding pairs because the Tristan islanders had taken them for food; but comparing his and Kirby's observations made eight years later (Roberts 1948), Hagen thought that the population had remained at these numbers for at least a decade. It is not known whether the birds have increased in numbers, remained static, or disappeared from Inaccessible since 1952. Inaccessible is the only known breeding station in the group of the 'spectacled' form of White-chinned Petrel, Cape Hen or Shoemaker *Procellaria aequinoctialis,* of which about 100 pairs were estimated to be nesting in wet burrows on the plateau in 1952 (H. F. I. Elliott, personal communication).

The four species of breeding land birds include the small flightless rail *Atlantisia rogersii* which scurries among the tussock grass stools in an almost mouse-like fashion. Hagen (1952) estimated its total population to be upwards of a thousand birds, distributed all over the island but probably most abundant in the *Spartina* tussock. It was seen to be numerous in the tussock communities above Blenden Hall in March 1961, and above Waterfall and Tom's Beach in February to March 1968, but no estimates of numbers were possible. The thrush or 'starchy' *Nesocichla eremita* was abundant and very tame on the coasts in 1968. The secretive small-billed finch or 'canary' (*Nesospiza acunhae*) was also abundant in the adjoining tussock, but nothing was seen of the large-billed canary (*Nesospiza wilkinsi*) in 1968. This last species frequents *Phylica arborea,* (on which it feeds) on the plateau. The Tristan islanders could give no information about its abundance on Inaccessible, but there is no reason to doubt that it still survives on the plateau in the fern bush, where *Phylica* is more abundant than on the coasts.

Fifty-eight land invertebrate species have been recorded from Inaccessible Island: ten of these are definitely alien and nine doubtfully so. The island is particularly rich in the listroderine weevils endemic to the group as a whole. Little is known of the fauna of the island away from the areas of the north coast where human disturbance has been concentrated, but it is clear that it is of unusual interest and that the habitat over much of the land surface remains substantially unaffected by human activities.

5.3.4. Alien Fauna and its effects. Cattle, sheep, goats and pigs have all been on Inaccessible at one time or another, but there is no evidence that any re-

main there now. Cattle were kept at Salt Beach in 1923 (Rogers 1926) and during the abortive attempts to farm the island in 1937-38 (Christopherson 1940), but the steep cliffs prevented the escape of any animals up to the plateau. Descendants of the cattle introduced in 1937-38 were finally shot out at Salt Beach in the 1950s, and there are now no cattle anywhere on the island. Sheep were grazed on the island in 1923 (Rogers 1926), and introduced again in the 1937-38 farming venture: they were grazing on the plateau at the western extremity in 1950-52, but all were reported to have been shot out in 1955 (H. F. I. Elliott, personal communication). Goats were present in 1870, when one was taken by seamen from a visiting whaler (Davis 1870). These goats were possibly the descendants of some said to have been put ashore from Tristan in the early 1820s (Munch 1945): they lived on the plateau (Moseley 1892), but were exterminated in 1872 when two Germans settled on the island (Thomson 1877), and goats have not been reintroduced since. Two pigs swam ashore from a shipwreck in 1821 (Furlong 1821), and were possibly the progenitors of those in the interior of the island, some of which were killed by the Germans in 1872 (Thomson 1877). In the 1950s feral pigs were alleged to have been dangerous pests in the tussock grassland (Booy 1957), but none was reported as remaining after this period. No sign of pigs was seen on the eastern coasts in 1968, nor at Blenden Hall or inland in 1962 (M.W.H.) nor in 1971 (Rous, personal communication). Whether feral pigs are still present on Inaccessible thus remains doubtful, and nothing is known of their past effects upon the vegetation or the breeding birds.

Dogs are occasionally taken over to Inacessible by the Tristan islanders, and individual animals may have run wild there in the past (Rogers 1926), but there is no feral population ashore now. Neither cats, rodents, nor any other alien vertebrates have ever been present on the island so far as it is known. Some of the recorded alien invertebrates, notably the millipede *Cylindroiulus late striatus*, the centipede *Lithobius melanops* and two species of aphid, are likely to have spread widely into undisturbed native habitats but have not caused any major ecological changes there.

Fires have been recorded from Inaccessible in 1872, when much tussock grassland on the cliffs was destroyed (Thomson 1877) and in 1909, when a fire in the tussock is said to have burned for a month (Hagen 1952). These fires must have been destructive, both to the vegetation and to nesting birds, but no effects of fire were apparent on the eastern coasts in 1968.

5. 3. 5 Human Activities, Vulnerable Species, Summary. Apart from the activities of feral pigs (whose impact has been small compared to that reported on other islands such as He aux Cochons in the Crozet group—Goodrich 1832), and the old tillage near Waterfall Beach, the terrestrial biota of Inaccessible Island has apparently been little affected by man. Firing of the tussock grasslands and the importation of carnivores are probably the greatest foreseeable hazards to the continued stability of the native ecosystem. *Atlantisia* would be particularly vulnerable to cats or rats, if these got ashore. The Tristan islanders seldom visit Inaccessible: two longboats which sailed over from Tristan in February 1968 were the first island visitors since the eruption on Tristan in October 1961. Although this absence of contact perhaps makes for self-protection of the native biota, the islanders' attitudes to some of the endemic species may pose problems for the future. In 1968 rumours were circulating on Tristan that a single plant of *Peperomia tristanensis* would fetch £40, 000! Such notions, although fanciful, could lead to the rapid extermination of rare species. Elliott (1970) comments on the museum demands for skins of *Atlantisia* and other birds, placing a high value on specimens—and the urgent need to maintain strict controls on numbers taken.

5.4 NIGHTINGALE ISLAND

Nightingale is now the most frequently visited of the smaller islands, with regular longboat excursions taking large parties of islanders over from Tristan to exploit the seabirds several times a year. Its main features are therefore fairly well known, although the island remains unmapped, and the only scientists to work ashore there in the winter (RYS QUEST visit of June 1922) stayed very briefly (Wild 1923).

5. 4. 1 Vegetation. The island is covered by dense *Spartina* tussock grass, which forms almost pure stands growing to a height of two metres or more, usually on hard fibrous peat. This remarkable vegetation covers the hills and the gentler slopes inland, and all but the steepest coastal cliffs, as well as Middle and Stoltenhoff Islands. Small groves of *Phylica arborea* fill some inland gullies, but they have few epiphytes (other than lichens) and a sparse under-storey. Around the central swamps, and on some of adjoining gently sloping ground, meadows of hummock-forming pachycaul *Scirpus* replace the *Spartina* tussock.

This vegetation has been little disturbed by man. No tillage has ever been attempted, apart from a few apparently unsuccessful attempts to establish potatoes near the islanders' huts (and probably elsewhere on the coasts by sealers). Although there are reliable accounts of local firing of the tussock grass near the huts, there is no evidence that the *Scirpus* meadows are fire-induced (cf. Wace and Dickson 1965).

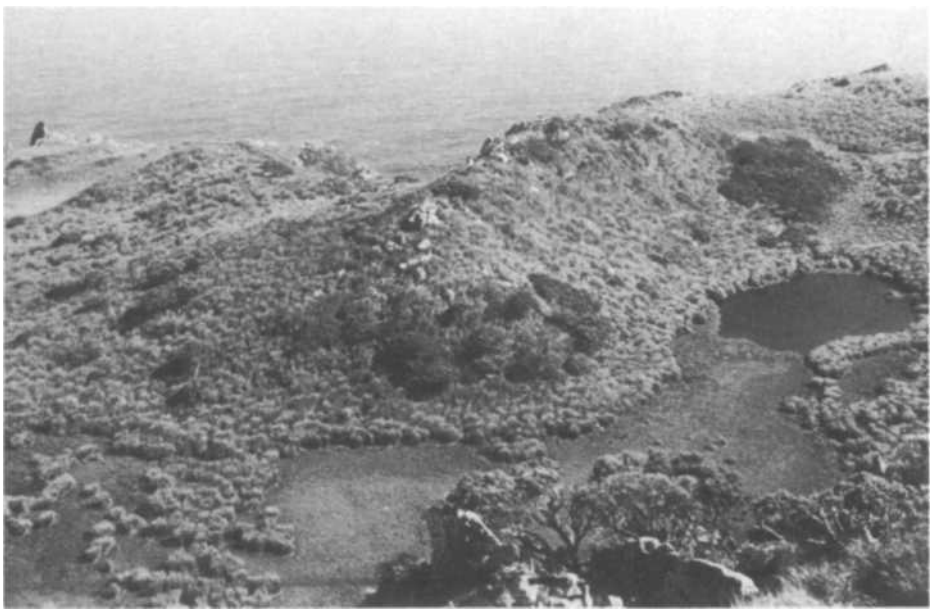

Plate VIII Nightingale Island interior, looking northeast over Second Pond from the side of High Hill, April 1968. *Scirpus* meadows (with mollymauk nests) in the valley, and *Spartina* tussock grassland with thickets of *Phylica arborea* on the slopes. These *Phylica* clumps on Nightingale and Inaccessible Islands are the habitat of the endemic Tristan grosbeak, or large-billed bunting. (Photograph, N.M.W.).

5. 4. 2 Native and alien flora. The native flora is poor in species, due to the smaller size and narrower range of environments there than on the other islands of the group. Nineteen species of flowering plants and fifteen pteridophytes are native, and only six alien vascular plants had been recorded as naturalized there up to 1968.

Phormium tenax is the most aggressive of the aliens. It had been taken up to the Ponds area, from an older planting near the huts, some thirty years ago (Thomas Glass, personal communication) and was spreading rapidly in wet ground to the east of First Pond in 1968. *Phormium* forms massive clumps in the tussock grassland and *Phylica* groves and threatened to spread all over the island, thus altering irreversibly the nesting environment of the bulk of the world population of *Puffinus gravis.* Steps were therefore taken to destroy the *Phormium.* clumps in 1968, and the work has been continued by the islanders since, although some regrowth was noted in 1971 (Green and Rous, personal communication). *Phormium* growth, is a serious problem under comparable climatic conditions in upland St. Helena (St. Helena Dept. of Agriculture and Forestry Reports for 1965 and 1966) and its clearance from Nightingale has been supported by the Tristan Island Council.

A few apple trees had been planted in a gully by First Pond, and some seedlings were seen in the nearby tussock in 1968. The remaining alien plants are small herbaceous species and only *Holcus lanatus, Rumex obtusifolius* and *Sonchus oleraceus* were seen away from the vicinity of the islanders' huts.

5. 4. 3 Native fauna. The native fauna of Nightingale is limited. Furseals breed on the southern beaches, especially at Ned's Cave, where a few were heard from above in March 1968. Ninety were counted ashore in November 1951 (Elliott 1953). Elephant seals may also haul out occasionally, but no counts have been made and the steep rocky beaches are hardly suitable for them.

Large colonies of rockhopper penguins (*Eudyptes crestatus*) are found on the lower tussock-covered slopes near the islanders' huts and on Middle Island. Small numbers were seen in 1968 at Petrel Bay and at Ned's Cave, and doubtless form small rookeries elsewhere in the thick tussock. Hagen (1952) thought that 'thousands' of birds bred near the islanders' huts in 1937-38, but considered that they had decreased in numbers since 1873 when the naturalists from HMS CHALLENGER gave a graphic account of their experiences in this penguin rookery (Moseley 1892). Rowan (1952) estimated that the penguin rookeries occupied about fifteen acres on the tussock slopes near the huts in 1950. Possibly some ten thousand penguins were moulting ashore on Nightingale (main island) in March 1968 when there were many birds dying in the hot weather. There is also a large colony of penguins with 'a very truculent disposition' (Elliott 1957) over the whole of Middle Island.

Yellow-nosed albatross (*Diomedea chlororhynchos*) nest throughout much of the tussock, and in colonies near the Ponds (Rowan 1951, Hagen 1952). Estimates of numbers are difficult to make because of the dense vegetation, but there were probably between 500 and 1000 occupied nests throughout the island in March 1968. If this estimate is correct, the species must have declined greatly in numbers since 1924, when Rogers (1926) saw 500 mollies around the Ponds alone. Many empty nests are encountered in the tussock during the breeding season, but Elliott (1970a) suggests that the molly on Nightingale may be a biennial breeder as is the wandering albatross (*Diomedea exulans*) on Bird Island, S. Georgia (Tickell 1970) and Marion Island (van Zinderen Bakker 1971). Sooty albatross (*Phoebetria fusca*) nest on the cliffs

above Pequena Point and doutbless elsewhere, but their numbers are not known: Elliott (1953) thought that only 'a few pairs' nested on Nightingale in 1951-52.

Of the remaining eleven species of seabirds which are known to breed on Nightingale, the great shearwater (Puffinus gravis) is the most numerous, and certainly has the greatest impact on the vegetation. Rowan (1952) estimated that upwards of two million pairs bred there in 1949-50, and that their burrows covered the island at a mean density of one per square yard. Brown and Baird (1965) also estimated the Nightingale breeding population as about four million birds in 1962. Almost all the ground beneath the tussock, the *Phylica* groves and the *Scirpus* meadows, is riddled with Shearwater burrows. Hagen (1952) estimated that up to 100 tons of marine food was consumed daily by the Nightingale seabirds (mostly by *Puffinus gravis)* and much nutrient is deposited as guano on the island. The extent and luxuriant growth of the *Spartina* tussock on Nightingale is no doubt largely due to the effects of petrel excreta and burrowing. No attempt was made to count birds in 1968, but a lookout was kept for unhatched eggs in burrows during April to see whether *Puffinus gravis* is affected in the same way as the Bermudan petrel (*Puffinus cahow*) by pesticide residues reducing the fertility of the eggs. A search of more than a hundred burrows on the northern face of High Ridge revealed only four eggs and, although many smashed eggs were seen on the surface and in burrows, it was not known whether these were brittle due to induced thinness of shell, or whether chicks had hatched from them previously. Many eggs are, in any case, laid on the surface and not incubated (Rowan 1965), and accessible eggs are broken open and consumed by the starchy (*Nesocichla eremita*).

The broad-billed prion (*Pachyptila vittata*) is probably the most numerous of the remaining seabirds and is very abundant on rocky slopes and cliffs all over the island. No estimates have been made of its numbers, nor of those of the other seabirds which breed there. Elliott (1953) thought that *Adamastor cinerea* and *Pterodroma macroptera* which formerly bred on Nightingale may have been ousted by the aggressive *Puffinus gravis.* Neither of the former species was seen in March and April, 1968. Among the smaller seabirds, the nesting of unknown (but probably fairly substantial) numbers of the storm- and diving-petrels *Fregetta grallaria* and *Pelecanoides urinatrix* is of special interest. Both are vulnerable to skuas and introduced carnivores, and are mainly nocturnal.

Two closely related finches, differing in their bill sizes and feeding requirements inhabit Nightingale. They are similar to, but racially distinct from the same species on Inaccessible (Hagen 1952). These birds are of singular interest because they seem to present a case of evolutionary divergence paralleling in miniature that of the Galapagos finches studied by Darwin (Lack 1947). Hagen (1952) estimated the total world population of the small-billed finch (*Nesospiza acunhae*) on both Nightingale and Inaccessible to be numbered in 'thousands' in 1938. No estimates are available of the size of the Nightingale population, but the species was frequent all over the island in the tussock in March and April, 1968. The large-billed finch, or Tristan grosbeak (*Nesospiza wilkinsi*) which is largely dependent upon *Phylica* seeds as food, is far less common: it was only encountered once in April 1968, in a *Phylica* grove north of Second Pond. In 1957, it was estimated that the Nightingale population of this species numbered not more than about ninety birds (Fisher *et al.* 1969), but there is no reason to suppose that the species has suffered a decline since then: Hagen (1952) found none on Nightingale during the first ten days of searching in January to February 1938.

The thrush or 'starchy' (*Nesocichla eremita*) was extremely tame, to the point of becoming a nuisance in tents, huts etc. throughout Nightingale in March and April, 1968. The total world population of this species (on Inaccessible and Nightingale with a remnant on Tristan) was said to number 'thousands' in 1938 (Hagen 1952). Elliott (1953) noted it as 'very numerous indeed' on Nightingale in 1950-52. Apart from the finches and thrush, no rails or other land birds are known to breed on Nightingale.

Forty-two species of terrestrial invertebrates have been recorded from Nightingale. Of these, only six are certainly alien, and three of doubtful status. The smaller size of the fauna, compared to that of the other islands, probably reflects the less diverse habitat and the small size of the island itself, as well as lack of collecting. The island supports a number of endemic species: five listroderine weevils are confined to it, and seven of the nine drosophilid (*Scaptomyza*) species which are endemic to the Tristan-Gough Group inhabit Nightingale (of these seven species, three are confined to Nightingale). The island is thus rich in the more distinctive of the Tristan-Gough Group invertebrates, and it has clear faunistic affinities with Inaccessible.

5. 4. 4 Alien fauna and its effects. Nightingale has been less affected by alien animals than any of the other islands in the Tristan-Gough Group. No alien vertebrates have ever established themselves there. An attempt to graze sheep in the tussock in the 1930s failed, when all the animals died (Glass, personal communication). The few alien invertebrates—four species of fly, a staphylinid beetle, and the millipede *Cylindroiulus latestriatus* are unlikely to have any significant ecological impact. The Tristan islanders visit Nightingale, usually three times a year, to collect the seabirds' eggs and fat and guano. They have about thirty huts and shacks perched on a rocky shelf on the northeast coast, which they use during these visits. The islanders are fully aware of the importance of keeping alien animals off the island in order to preserve the shearwaters: no dogs or cats are ever taken over from Tristan, and pains were taken to ensure that a live rat once found in a long-boat sailing over from Tristan was killed before landing (Green, personal communication).

5. 4. 5 Human activities, Vulnerable species, Summary. Sealing has reduced stocks of furseals in the past, since Rogers (1926) stated that there were no seals there in 1924, but about ninety were seen in 1951 (Elliott 1953). Despite regular large scale predation by the islanders on penguins and shearwaters on Nightingale, the island appears to have retained most of its pristine features without radical change. It seems unlikely that the numbers of any of these species is now declining through this harvest, although the mollies may have been reduced.

Elliott (1953) estimated that some 12, 500 penguin eggs were taken on Nightingale in 1951 and Flint (1967) put the number taken at 23, 000 in September 1963. Although these huge numbers may have had some effect on the size of the population in the past before a rule was introduced in 1951 prohibiting the removal of more than two out of three eggs in any nest, there was no evidence of abandoned rookeries in the tussock in 1968 and the numbers of both eggs and birds now taken are very small. The effects of human predation on the mollies on Nightingale are less certain, in the absence of any reliable estimate of the numbers of birds present, the numbers taken, and how frequently they breed. Rowan (1951) thought that a minimum of 5500 mollies (total of eggs and chicks combined) were taken annually from Nightingale in 1949-50, but that the population could probably withstand heavier cropping than this. Elliott (1953)

and Flint (1967) noted that 2500 chicks and 1500 eggs were taken in 1951 and 1963 respectively. In April 1968 some 150 molly chicks were taken, but according to the islanders no eggs or adults had been taken earlier that season, as they had in the past. The colonial nesting of the molly on Nightingale has undoubtedly made it extremely vulnerable to human predation: there were certainly far fewer birds nesting near the Ponds in 1968 than is suggested by the illustrations taken thirty years previously (Hagen, 1952).

Great shearwaters, or, as they are invariably termed by the islanders 'petrels', which have been an important resource in the islanders' economy, are taken by the islanders on three occasions during the year:

(a) Eggs are collected in November. Hagen (1952) estimated that about 30, 000 eggs were taken in 1937. Rowan (1952) and Elliott (1953) noted that about 15, 000 were collected in both 1950 and 1951, but the numbers taken more recently are not known. In 1967 it was not more than a few thousand, and these numbers must represent only a tiny fraction of the total laid and a very small part of the natural wastage of eggs which are laid outside the burrows (Rowan 1952, 1965).

(b) When penguin guano is collected from Nightingale by the islanders in the summer, some young petrels are generally taken for food. In 1968, the number of petrel chicks so taken could not have exceeded 2000.

(c) In the autumn (usually April or May) the young petrels are taken for fat and for salting down, shortly before they fledge. Rowan (1952) and Elliott (1953) estimated that this activity accounted for 10, 000 birds in 1949 and between 15, 000 and 20, 000 in 1951. With fewer islanders going to Nightingale and with imported and less highly flavoured cooking fat and other food available in 1968, the number killed in April 1968 was about 6, 000 (including some salted down and others eaten at the time of the visit).

The above figures for 1967-68 are outside estimates and in that season they accounted for not more than 12, 000 chicks and eggs of *Puffinus gravis.* (The adults are not taken at any time.) This is an inconsiderable number when compared with the likely total population of more than two million nesting pairs. Previous investigators (Hagen 1952, Elliott 1953, Rowan 1952) who considered the impact of man upon the petrel population of Nightingale when human predation was much heavier than now, concluded that there was no danger of a decline in stocks. With the change in the economy of the islanders since commercial fishing became established in the 1950s, and imported food readily available, the seabirds have declined in their importance to the islanders. Visits to Nightingale have progressively taken on something of the aspect of a holiday, rather than an essential part of their economic activities (Munch 1970, 1971). But the presence of an exploited resource in the petrels, whose maintenance demands some care in management, augurs well for the conservation of the whole biota of Nightingale, and especially in checking the spread of alien plants or animals to the island. Serventy, Serventy and Warham (1971) have pointed out the similarly protective effects of 'mutton bird' exploitation on the Bass Strait islands where they breed.

The remaining seabirds on Nightingale are probably little affected by the islanders and will remain so as long as alien predators are kept away. The land birds would be extremely vulnerable to any such predators and the finches in particular (especially *Nesospiza wilkinsi)* need continued protection from the taking of specimens for sale to museums.

The absence of potable surface water on the island to some extent protects it against land-based activities which might disrupt its native biota. Fire is perhaps one of the greatest hazards to the maintenance of the status quo, but the islanders are well aware of the dangers of burning the tussock grass, which would readily take fire during dry spells in the summer when the peat under the tussock stools might burn unchecked for long periods, destroying the nesting environment of the shearwaters. So long as *Phormium tenax* is finally eliminated from the island by pulling out any new seedlings or regrowth, and as long as firing of the tussock and the release of alien herbivores or predators is prevented, the terrestrial ecosystem on Nightingale will probably remain little affected by man's present activities on the island. Because of its enormous population of accessible and exploited shearwaters, Nightingale could become important in monitoring the Atlantic for pollutants in future (see 6.4.4.1).

5. 5 GOUGH ISLAND

Gough Island is the wettest, coldest and the most rugged of all the Tristan-Gough Group, and presents the most formidable environment for human exploration or use. No resident scientists have penetrated into all the deep ravines and glens of the north and east coasts, or explored the island during the winter, but its vegetation is described, and at least the outline of its flora and fauna known.

5. 5. 1 Vegetation. Gough Island supports five vegetation types, so far almost untouched by man or species that he has introduced. The coastal cliffs and penguin rookeries are mantled with tussock grasses (both *Spartina arundinacea* and *Poa flabellata)* (Plate IX). The more sheltered lower ground up to about 300 m is covered by fern bush, where dense thickets of the island tree *Phylica arborea* grow amongst dwarf tree ferns (Plate X). Together with numbers of other ferns and numerous epiphytes, this forms a thick tangle of vegetation usually growing over moist and uncompacted peats. Above this fern bush is a zone of wet heath vegetation with low creeping plants, tufted grasses and sedges and moss mats, extending to around 600 m altitude. Above this again, and extending to the tops of the highest peaks (c. 900 m), is a feldmark montane vegetation with a sparse plant cover and thin wind-eroding peats (Plate XI). The upland valleys contain bogs, mostly covered by sphagna and other bryophytes, with peat up to 4. 5 m deep (Wace 1961).

5. 5. 2 Native and alien flora. Some 35 species of flowering plants and 27 pteridophytes are native to Gough Island, and these include a number of species not now found in the Tristan group. Most of these are subantarctic and Fuegian species (e.g. *Poa flabellata, Tetroncium magellanicum* and *Ophioglossum opacum*), but they include the small tree *Sophora microphylla* which grows in coastal southern Chile and has been found on Gough only in one of the deep valleys, now called the Sophora Glen. Other species may yet remain to be discovered in some of the more inaccessible northern glens on the island.

Only twelve alien species of vascular plants were recorded up to 1956, and several of these could not be found again in 1968 and may have disappeared from the island. The native vegetation is remarkably little affected by alien invasion despite twenty years of continuous occupation of the island by men operating the South African weather station. A few alien herbs are widespread (such as *Poa annua, Holcus lanatus* and *Sonchus oleraceus* over most of the

Plate IX Gough Island, showing the southeast coast and Transvaal Bay, from the side of Richmond Hill, May 1968. The nearby cliffs are covered by *Poa flubellala* tussock grass, and the gentler but broken slopes towards the Meteorological Station in the distance support thick fern-bush (Photograph, N.M.W.)

Plate X Gough Island, looking northeast down the Sophora Glen, May 1968. The steep sides of the Glen are here about 400 ft (120 m) deep and covered by fern bush (Photograph, N.M.W.).

Plate XI Gough Island, looking southeast from Edinburgh Peak across the bogs of Tarn Moss and Albatross Plain towards Kern Crag, South Peak and Mount Rowett, May 1968. Wind erosion of the peat surface along the ridge in the middle of the picture shows up with a sharp difference between the wind-cut moss on the exposed western face (right) and grass on the sheltered eastern face (Photograph, N.M.W.).

island, and *Rumex obtusifolius* by the streams and the shore), but no aliens have assumed dominance away from the few coastal sites that have been inhabited by sealers or visiting scientific parties etc. The alien 'sour grass' (*Rumex acetosella*), which is so important in upland Tristan, was not established on Gough in 1955-56 or 1968 and there are no woody alien species on the island.

5. 5. 3 Native fauna. The native vertebrate fauna of Gough Island consists of two breeding species of marine mammals, twenty-one species of seabirds known to breed on the island (Swales 1965) and two species of resident land birds. The size of the elephant seal (*Mirounga leonina*) population was estimated at 200 to 300 in 1955-56, and it is doubtful if it was ever very much greater than this, even before the sealing visits of the nineteenth century. There were estimated to be about 13, 000 fur seals (*Arctocephalus tropicalis*) ashore in 1955-56, but accurate counts of the animals are extremely difficult to make because of the very rugged nature of the beaches. Recent estimates suggest that the population: may have been increasing at around 8% per annum and now exceeds 20, 000 (Swales, in prep.:Shaughnessy, pers. comm.).

About two million pairs of rockhopper penguins (*Eudyptes crestatus*) breed in rookeries all round the coast. Some of the rookeries are large—one was estimated to contain 200, 000 pairs of birds (Swales 1965). Gough Island is the only remaining major breeding ground for the Tristan subspecies of the wandering albatross (*Diomedea exulans dabbenena*), and probably about 2000 pairs nest on and around the upland bogs every year. The yellow-nosed (*Diomedea chlorohynchus*) and sooty albatross (*Phoebetria fusca*) have breeding populations probably of some few thousands of pairs each. Only one small nesting colony of giant petrels (*Macronectes giganteus*) with about sixty nests has so far been discovered on the island, but other nesting sites may remain to be found: Shaughnessy (personal communication) found a single nest at Long Beach (opposite Penguin Island) in October 1973. Swales (1965) estimated that not more than 200 giant petrels were present on the island in 1955-56.

Very large breeding populations of some smaller seabirds inhabit the island at different times of the year. From summer and autumn observations in 1955-56, Swales (1965) estimated that the breeding populations of the broad-billed prion (*Pachyptila vittata*), the dusky shearwater (*Puffinus assimilis*), the soft-plumaged petrel (*pterodroma mollis*) and the Kerguelen petrel (*P. lugens*) were probably to be numbered in millions. Elliott (1970b) estimated that some 600, 000 (or even up to three million) great shearwaters (*Puffinus gravis*) may breed on Gough Island in the coastal tussock and cliff-top Scirpus meadows, mostly in the south of the island. The colony there may thus represent up to twenty per cent of the total world population of this species, but it may have increased substantially there in recent years. Broekhuysen (1949) sighted *Puffinus gravis* at sea near Gough Island in 1948 but no birds were recorded as breeding ashore there before 1951 (H. F. I. Elliott, personal communication). Swales (1965) considers that Schlegel's petrel (*Pterodroma incerta*) is the most abundant of the larger petrels nesting on Gough, but this species and both the pediunker (*Adamastor cinereus*) and the great-winged petrel (*Pterodroma macroptera*) apparently nest in the upland in winter (as they do on Tristan), and no estimates have been made of the size of their breeding populations, although Swales noted all three as 'abundant'. The diving petrel (*Pelecanoides urinatrix*) and two of the three species of storm petrel thought to breed on Gough Island (*Garrodia nereis* and

Fregetta grallaria) were also noted by Swales (1965) as 'abundant', but there are few data on the nesting zonation or phasing of their breeding on the island.

Of the three species of smaller diurnal seabirds breeding on Gough Island, skuas (*Catharacta skua hamiltoni*) are the most widespread, being commonly seen both inland and around the coasts. Swales (1965) estimated the skua populations at between 2000 and 3000 pairs. He noted the Antarctic tern (*Sterna vittata*) as 'abundant' with some 500 pairs nesting on cliffs between Haulround Point and South Point; and the noddy (*Anous stolidus*) as 'common', but probably less abundant on Gough than at Nightingale and Inaccessible.

The two resident land birds are both endemic to Gough Island. The moorhen (*Gallinula nesiotis comeri*), first noted in 1888-89 (Allen 1892;Verrill 1895) is very like *Gallinula nesiotis nesiotis* of Tristan da Cunha (Beintema 1972). The presence of these two populations of very similar flightless land birds which have clearly diverged only recently in evolutionary history, on islands some 350 km apart poses some problems in evolutionary biology. It is possible that both derived from fairly recent simultaneous colonization of the islands by wind-drifted vagrants from South America. It is also possible that the Gough Island moorhen was introduced to that island from Tristan just as the present Tristan population may be a re-introduction from Gough. But the evolution of similar flightless forms of invertebrates on different islands in the Tristan-Gough group seems to be a widespread phenomenon (Holdgate 1965) and in this sense the *Gallinula* subspecies conform to a general pattern rather than stand out as exceptions. The total world population of *Gallinula nesiotis* on Gough Island, Tristan da Cunha and in various zoos in Europe and North America probably numbers only a few thousand birds (Swales, personal communication). On Gough Island, it is confined to fern bush and tussock grassland and does not occur above an altitude of about 450 m (Holdgate 1958; Elliott 1969). In captivity it has bred freely (first recorded by Wilson and Swales 1958) and has probably interbred with *Gallinula chloropus* in England and run wild there (Swales, personal communication).

The other species of resident land bird, a bunting or finch *Rowettia goughensis* is more numerous than the moorhen and occurs all over the island. It is considered a more recent arrival than the finches of the Tristan group (H. F. I. Elliott, personal communication), having diverged to a much lesser extent from supposedly ancestral forms in southern South America. It resembles the black-throated finch or 'sparrow' of the Falkland Islands (*Melanodera m. melanodera)* and its mainland relative in southern Argentina and Tierra del Fuego (*M. m. princetoniana*), but there are substantial plumage differences. In the Gough Island species the adults of both sexes are greenish-yellow in hue, with dark markings on the throat and cheeks: the newly fledged young are darkly speckled on a pale brown background and the immature, probably first-year birds, are more lightly speckled in dark brown on a pale brown ground. The Falkland birds differ first in that the adult male is more vividly coloured, with a slate blue head and mantle and much darker throat patches. Secondly, the adult female *M. m. melanodera* has a speckled brown plumage very like the immature *Rowettia* (Woods 1975: Carins, personal communication to N.M.W.: M. W. H., personal observations). The Falkland and Gough Island species are very similar in behaviour and feeding habits, taking a wide range of small seeds and invertebrates from inland habitats and along the beaches: the Gough species also scavenges for food in garbage cans at the meteorological station in Transvaal Bay (Elliott 1970a).

Eighty one species of land invertebrates have been reported from Gough Island. This total does not include ten or more species of spider, yet to be

identified, which are abundant and ecologically important. Nor does it include the soil fauna of mites, Collembola and nematodes which are abundant and fairly diverse. Of the recorded invertebrate fauna, some eight species are restricted to Gough and another fourteen endemic to the Tristan-Gough Group. Nineteen species of introduced invertebrates have been recorded and there are twenty-two others whose status is doubtful. Many of the most important invertebrate species occupy a wide range of habitats, in common with the food plants on which they depend, which also range widely. In contrast to the northern islands—and especially Nightingale and Inaccessible—Gough is relatively sparsely inhabited by endemic species of those groups that show wide radiation: there is but one listroderine weevil (also found on Tristan) and two species of drosophilid flies (*Scaptomyza*).

5. 5. 4 Alien fauna and its effects. Mice (*Mus musculus*) are the only alien vertebrates which have established themselves on Gough Island. They are very numerous all over the island. Although a nuisance to man, they probably have little effect upon the native biota, except perhaps in limiting the regeneration by seed of large-seeded species such as *Sophora microphylla* and the tussock grasses. Sheep were kept at The Glen from 1956, but are not now allowed to be landed. All sheep were destroyed in 1963 when the meteorological station was moved from The Glen to its present site at Transvaal Bay. They apparently did little damage to the vegetation in The Glen, to which they were confined, and even the Falkland tussock grass (*Poa flabellata*) which is known to be extremely sensitive to grazing (Davies 1939) has not suffered greatly in the area where the sheep are kept.

A goat and a dog, each landed in 1957 were destroyed or removed. Poultry are the only vertebrates at present allowed to be imported to the island. About two dozen fowls are kept in a wired enclosure near the Transvaal Bay meteorological station, and their numbers replenished annually. They pose no direct threat to the native ecosystem. On the other hand, the possibility of introducing avian diseases remains, and it is suggested that this risk may outweigh the benefits conferred on the station by this very small flock. A review of policy is suggested. Only one newly arrived alien plant (*Agrostis lachnantha*), could be detected at the meteorological station in May 1968, and possibly owes its origin on the island to import with chicken feed. There are no rats on the island (although a long-dead carcase found in a crate landed at the Weather Station in 1968 provided a reminder of the constant risk of introduction), and the landing of any domestic animals such as cats is prohibited.

Nineteen species of alien invertebrates have been recorded from Gough Island (Holdgate 1965). These include earthworms (*Lumbricus sp.*). slugs (*Milax gagates* and *Agriolimax reticulatus*), gastropods (*Oxychilus alliarus*), woodlice (*Porcellio scaber*), and a number of insects, including the blowflies *Calliphora vomiloria* and *Lucilia sericata.*

In 1955-56 large earthworms were abundant on the uplands of the island, but virtually absent from the peaty soils of the fern bush. In May 1968, however, they were abundant in the fern bush of The Glen, and also in tussocks above the shore on the northeast coast of the island and in the soil of fern bush around the new Meteorological Station above the South Coast. In part there appears to have been a genuine change in the abundance of these animals over a twelve-year period, but since they are now so widespread at low levels it seems unlikely that they were completely absent there in 1955-56 as was assumed at the time (Holdgate 1965).

A more certain change has occurred in the distribution of slugs. In 1955-56 specimens were found only on lettuces imported to Gough Island from Tristan and planted in the mouth of The Glen. In 1968 slugs were abundant in the fern bush of The Glen up to 500 m inland and up to the crest of the ridge between the mouths of The Glen and Sophora Glen. No slugs were found elsewhere on the island. The centipede *Lithobius melanops,* also believed introduced from Tristan in 1955 (when one individual was found under a packing case in The Glen) was abundant in 1968 at the mouth of the valley but nowhere else. By analogy with Tristan this species may also be expected to spread slowly into undisturbed native habitats. As a result of these introductions, the soil and litter fauna of Gough island, like that of Tristan, is becoming dominated by large alien invertebrates but these are filling niches hitherto vacant rather than replacing native species.

5. 5. 5 Human Activities, Vulnerable species, Summary. The furseals and some of the larger seabirds were reduced in numbers until about 1900 by sealing gangs. Parties from Cape Town are known to have taken eight tons of guano, 4000 penguin eggs and 151 sealskins, probably all from Gough Island, in 1881 (Cape Argus 1881). Since 1900, and apart from the small numbers of elephant seals (for sale to zoos), and albatrosses and penguins taken illegally for fishing bait since the start of commercial crawfishing operations in 1951, man has had no influence on the size of stocks, which have recovered from the sealers' onslaughts in the nineteenth century. The taking of furseals (for pelts) on a small scale occurred illegally in several years prior to 1955/56, and since then a few hundred have been taken by the fishing company under permit from the Tristan administration. Calculations based on a census in 1955/56 (Swales 1956) suggest that up to 450 immature animals could safely be taken each year, but owing to wide differences in the accessibility of the beaches it is difficult to spread any such harvest evenly. A larger crop could now be taken from the increased population. The average number of seals taken over recent years certainly falls well below the sustainable yield. The inaccessibility of the main furseal breeding grounds which are on the west coast, below high cliffs and washed by an almost incessant swell, makes them a natural sanctuary, and thus safeguards the population from any but the most determined sealers.

Some moorhens and buntings, as well as seabirds, have been taken from Gough Island since the start of the commercial fishery in 1951, both illegally and under licence from the Tristan administration, for sale to zoos and museums. Such traffic is now regulated by a careful issue of permits, the number of which needs to be kept under constant review if over-exploitation is to be avoided.

In summary, the terrestrial ecosystem of Gough Island remains almost untouched by man although certain plant and animal communities there are known to be extremely sensitive to man-induced disturbance. The tussock grass *Poa flabellata,* which covers large areas on the coasts is rapidly destroyed by grazing domestic animals (Davies 1939) and is very susceptible to fire. The enormous populations of breeding seabirds are extremely vulnerable to imported predators such as cats, rats or dogs, which would rapidly reduce them if allowed to establish themselves ashore. Direct human predation on commercially valuable animals such as furseals, and the killing or capture of specimens of the endemic fauna for sale to zoos and museums (notably the flightless moorhens and the buntings) probably constitutes the greatest potential danger to the native fauna. The taking of penguins and seals for crayfish bait is also a danger, although the use of synthetic baits and improvements in the design of craypots may reduce this danger in future.

So long as the present regulations covering human activities ashore (and especially the importation of alien species) are enforced, the native ecosystem of Gough Island should remain in its present condition indefinitely. The continued importation of poultry should, however, be reconsidered in view of the risk of introducing diseases (cf. Warner 1968). Because of its nearly pristine state, and its enormous population of breeding seabirds, Gough Island perhaps has a greater potential value for monitoring of the marine and atmospheric environment than any of the other islands in the Tristan-Gough Group (Wace 1972).

5.6 THE MARINE BIOTA

5.6.1 Although less dramatically productive than the waters south of the Antarctic Convergence (El-Sayed 1970, 1971), the seas around Tristan and Gough Island are rich in marine life. Inshore waters support large populations of cryfish, demersal fish and seals. The teeming seabird life of the islands depends (especially during the breeding season) on the productivity of the marine ecosystem within a few hundred miles of the islands (Murphy 1962).

This marine fauna has not been studied in great detail from an ecological standpoint, although collections of many taxonomic groups made around the Tristan Group (but not Gough Island) by the Norwegian Scientific Expedition of 1937-38 have been reported on in their Expedition Results (Nos. 8, 12, 16, 19, 21, 29, 33, 45, 49, 51, 52, 53). Earlier collections, including deep water dredgings around Gough Island, were made by S. Y. *Scotia* in 1904, the German oceanographic vessel *Meteor* in 1925 (Stocks, 1953), RRS *William Scoresby* in 1927 and RRS *Discovery II* in 1930. The records of the Gough Island littoral are summarized in Chamberlain, Holdgate and Wace (in preparation). A few dives, made recently, suggest that the shallow-water benthic fauna around the islands is sparse, although sea urchins (*Arbacia dufresnii*) are common (Heydorn 1969).

Marine creatures have been, and still are, the basis of the islanders' commerce, but few groups have been systematically investigated in all the islands, or their abundance described. Those breeding ashore (seals and seabirds) have been considered already. The products of the seas of which some accounts have been published, or which are commercially important, will be briefly considered here. So far as is known, no marine species has been introduced to the island waters by man.

5.6.2 Seaweeds. The marine algae of the Tristan Group were described by Baardseth (1946), and of Gough Island by Chamberlain (1965). An ecological account of the littoral algae and associated fauna of Gough Island is in preparation (Chamberlain, Holdgate and Wace). Extensive kelp (*Macrocystis pyrifera*) surrounds much of the coast of all the islands, rooting to a depth of about 20 metres offshore (Heydorn 1969). Thick beds of bull kelp (*Durvillea antarctica*) grow on the sublittoral fringe of Gough Island, but this species is not found in the Tristan group.

5.6.3 Fish. Current knowledge of the fish of Tristan and Gough waters has been summarized by Rowan and Rowan (1955) and by Penrith (1967). Although Tristan surface waters are some 5°C warmer than those around Gough, almost all eight species of coastal fish known from Tristan reach Gough also, and the apparent absence of most of the fifteen species of oceanic fish from Gough is thought to be due to under-collecting there (Penrith 1967).

5.6.4 Crayfish. The crayfish *Jasus tristani* is found from close inshore to depths of at least 400 metres round all the islands. Because of the steeply

shelving underwater slopes from which the islands are built up, there is little area of less than this depth except around Inaccessible and Nightingale. Crayfish have been exploited commercially since 1951, and the catch size and the future stability of the population is considered below (6. 2. 8).

5. 6. 5 Whales. Two species of whale frequent the waters in the vicinity of the islands to a degree that has rendered them important as a resource to man. The southern right whale (*Eubalaena glacialis australis*) breeds around the main island, and until 1962 was common offshore in the spring. The sperm whale (*Physeter catodon*) is also found in Tristan waters, mostly during the summer. Both species, as well as smaller cetaceans, were hunted intensively between 1830 and 1870 near the islands (Wace 1969), mostly by American whaleships. Although trading with these vessels dominated the economy of the islanders at the time, no shore-based whaling has ever taken place from any of the islands.

Whales are now much reduced in Tristan waters, as elsewhere, despite official protection under the International Whaling Convention. During 1963 a Russian whaling fleet illegally took many right whales off Tristan, greatly reducing the local population which was later said to number only a dozen adults and some young (Flint 1967). The islanders themselves now set no value by the whales, which they tend to regard as a nuisance, since their boats have occasionally been bumped by them, and there are local traditions of boats being upset on trips to Nightingale (Green, personal communication).

Future Development of the Islands' Resources, and its Impact on their Ecosystems

6. 1 On any conventional view of resource appraisal, the Tristan-Gough Islands and their surrounding seas present only a narrow range of resources for the support of a local human community, or as a source of profit for the islanders or outsiders. The object of this section is to define the resource base of the islands, and to consider the potential of the various resources, and the likely impact of their development upon the native biota.

Almost all the resources of the Tristan-Gough Islands are of recent biological origin. They may be grouped under three headings:

(a) **Extractive:** those resources (renewable or non-renewable) which are exploited by the removal of animate or inanimate materials present in the islands before the arrival of man (6. 2)

(b) **Agricultural:** those resources whose value depends upon the use of the altered insular ecosystems by imported plants and animals, under a regime of tillage, grazing or cropping (6. 3)

(c) **Ancillary:** intangible resources whose value depends upon the special strategic, recreational or scientific qualities of the islands (6. 4).

Most of these resources may be exploited to improve the standard of subsistence of the islanders, for commercial profit by outsiders, or for a combination of both of these ends. The development of any one resource may greatly affect the availability of others for future exploitation, but they will be considered separately here before the effects of various combinations of exploitation pattern are discussed.

6. 2 Extractive Resources

6. 2. 1 The only potentially valuable **mineral** that has been found (or might be expected to occur) in the islands is sulphur; but the deposits are very small, and the costs of extraction and transport would be far too high to make any export worthwhile, especially since there is a present world surplus.

6. 2. 2 Quarrying of tuff for house construction, of beach sand for cement, and of rock scree for roads is carried on near the Tristan settlement, but has little impact on the local environment or on its largely alien biota. Ample supplies of these materials are available near the Settlement for all conceivable future use, but quarrying may pose threats to environmental stability if roads were constructed up to the Base on Tristan (5. 2. 5).

6. 2. 3. Peat occurs in one small bog near the Tristan settlement, and extensively on the uplands of Tristan and Gough and on the smaller islands. It has never been used as a fuel (or for any other purpose) by the islanders. The deposit near the Settlement is too small to be of much use, while the labour of carrying peat down from the Base on Tristan to the Settlement would make it unattractive as a source of fuel, when compared to firewood which could be grown nearby (see below, and 6. 3. 3).

6. 2. 4 There are no native **land plants** that could form the basis of any commercial extractive industry. The native tree *Phylica arborea* is too small and crooked to have much use for constructional or fencing purposes, but cutting for firewood has already seriously denuded the Cliffs and Base nearest to the Settlement on Tristan, and reduced the area of the wood patches near the huts

on Nightingale. Local generation of electricity, and the importation of kerosene has already helped to relieve this pressure on the stocks of *Phylica,* but planting of suitable trees for constructional timber, fencing posts and firewood (6. 3. 3) could further protect it and provide a better fuel.

6. 2. 5 **Guano** deposits from penguin rookeries on the smaller islands are used casually by the islanders to fertilise their potato patches, and trial shipments have at times been exported. Analyses (e.g. Wild 1923) have shown that the material is of poor quality because of leaching of nutrients in the high rainfall and this, coupled with the small amounts available, together with the difficulties of collection and the extremely high costs of transport, would not warrant the establishment of any export industry. So far as is known, there are no phosphates or other minerals of older biological origin on any of the islands.

6. 2. 6 **Kelp** cast ashore on the beaches is used locally to fertilise the potato patches on Tristan. However, Goh and Whitton (1975) have shown that kelp extract has little effect in promoting growth of white clover in New Zealand. Seaweeds are cropped commercially for alignates, but it is doubtful whether either *Macrocystis* (round all the islands) or *Durvillea* (in the littoral of Gough Island) which are the only two species of large accessible seaweeds growing in abundance, could be harvested and exported economically. Since *Macrocystis* is important in subduing the ocean swell around the islands, its removal (at least from the vicinity of landing beaches) would be unwise.

6. 2. 7 **Furseals** (especially on Gough Island) have recovered from overexploitation in previous centuries, although their continuing increase is an indication that they have not reached the maximum numbers that the islands could support. Killing of seals is now prohibited, although poaching for crayfish bait, for belts, or for sale to zoos has led to prosecutions recently. The furseals could be cropped, especially if their numbers are allowed to increase further, as a supplement to the islanders' economy: but there is no reason to suppose that they would ever attain the breeding densities now existing on the Pribilov Islands, and formerly recorded from South Georgia, the South Shetland Islands, and the Juan Fernandez Islands. Suitable breeding beaches in the Tristan-Gough group are short, and many of the coasts most frequented by the seals are extremely rugged and exposed, and difficult places from which to extract either carcases or pelts. Even with the most careful management, it seems unlikely that seals could become a resource of major economic significance to the islanders. Moreover, the present climate of opinion does not favour the killing of marine mammals, and markets for seal products could not be guaranteed, at least in the United States.

6. 2. 8 Several species of Tristan fish, notably *Acantholatris monodactylis* ('fivefinger'), *Decapterus longimannus* ('mackeral'), *Thyrsites atun* ('snoek'), *Helicolenus tristanensis* and *Sebastichthys capensis* (both called 'soldier fish') and *Seriolella antarctica* ('bluefish') are caught by the islanders for food, but none has been the basis of any commercial fishery, although numbers are taken by the crews of crayfishing vessels and deep frozen for later sale by individuals in Cape Town. Previous attempts to start a fishing industry in the islands in 1908-09 failed; probably as much due to the difficulty of enforcing a labour contract with the islanders, as to the difficulty and expense of storing and exporting the products (Munch 1971). Some species, such as bluefish and snoek (both of very high food quality) might be frozen for export or processed for fishmeal, but assessments of fish stocks have already been made with this in mind, and it seems unlikely that such exploitation could become important, ex-

cept perhaps for sale to visiting ships (6. 4. 2) or as a supplement to commercial crayfishing (6. 2. 9).

6. 2. 9 Extraction of **crayfish** (*Jasus tristani*) has become the economic mainstay of the human community since commercial operations were established in 1949. The crayfish are taken at depths down to c. 400 m (200 fathoms) round all the islands. The most extensive areas of less than this depth are found around Inaccessible and Nightingale Islands, but it is rarely possible to fish on these grounds because of exposure to wind and swell away from the lee of the islands.

Figure 12 shows the total annual catch from all commercial crayfishing operations round all the islands since 1952/53. Such data can give little indication whether exploitation is within the limits of an indefinitely sustainable yield, because no size gradings are available for most of this period, and there are few records of the catch around different islands. Different vessels, different fishing techniques, and different numbers of fishermen and fishing days (i.e. a different fishing 'effort') have also been employed at various times.

Heydorn (1969) compared the carapace lengths and sex ratios in exploited populations of *J. tristani* from Vema Seamount, Gough and Tristan waters. He found that in the overexploited population at Vema Seamount, the mean carapace length of both sexes fell by some 3 cm, following three years intensive fishing but that this trend was far more marked in the males than the females and that the overall percentage of females at Vema rose from 22. 2 per cent to 74. 6 per cent. The sex ratios of the Gough and Tristan populations sampled in April 1967 after some eighteen years of controlled fishing did not show the same high female ratios as those on Vema after only three years of uncontrolled exploitation; but the Gough and Tristan data are scanty, and Heydorn stated that 'conclusions about the effects of exploitation on the rock-lobster resources of Gough Island and Tristan da Cunha cannot be drawn from the results obtained during the present investigations'.

Figure 13 shows the breakdown of the total catch according to percentages of crayfish in the different tail weight categories since the 1965/66 season. The total number of fish caught has fluctuated between 1.75 and 2. 5 million per season over the last six years but the proportion of the smallest grades in the total catch has been increasing up to its present level of forty per cent of the total annual catch. Although it may seem from these data that the resource as a whole is being overexploited, it is impossible to be sure of this until more data are gathered on the whole fishing operation, and upon the biology of *Jasus tristani.* Analysis of the catches by one of the two vessels operating around the islands during the three seasons 1967/68 to 1969/70 shows that about half of the catch around the small islands came from Gough, but that this proportion is decreasing and that more fishing days are now necessary to obtain the same numbers of crayfish from there. However, there is no breakdown according to size of crayfish taken from the different islands, so that it is impossible to tell whether the fairly constant yield is due to progressive overexploitation of stocks around different islands, or whether the resource as a whole is being managed on the basis of an indefinitely sustainable yield.

Unlike the isolated population of *Jasus tristani* in the calmer waters of Vema Seamount, the crayfish around Tristan and Gough are to some extent protected by the inaccessibility of much of the fishing grounds, due to exposure and the proximity of rocky coasts. Heydorn (1969) said that eleven fishing days per month were considered good at Tristan, where fishing generally has to be carried out in the lee of the islands.

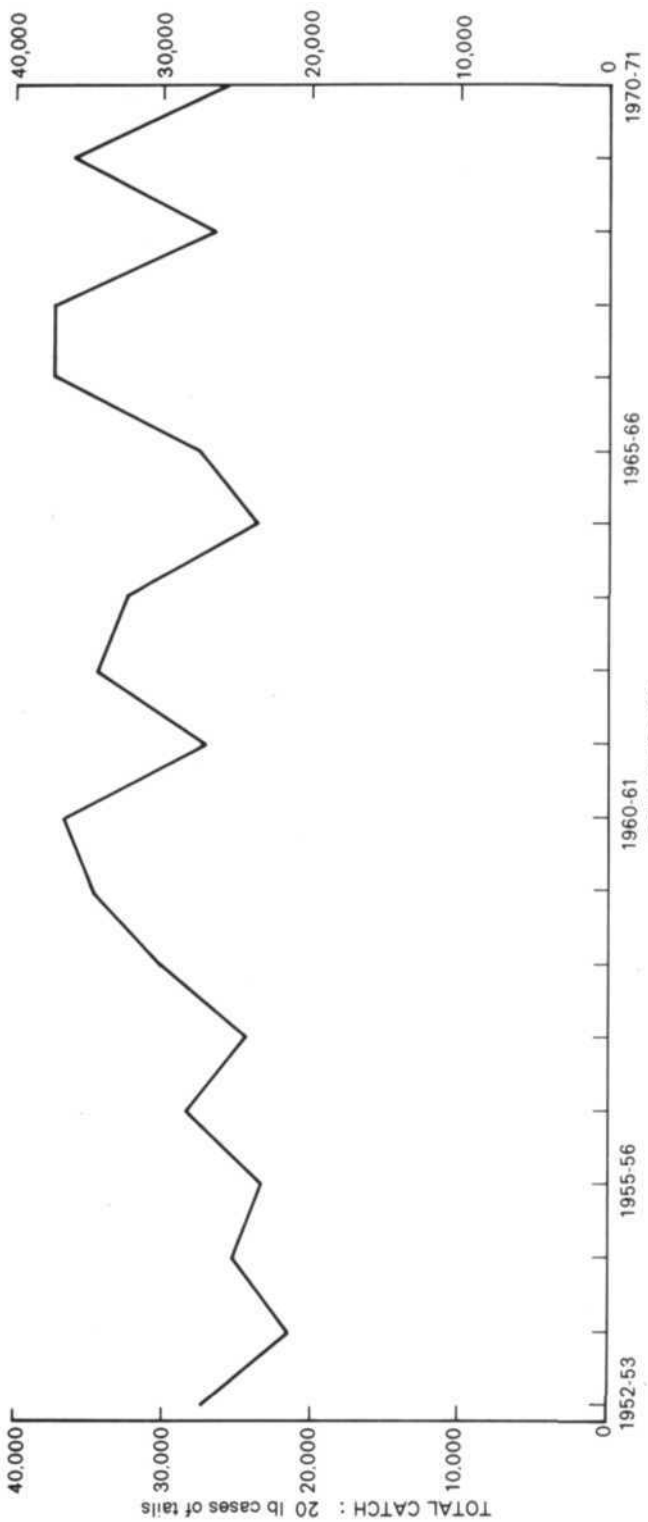

Figure 12.
Total crayfish catch from the Tristan-Gough Islands, from the fourth season of commercial fishery in 1952/3 to the 1970-71 fishing season. Data from Tristan Investments Pty. Ltd. Cape Town.

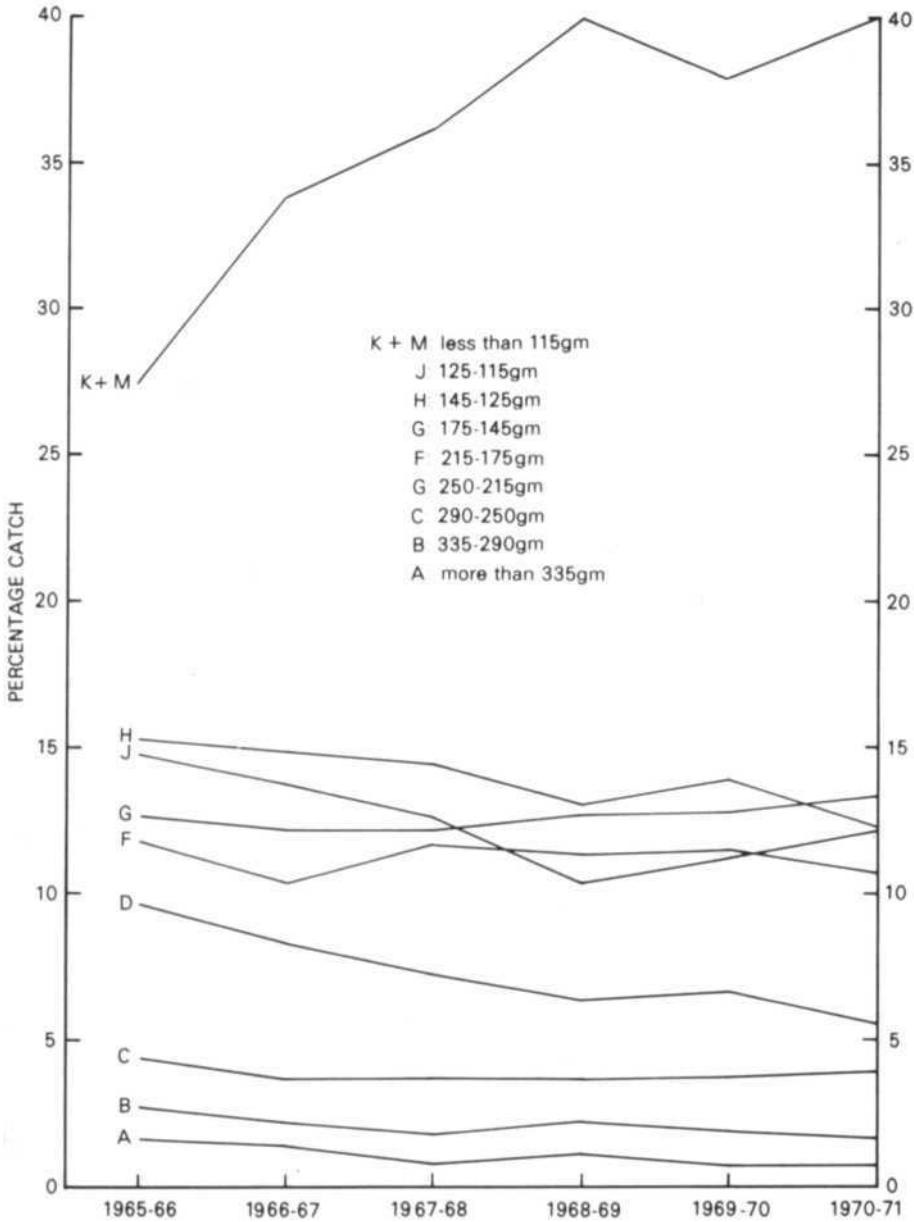

Figure 13.
Tristan-Gough Islands, crayfish catch 1955/66 to 1970/71 in size categories (tail weights) expressed as percentages of total catch from all the islands. Data from Tristan Investments Pty. Ltd. Cape Town.

Since crayfish are the single most important resource upon which the whole economy of the islanders depends, and since any decline in stocks would probably lead to economic hardship and to possibly destructive exploitation of other resources as a short-term substitute, it is critically important that more research be carried out upon the effort expended in the fishing operations, and upon the biology of the isolated crayfish population which is being exploited. Tristan Investments (Pty) Ltd engaged the services of a marine biologist in May 1971 to carry out such a research programme under the general supervision of the South African Division of Sea Fisheries and to establish a system of monitoring the stock.

Experience with isolated stocks of closely related species of crayfish in similar situations at Amsterdam and St Paul Islands (Grua 1960) and at the Chatham Islands (New Zealand Marine Department Reports 1971 and 1972) show that yields from such newly-exploited stocks may fall very rapidly from early levels. In the case of the Chatham Islands crayfishing, however, it is not clear whether declining yields have been due to a removal of surplus mature animals (mostly large males) from the hitherto unexploited populations (as suggested by Kensler 1969), or whether the fishery has been permanently impaired by gross overexploitation (Arbuckle 1971).

Bonanza crayfishing in the Chatham Islands from 1966 was associated with intense competition between many boats (Arbuckle 1971) and overcapitalization on boats and equipment (Eggleston 1972). The monopoly of fishing around Tristan enjoyed by Tristan Investments (but in association with the Administration) puts the islanders in a potentially favourable position to manage the crayfish stocks in their own long-term interests, since competition between independent operators exploiting a 'commons' for individual gain (Hardin 1968) is avoided. Tristan Investments are able to supply capital and equipment on a scale that would be impossible from within the islands, and this is essential if crayfish stocks around the small islands are to be fished effectively and the fishing grounds policed against poachers (whose numbers have recently shown signs of increase). The regular passage of fishing ships between Tristan and Cape Town is also an essential life-line, without which it is doubtful if the island community could now be maintained.

6. 2. 10 Despite their importance as a crop for the islanders, the seabirds in the islands have never been exploited commercially on any scale. In the early 1950s the possibility of exporting small numbers of penguin eggs to supply a luxury market in the Cape was explored (Elliott, personal communication) and there could be renewed interest in this trade now that South African jackass penguin (*Spheniscus demersus*) colonies are no longer cropped because of the threat to their numbers from oil pollution. The rockhopper penguins of Tristan-Gough commonly lay 3 eggs but rear only 1 chick so that carefully managed harvesting could be carried on without harm to the stocks. 'Tossel mats' made from penguin scalps used to be sold to visitors (Munch 1946), but more ambitious plans to exploit the seabirds for feathers (Lockerby 1808, in Im Thurn and Wharton 1925; Barrow 1910), or as the basis of a 'mutton birds' industry came to nothing. It is clear that some seabirds breeding in the Tristan group have been overcropped, just to meet the domestic needs of the islanders (e.g. smaller albatrosses on Tristan and Nightingale). Other species could probably sustain a higher level of exploitation (e.g. great shearwaters), but not enough is known of their population dynamics to manage such cropping efficiently. Although similar shearwaters are harvested and sold commercially in nearby markets as a luxury food in New Zealand and Tasmania it is not clear where a market for such produce from the Tristan-Gough Islands would be found, while

there would be vigorous opposition on conservation grounds to any commercial operations involving the seabirds of Inaccessible, Nightingale or Gough Islands. The seabirds breeding in the islands should therefore be regarded as a resource to be cropped on a sustainable yield basis for consumption only within the islands.

6. 2. 11 Landbirds are unimportant as a resource, except in so far as their rarity and scientific value makes them attractive to zoos or collectors. Although offering the possibility of very considerable profit, the commercial exploitation of any landbirds for this purpose would pose serious dangers to the species, and would be liable to lead to an immediate and rapid reduction in their numbers, because of competition between the islanders (or others) to capture or sell them for individual gain. Some sort of control would be essential to hold the numbers taken well below the sustainable yield, but at present so little is known of the population dynamics of these species that such yields can hardly be determined. Under present regulations, all species of landbirds are protected, and may not be taken except under licence. It is essential that these regulations continue to be rigidly enforced if the species are to survive; yet it is reasonable to allow for capture for zoos or other sanctuaries of small numbers, if these are made the nucleus of captive breeding groups, for this is some insurance to the species against possible disaster in the wild (e.g. should rats gain access to the smaller islands). The small numbers, limited range and high vulnerability to predators make all the Tristan-Gough landbirds 'endangered species' in a technical sense, even though there is no immediate threat to their survival. Any trade in them should be controlled in accordance with the provisions of the Convention on Trade in Endangered Species of Animals and Plants, which the United Kingdom and most other nations involved in the zoo trade signed in Washington in March 1973.

6. 2. 12 Recent developments at the Law of the Sea Conference in Caracas (1974) and Geneva (1975) suggest that there may be some extension of control over the utilization of seabed resources and fishery out to 200 miles from the shores of coastal states. If this happens, the Tristan-Gough Group would acquire rights over a substantial area (about 250, 000 square miles) of the South Atlantic, the mineral resources (e.g. manganese nodules) and pelagic fishery potential of which are not well known. It would clearly be right to survey such resources, which should be managed for the benefit of the island community.

6.3 AGRICULTURAL RESOURCES

Although a number of indigenous plants and animals in the islands have been useful to man on a basis of extractive exploitation, none has been domesticated or found more than a very minor use in agriculture or forestry. These activities rely entirely on imported species. The native flora is of little value for pasture, and has been replaced under grazing pressure by volunteer alien plants.

6. 3. 1 Pasturage Grazing of domestic stock was one of the earliest forms of land use on Tristan. The numbers of cattle and sheep ashore at different times are summarized in Fig. 8. Some poultry are kept in enclosures at the weather station on Gough Island, but all the remaining livestock are confined to Tristan. Difficulties of collecting and transporting any animal products from Inaccessible or Nightingale would make their exploitation for pasture inefficient, and

past attempts to graze sheep and cattle on these islands demanded more effort than the results justified (5. 4. 4).

Except for a small flock of sheep on the Peak, livestock on Tristan are confined to the coastal strips where the poor and over-grazed pastures consist almost entirely of summer-growing alien plants. Little milk is taken from the herd of several hundred cattle on the Settlement Plain, except in the spring, and beef is regarded as something of a luxury. Death from starvation of at least some animals is barely avoided in most winters. These features have probably become important on Tristan since the decline in maritime trading in the 1870s (4. 4 and 4. 5), and are well attested for the early 1900s (Barrow 1910), but they were not characteristic of the early days of the community, when stocks of grazing animals were smaller (Fig. 8), and the fertility of the pasturage probably greater. Today the pasture soils are light, friable and freely draining, with a pH of around 5.0 and low phosphorus and available nitrogen (Jack, personal communication). When first cleared of bush and tussock the organic content would have been higher, and if there had been seabird colonies there comparable with those on the smaller islands, much more phosphate and nitrate also. Leaching and depletion of nutrients by constant overgrazing are presumably the causes of the present impoverishment. The difficulties of the islanders have been increased by their common ownership of the pastures, which were for a long time unfenced, and by the lack of any agreed policy of control of animal numbers, e.g. by the allocation of grazing 'stints' to each household. Some fencing to divide pastures was erected in the 1950s, but in 1968 there was still considerable scope for increasing the productivity of the swards on the coastal strips by more fencing, so that rotational grazing can be enforced. Recently, this has been done (Jack, personal communication) and areas near the Settlement and around the Hillpiece are rotated independently. The number of cows per family has been fixed at 4: bullocks, no longer used as draught animals, are normally slaughtered when 4 years old, and each family is allowed only one donkey.

All these recent developments will improve agricultural productivity. Attempts are also being made to improve the pastures by introducing new pasture plants (particularly clovers). It would be useful to establish winter-growing species and to conserve fodder for winter feed by silage or haymaking. An attempt to establish kale for winter feeding is being made. Increasing the quality (but not the numbers) of cattle kept on the coastal strips would relieve pressure for exploitation of the pastures on the Peak by cattle, which could have disastrous effects upon the stability of the vegetation cover there (5. 2. 5). Grazing cattle on the Base would in any event be unlikely to succeed in view of the harsh climate, coarse herbage and rugged terrain. Similarly, the almost unmanaged cattle at Stony Beach have caused erosion and contributed little: today this herd has virtually been abandoned as a source of stock (Jack, personal communication) and it might be wisest to shoot it out for meat over a period of years. A general improvement in the quality of the cattle near the Settlement on Tristan, with local use of home-grown meat and dairy products could contribute much to the welfare of the islanders without impinging upon the native biota, and would reduce their dependence upon expensive imported supplies.

The number of sheep on Tristan has increased considerably since 1968 and now numbers about 800. These sheep are fenced off the cattle pastures, at the western end of the Settlement Plain, around Molly Gulch and the Bluff, and they have little impact upon the native biota. Sheep might be grazed on the small sections of the coastal strips at present little used (e.g. at Anchorstock Point or Sandy Point). The flock on the Peak might be built up during the summer months, but

some ecological and hydrological research should first be carried out upon the likely impact of sheep grazing on the upland peats, despite the lack of evidence of adverse effects when several hundred sheep were kept on the Base in the early 1950s. Difficulties of shepherding the flock and transporting fleeces and meat down to the Settlement impose limitations on the use of the Peak for pasture, and although transport facilities might be improved (see below), it is unlikely to be worth the enormous cost and labour needed to provide a network of tracks on the mountain for efficient sheep management. In recent years, indeed, there has been a tendency to move sheep off the Peak. The small flock on the Peak in 1968 grazed largely on the volunteer alien plants *Rumex acetosella* and *Holcus lanatus*, and probably had little impact on the native animal life. Norman (1970) has shown that sheep appear to have little effect upon the breeding success of the burrow-nesting seabird *Puffinus tenuirostris* on Big Green Island in Bass Strait, while Fleming (1939) and Wilson and Orwin (1964) considered that sheep grazing actually increased the suitability of the habitat for albatross and other ground nesting seabirds in Chatham and Campbell Islands respectively. Serventy, Serventy and Warham (1971), and Sorensen (1951) maintained that stock grazing reduced seabird breeding in southern temperate and subantarctic islands, but it is likely that any direct effects of sheep grazing on the remaining seabirds of the Tristan Base and Peak would be small.

Two pregnant sows were imported to Tristan in 1969 (St Helena Report 1968-69). Pigs could serve as useful scavengers in the potato patches, and for the consumption and conversion of fish offal, as well as providing a valuable source of locally produced meat. If well managed on a communal basis, they could serve as an integrating factor in the agricultural economy of the island, conserving soil fertility (cf. Darling 1955, p. 392). Pigs should not be allowed to escape to build up a feral stock on the Base or the Peak, where they could not be managed effectively, and where their activities might disrupt the peat cover and exterminate the remaining burrow-nesting seabirds. If pigs are used in the potato patches, infestation with Ascaris should be guarded against, since direct infection of man from potatoes has been a problem on Tristan in the past (Thacker 1963).

Large numbers of geese roamed the Settlement Plain in the 1950s but overgrazed the greensward and may have contributed to local erosion. All of them were destroyed (presumably by dogs) after the eruption in 1961. Geese have not been reintroduced, although a. properly managed flock, together with other poultry, could be a useful supplement to the islanders' diet. Chickens and ducks have been kept on Tristan from time to time, and larger numbers could be raised at the Settlement without any impact on the native biota. Some 200 laying hens and about 60 cockerels were kept at the Settlement in 1968, but many eggs were still imported from Cape Town. Two incubators were purchased in 1971 in order to increase the number of poultry on the island (St Helena Report 1968 and 1969). It is important that any imported poultry be free of diseases which might spread to the native birds, and thence possibly to man, as occurred with ornithosis in fulmars (*Fulmarus glacialis*) in the Faeroe Islands (Fisher 1952). Introduced bird diseases have disastrously reduced the native land birds of the Hawaiian Islands (Warner 1968) and it is probable that the Tristan land birds would be similarly vulnerable to introduced diseases.

6. 3. 2 Tillage in the islands is limited both in extent, and in the range of species cultivated. With the exception of a few potatoes grown casually near the Caves on Tristan, and near the huts on Nightingale, no tillage now takes place away from the Settlement Plain, although attempts were made to set up a market garden, a mixed orchard and experimental windbreaks in the most shel-

tered part of the island at Sandy Point in the 1950s. The potatoes are grown in walled enclosures at the Patches, some 3 km from the Settlement, (Plate III) and the islanders rely on these as their principal source of carbohydrate (Chambers and Southgate 1969). Yields from similar patches, but cultivated by different families vary considerably; and the size of the crop as a whole also varies greatly from year to year, due to diseases (including in very recent years potato blight), rats and above all climatic factors. The annual yield of potatoes was said to average ten tons per family in 1842 (Brierly 1842), and some 130 tons were produced annually by the twenty-five families on the island in 1948-51 (H.F.I. Elliott, personal communication). Before 1952 leaf curl was the only known potato disease on the island (H. F. I. Elliott, personal communication). In 1964-65 the crop failed for the first time from blight (brought in on potatoes taken from a ship); in 1968 yields were again down (due largely to drought) and on both occasions potatoes had to be imported from Cape Town, thus putting the future of the staple crop at permanent hazard from the importation of eelworm or other new pests. Since potatoes are in general very well suited to the conditions on Tristan and very high yields have been obtained experimentally, there seems no reason why the island should not be self-sufficient. It is clearly important for future stability that the staple crop is not threatened with the import of further pests which would make their cultivation still more difficult. With some additional effort directed to improving their cultivation, and controlling existing pests and diseases the island should be completely self-supporting both for seed and crop potatoes. Traditionally, turf and some seaweed (kelp, *Macrocystis pyrifera*) were used as fertilizer on the potato patches. More recently, the use of crayfish offal has been proposed, but this is now exported as an ancillary livestock feed and artificial compound fertilizers are imported. Some kelp is still used, but on a small scale, and diminishing organic content in the soil may pose problems in future (Jack, personal communication).

Some other vegetables are grown in gardens around the houses at the Settlement. In 1968, these included carrots, cabbage, onion and parsnips; but only very small quantities were grown. Horticulture could easily be expanded at the Settlement and this would be an important means of improving the health of the community and lessening their dependence upon cash earned in purely extractive activities, thus contributing to the stability of man/environment relations in the islands. It would be quite possible for one or two islanders to set up as specialists in horticulture, growing vegetables for sale, but social attitudes are against buying and selling within the community and such a development might in consequence, have to be a Government initiative. Extension of horticulture will demand introduction of new plants to Tristan, and each introduction brings with it the inevitable risk of importing plant pathogens and pests. Mention has already been made of how willow aphis and some weevils reached the island in this way (5. 2. 4). Wherever possible, plants should be imported as seed with adequate certification against disease, and all first generation imports should be kept under close inspection. Livestock fodder should not be imported, and growing plants should not under any circumstances be taken to any of the smaller islands, whether directly from outside the Group or from Tristan.

6. 3. 3 Forestry. Attempts have been made from time to time to grow trees at the Settlement, especially to provide shelter but also for firewood, and for constructional and fencing timber, but these have not been successful. Few trees of any size now survive on the Settlement Plain, except for some stunted fruit and pohutukawa trees in gardens, willows near Big Watron, and a pine tree sheltered in a gulch near the bottom of Burntwood. Exposure to salt winds,

damage from stock and attempts to grow unsuitable species are probably the cause of this lack of success. Attempts have recently been made to introduce some suitable Australian and New Zealand species for growth as windbreaks, and as fencing timber and firewood sources on the new lava near the Settlement. The development of suitable species for these needs within reach of the Settlement would protect the native vegetation from further destruction, and lessen the dependence of the islanders on imported timber. The experimental forestry plantation at Sandy Point, established from 1952, where pines, eucalypts, poplars, wattles and willows all seem to be doing well (and where trees were reported in 1974 to be some 30 feet high—Jack, personal communication), is difficult to exploit because of the distance from the Settlement, and the impossibility of handling large trees on very steep slopes without powered machinery.

The future development of Tristan's agriculture and forestry, could greatly decrease the dependence of the islanders on money earned from purely extractive activities, and thus indirectly help to preserve the existing biota while simultaneously improving the economic and medical health of the community. With the exception of the use of the new lava near the Settlement for forestry, and the possible redevelopment of the lower part of the Tristan Peak for grazing sheep, any such initiatives should take place on land already used for such purposes on the coastal strips of Tristan. There is plenty of land available in these areas to sustain a much more productive agriculture than at present, if management continues to concentrate on increasing the fertility of the swards and the quality of the produce. Any extension of grazing, tillage or forestry to other parts of Tristan, or to the other islands, could only be on an extensive and lightly-managed basis, and would be unlikely to provide the same benefits as more intensive use of the lowland strips. Farming on the small islands would also immediately lessen their value as wildlife refuges for exploitation by the islanders (as on Nightingale) or for their scientific interest (see below). Extraction of the products of any such development would also be so difficult and expensive as to call in question the economic viability of any such schemes. All these considerations reinforce the wisdom of the present policy of the Island Council and Administration in devoting their efforts to enhanced agricultural efficiency in the Settlement area.

6.4 ANCILLARY RESOURCES

The activities grouped here are those which rely upon the intangible characteristics of the islands, such as their geographic position, their scenic or romantic appeal for recreation, or those features which stem from their importance in scientific investigations of man or other organisms, or of the local or global environment.

6. 4. 1 Strategy and communications. The early interest of European maritime powers in the Tristan Islands was based on civil and military strategic considerations (Wace 1969), but since the replacement of sailing by powered vessels and the cutting of the Suez Canal, the Tristan Islands have not lain on or near any important shipping route. Although they are near the great circle route from Cape Town to the River Plate, most vessels avoid them because of storms and the danger of shipwreck. The Tristan harbour admits only the smallest boats: there is only uncertain shelter for ships, and the islands produce nothing to attract trading vessels. It is difficult to see any changes in this situation, which would bring them into contact with seaborne visitors on passage elsewhere (except for recreational visits by cruise ships: 6. 4. 2). Commercial aircraft flying between South Africa and South America also pass

well north of Tristan. There is no airfield on any of the islands, and because of the smaller width of the South Atlantic and the great range of modern aircraft, the Tristan Islands can offer little advantage as a staging post for inter-continental aircraft, such as that provided on Easter Island in the South Pacific. In the late 1950s and early 1960s there was some speculation in the press (e.g. London Times, 4 Nov. 1963) that a staging post for military aircraft might be established in the Tristan Group, as was proposed at the same time for Aldabra Island in the Indian Ocean. Nothing came of these ideas, and there have been no such proposals more recently. The Tristan Islands, with their mountainous terrain, would present far greater obstacles to airstrip construction and use than the low-lying coral limestones of Aldabra.

The construction of an airstrip on any of the small islands in the Tristan-Gough Group would have immediate and catastrophic effects upon their native wildlife—especially on their breeding seabirds, which would present a severe bird-strike hazard to aircraft. On Tristan itself, any airstrip would almost certainly have to be sited on one of the coastal strips, thus leading to a loss of valuable land for agriculture. Any airfield in the islands would lead to a sudden and accelerated breakdown in the biological isolation, and the rapid arrival of continental species. It would also increase the dominance of the island community by outside interests, make it even more dependent upon imports, and set in train many of the changes that mass-transport and tourism have initiated in wildlands elsewhere (Darling and Eichhorn 1967). From the point of view of the conservation of their native biota, an airfield on any of the Tristan-Gough Islands would be a disaster. There would, of course, be economic benefits to the island community from the influx of money and the easier communications that an airfield would bring; but there would also be a risk of severe ecological and social disruption.

Any former naval strategic value of Tristan was lost when trade routes from the North Atlantic to the Orient and Australasia were diverted from the westerlies to the Mediterranean and the Cape of Good Hope. The islands are too far from the Cape route to warrant anything but the most cursory attempt at fortification, and lack of any harbour or even a sheltered anchorage prevent their being used as a naval base or victualling station. During World War II, a British naval communications facility was maintained on Tristan from 1942 to 1945, to watch for submarines or surface vessels raiding trade routes.

Despite the increased use of the Cape shipping route during the closure of the Suez Canal from 1967 to 1975, there is little reason to expect any change in the strategic importance of the islands which might lead to the establishment of overt military establishments ashore, although they may have a value as ground stations for locational purposes. Modern navigational systems based on positioning from artificial satellites, demand precise location of isolated sites for repeater stations. Already, the US Coast and Geodetic Survey has had a surveying party on Tristan taking sightings at passing satellites, and a small naval communications and navigation facility could be established there in order to cover the Southern Atlantic and Western Indian Oceans. This, if it incorporated a meteorological observatory, and increased the scientific presence in the islands, could be an asset to the community (6. 4. 3. 4).

6. 4. 2 Tourism. In 1786 Alexander Dalrymple suggested the establishment of a convict settlement in the Tristan islands in preference to Botany Bay in New South Wales (Wace 1969), but tourism is now a more likely form of recreational use of the islands, although there are no facilities for accommodating, victualling or entertaining tourists on the island at present. Several cruise

liners have called at Tristan annually in some recent years, but passengers are often prevented from landing by the heavy swell. Gough as well as Tristan has been included in the itinerary of cruise vessels returning from the Antarctic, but sea landings are even more difficult on the smaller islands, and helicopter landings would be hazardous, due to atmospheric turbulence, steep terrain and bird strikes.

The scenic and wilderness appeal of the islands for tourists might be assessed very highly, for those interested in energetic outdoor pursuits and natural history, but any opening of the smaller islands to this type of activity on any but the smallest scale would rapidly affect their native biota, unless rigid controls were imposed on numbers of visitors, and on their behaviour when ashore. Landings depend upon changeable and unpredictable weather and sea conditions, and would make regular commercial tourist schedules involving landing and re-embarkation impossible to maintain. The visits of cruise vessels to the island are inevitably brief and intermittent. The islands do not present the kind of environment, or possibilities for mass enjoyment of the type of experiences sought by most tourists: the weather is extremely changeable and often wet and stormy, bathing is cold and dangerous, sandy beaches are few and both the coasts and the mountains extremely dangerous to the unfit, and those unused to rugged experiences. Since 1956 three fit young men stationed at the South African weather station on Gough Island have died of exposure when benighted on the uplands. There is also little in the way of a native culture on Tristan that could be commercialised and sold, and almost no social life as understood by the majority of tourists. It is therefore unlikely that the provision of shore accommodation for tourists on Tristan would be economically worthwhile. Except possibly for small parties of naturalists and adventurers, recreational use of the islands is hardly feasible. Any attempt to promote mass tourism would greatly affect both the human population and the native biota in the islands, and would diminish their appeal to those for whom they have the greatest inherent interest.

6. 4. 3 Philately. Tristan relies heavily on the sale of its postage stamps as a source of revenue, although the proportion of income coming from this source has declined over the last few years. Most of the Tristan stamps are sold direct to dealers or collectors and go nowhere near the islands. Most of the stamps that are franked on the island adorn the empty letters of stamp dealers or philatelists. They are therefore produced primarily to meet the needs of collectors, rather than as prepayment for the transmission of messages, and Tristan postage stamps can therefore be seen as tokens of a kind of vicarious tourism. As such they could be considered part of the recreational resources of the islands.

New sets of postage stamps have been issued recently at the rate of one large 'definitive' set (with a complete range of twelve or more denominations) every four to five years, and one or two small sets (of about four stamps each) every year. Expansion of these numbers above what philatelists maintain is the genuine postal demand might lead to resistance on the part of the collectors, and a resulting decline in profit. Tristan stamps are now much sought after (Lake 1969), and regarded as a sound investment by collectors (Garden 1967, Williams and Williams 1970). The islands may already be operating near the maximum sustained profit from this source of income, although there appears to be no clear relation between the number of stamps issued (or their face values) and the profits made through the post office in the same or subsequent years.

6. 4. 4 Science. Studies in the natural sciences on the islands have been summarised in section 4. 9. Medical and sociological work on the islanders (much of it carried out on Tristan) is outlined by Lewis *et al.* (1963), Lewis (1969) and Munch (1971). Some modern developments are likely to increase the scientific value of the islands for research purposes in future, and these are considered below.

6. 4. 4. 1 ***Environmental monitoring.*** As the earth's human population increases, and the range and scale of human industrial activity expands, there is a pressing need for world-wide monitoring of the environment for pollutants, and other side-effects of human activities (Munn and Bolin 1971, Munn 1973). Remote islands in which there is no industrial activity, and which are distant from large concentrations of human populations, are particularly valuable sites from which the monitoring of both the atmosphere and oceanic waters may be carried out, in order to detect any overall (as opposed to purely local) changes in the quality of the environment. Situated in the centre of the South Atlantic athwart the oceanic subtropical convergence, and within the southern hemisphere westerlies, the Tristan Islands would be good sites from which such sampling of the southern maritime air masses and southern temperate waters could be carried out. Sampling of marine animals and seabirds would extend monitoring to certain persistent materials (such as PCBs) which tend to accumulate in the tissues of predators and are therefore readily detectable in this situation, but are found at concentrations too low to be detected in the sea itself, or in organisms living at lower trophic levels (Wurster and Wingate 1968, Cox 1971). The establishment of environmental monitoring facilities in the islands could be linked to the existing meteorological base on Gough Island, and that proposed for Tristan.

Since remote islands are likely to acquire an increasing value for these purposes in future, it is very important that any activities which might pollute the environment from purely local sources be discouraged, and that adequate records and close control be kept of the import and use of synthetic biocides such as DDT on Tristan, and that such substances are kept off the smaller islands altogether.

6. 4. 4. 2 ***Biology.*** Scientific interest in the biota of oceanic islands has grown since the classical studies of Darwin and Wallace. The future of biological research in the Tristan Islands has been discussed by Wace (1965, 1966), and various proposals have been made for some of the islands to be declared sanctuaries (e.g. Holdgate 1957) on account of the interest and vulnerability to human activities of their indigenous wildlife. A new wildlife conservation ordinance has recently been enacted (see Appendix, p. 108).

Apart from studies of the use of the biota through extractive activities such as crayfishing or agriculture, and the monitoring of bird populations for pollutant levels in seabird tissues already mentioned, biological research interests in the flora and fauna of the islands as a whole are likely to increase because of their greater accessibility, international economic interest in the marine resources of the Southern Ocean, and a general awareness of the importance of environmental studies. Such an increase in research interests in the biota of the islands could not be catered for without the establishment of better facilities there. The interests of the islanders, as well as those of visiting scientists, could best be served by setting up a small research facility in the Tristan Settlement (see below).

6. 4. 4. 3 ***Medicine and Sociology.*** The enforced evacuation of the Tristan

islanders to England in 1961 led to a very great interest in their medical biology and sociology. A variety of medical studies (formerly coordinated on behalf of the British Medical Research Council by the late Dr Harold Lewis) on the islanders continues. Social changes within the Tristan community as a result of the evacuation are also a subject of continued research (Munch 1970, 1971). In any continuation of these studies, it is important that their primary objective should be the welfare of the islanders rather than the more intellectual curiosity of visitors, and that they should intrude as little as possible on the privacy and the way of life of the community. Such medical and sociological studies would also be facilitated by the establishment of a research facility on Tristan.

6. 4. 4. 4 ***Research Facility.*** All of these various scientific interests in the Tristan Islands and their inhabitants could best be exploited for the benefit of the island community as a whole by the establishment of a small research facility on Tristan along the lines of the Charles Darwin Foundation on the Galapagos Islands (Bowman 1963) or the Royal Society Research Station on Aldabra (Westoll and Stoddart 1971).

A survey was carried out in 1965 and 1966 to assess the scale of interest amongst scientists in research in the Tristan da Cunha Islands (Wace 1965). Some fifty replies were received, almost all from biologists who were interested primarily in ecological studies covering a wide range of organisms, (especially seabirds) and wishing to work on all islands in the group. Geologists, geomorphologists, marine biologists and medical specialists were also interested. It was concluded, in a report to the Southern Zones Research Committee of the Royal Society who established the enquiry, that there was substantial support for a research facility, and that while most would be content with simple facilities on Tristan alone, some (especially medical workers) wanted more sophisticated facilities on Tristan, and some needed access to and shelter on the other islands. Any research facility in addition to helping scientific studies, could serve as a powerful influence in conserving the insular biota from destructive human activities, and it would simultaneously introduce demands for the provision of local supplies and for some employment of islanders. In the case of environmental monitoring and biological research on the indigenous biota, this demand for the services of islanders would be largely away from the Settlement, and in thus re-creating a demand for the declining indigenous skills of the islanders at sea and on the mountain, it would provide a small but important type of employment independent of purely extractive or agricultural activities. Continuing research projects by individual scientists on the islands, could well be combined with teaching commitments in the island school, by the researchers or their dependents, and thus help to relieve the continuing problem of providing a good teaching service on the island.

6.5 SUMMARY

Tristan da Cunha presents a classic case of an extremely isolated human community originally dependent upon simple farming, wildlife cropping and fishing, and now precariously dependent for a standard of living nearer to modern expectations upon economic forces which are external to the community itself, and therefore outside its control.

The main components of the original ecological system on Tristan, and of the system after modification by man, are summarized in Figure 14. Like most

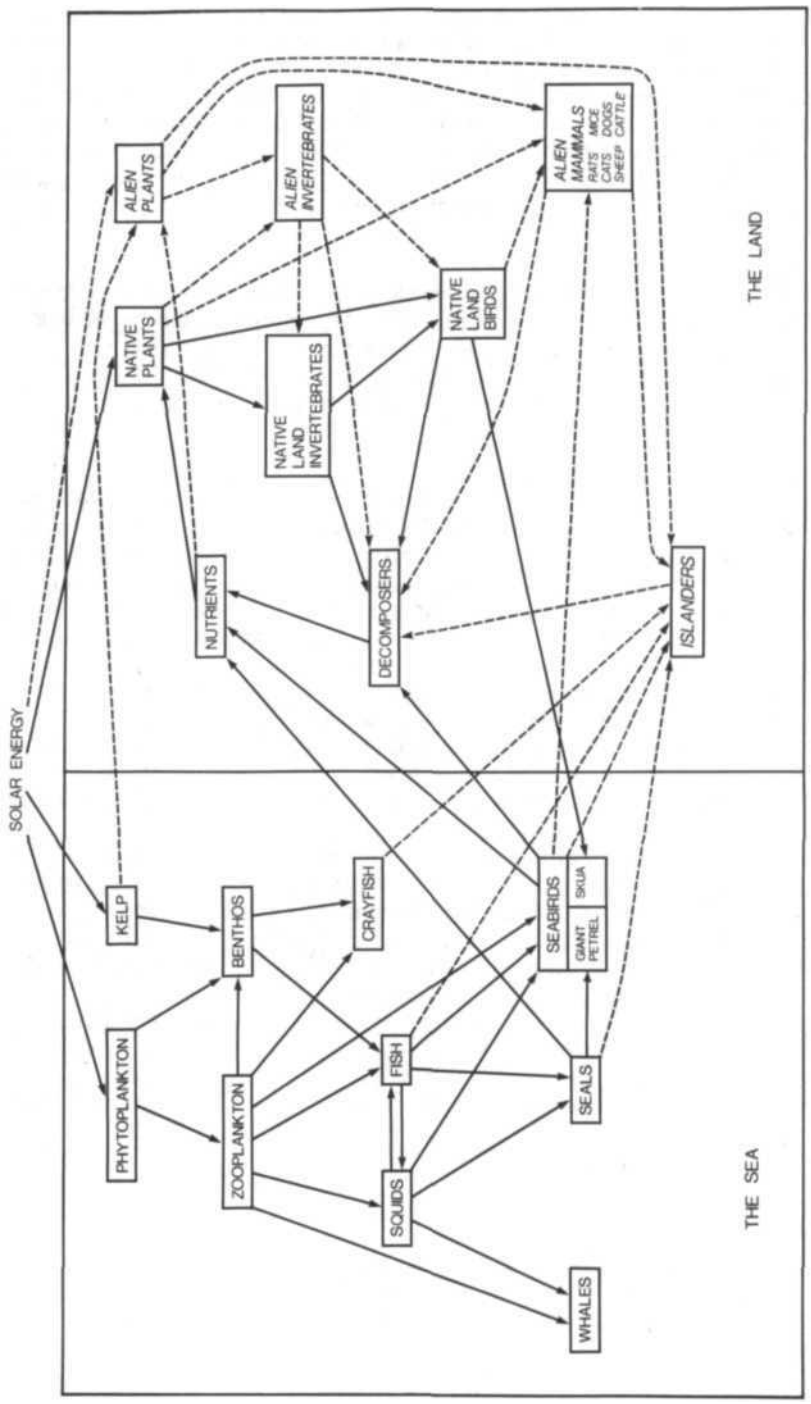

Figure 14.
Diagrammatic summary of the principal energy flows and interactions in the native and modified ecosystem of Tristan da Cunha. Solid lines link components of the native, and dotted lines the modified system.

insular oceanic systems, and especially those of sub-polar zones, marine birds and mammals dominated the highest trophic levels and brought a substantial nutrient flow from sea to land. This was so because the land areas provided these species with abundant space for their small breeding territories, from which they ranged widely to forage in the surrounding ocean. Man's initial impact was to crop those seabirds and seals and so superimpose himself as the summit of the trophic system. But he also modified the system by diversifying the species in the land environment, and reducing the numbers of marine birds and mammals, thereby weakening the nutrient flow from sea to land. The early cropping of seals and birds nearly led to the extinction of both species of pinnipeds in the Tristan Group. The land bird fauna on Tristan island was reduced, and at least one endemic species probably exterminated there, as a result especially of habitat changes due to wood cutting and burning and predation by imported mammals. These habitat changes, predation, and direct exploitation by man account for the severe depletion of numbers and impoverishment of species of breeding seabirds on Tristan. In contrast, there was an augmentation of the flora through the introduction of plants—many of them opportunistic, ruderal species able to exploit the disturbed habitats of cultivation, settlement or grazed pasture and cleared woodland. Many invertebrates were also introduced, including phytophagous insects and soil-inhabiting species. The most marked biotic changes have, however, been more or less confined to Tristan itself, and mainly to a small part of that island. Alien plants and invertebrates have secured a foothold on all the islands, and some species have spread widely, although not yet on a scale that has caused major changes in the insular ecosystems or the aspect of their landscapes.

6. 5. 1 Development. Because recent agricultural developments on Tristan have been intensive rather than extensive (concentrating on the already modified communities of the Settlement Plain and Sandy Point), they have not substantially disturbed the balance established between man and wildlife on that island over the first half of this century. There is no doubt that the yield of the cultivated areas and pastures on Tristan could be considerably increased by better management and the development of horticulture and garden crops. Such developments are urgently needed, and are receiving attention. Forestry in areas accessible from the Settlement, and using non-aggressive species appropriate to a windy, oceanic temperate climate, could provide substantial increases in timber resources.

Agriculture has been associated in the minds of many of the islanders with the lean days of subsistence farming since the decline of maritime trading in the 1880s, but the development of the agricultural resources on the coastal strips of Tristan—and especially the diversification and improvement of tillage, pastures and animal husbandry will bring several important advantages:

(a) It would raise the level of nutrition of the islanders, by replacing many imported preserved foods with fresh locally grown products.

(b) It would provide alternative employment opportunities within the island community, and thus diversify their life and cater for those islanders who want to retain their traditional freedom of self-employment and thus avoid the constraints of contract labour.

(c) It would provide employment which is independent of swell and tide conditions and the possibility of working fishing boats from the boat harbour on an open unprotected coast (factors which limit fishing activities from the island).

(d) It would reduce the present reliance of the islanders on imports of essential foods, and therefore the vulnerability of the community as a whole to external economic factors over which they have no control.

(e) It would safeguard the wildlife, and therefore much of the scientific and tourist interest of the islands, against raiding for food or other forms of exploitation in times of economic difficulty.

In general, development of agriculture on Tristan would help to provide the economic stability that the islanders increasingly expect, now that they are accustomed to imported luxury goods and a largely imported diet. The poorly developed agriculture of the recent past, and the absence of any systematic plan for timber growing has provided a continual incentive to the islanders to raid the native biota for both food and fuel, especially in times of economic recessions, and increased their dependence upon expensive imported supplies at least some of which could be locally grown at much lower cost.

A thought-out plan for the development of both agriculture and forestry on Tristan is much needed in order to replace the somewhat haphazard work of agricultural officers in the past. It must be admitted that the chief obstacle to agricultural innovation in the past has not, however, been the lack of such a plan but the innate conservatism of the island community. If the successive agricultural officers, who have generally been in substantial agreement about what should be done, are to work within the context of an integrated plan, this plan must also have the wholehearted support of the community as a whole. Rapid innovation is unlikely to be acceptable: a progressive development, building upon what has already been achieved and seen to be valuable, is likely to succeed. Such a plan should take into account the whole economy of the islanders and their rate of population increase, as well as recognizing the value of recreational and scientific (as well as purely extractive) resources for the future.

However much agriculture can be improved, the human population of Tristan now and in the future will depend substantially upon the sale of crayfish tails and postage stamps, probably with some financial support from Britain in the form of overseas "development funds, and the payment of expatriate staff who serve the island's needs. Both crayfishing and postage stamps are financed and operated from outside the islands, and the islanders are involved in them only as employees of the fishing company or the post office. Neither of them is destructive of the indigenous land-breeding biota, although both represent a somewhat precarious base for the economic support of the human population. Continued development of crayfishing for the export of tails alone could pose problems for the future economy of the islands (apart from the danger of over-exploitation of stocks already referred to), since it is highly dependent upon a single product sold in a distant luxury market. Refinement of product use (as in the extraction of meat from the crayfish limbs, or the use of offal as fertiliser on the islands) may be the best way in which the industry can be developed in future. There may also be some place for scientifically-based cropping of fish species as a minor component of the industry: the essential role of the fishery resources as a mainstay of the human community must be continually borne in mind. Market economics should never be permitted to lead to even a temporary overfishing, because for the Tristan community alternative means of support are so limited.

The intensive use of part of Tristan for agriculture and the shallow seas around all four islands for fishery is compatible with the conservation of the native biota and scientific interest in the smaller islands and the remoter parts of

Tristan itself. It will cost nothing for the islanders to deny themselves such agricultural produce as the smaller islands might provide, for there is no land there comparable to the lowlands of Tristan. Grazing of pasturage that might be developed on the small islands is also unlikely to offer returns to the islanders comparable with those that could be derived from improvement of the lowland pastures on Tristan.

The scientific interest and research potential of the smaller islands is a resource of world-wide value, even if in cash terms it will not bring in more than a modest income. But the cash value of undisturbed wildlife in a natural state, whether for scientific investigation or tourist appeal, is likely to increase sharply in future as such undisturbed situations become scarcer. The management of the smaller islands to conserve the ecological *status quo* and limit to an absolute minimum the impact of man upon them, will greatly increase their value in future, especially for environmental monitoring and biological research. At present these scientific resources are almost completely unexploited, but the setting up of a small scientific field station on Tristan could begin to bring some benefit to the islanders from these resources, through their provision of goods and services to visiting scientists. It would also greatly benefit the Tristan community through the diversification of the range of contacts that the islanders would have with the outside world. The development of such a research facility would not at first bring a great deal of money to Tristan, but it would help to promote in the islanders an awareness of the unique quality and value of their own environment and culture—local qualities and values which are not generally emphasised by the normal processes of outside-financed and operated development. Involvement of the international scientific community with Tristan, through the establishment of a research facility there, would create a group of people informed about environmental, biological, medical and sociological matters to advise the administration. For this reason alone, it might well be the best long term measure to conserve the biota that it is possible to take.

The sale of postage stamps will probably continue to occupy an important place in the island economy, as it does in other remote island communities (Williams and Williams 1970). It is important that their artistic quality (and therefore their present standing with philatelists), as well as their value as an investment, is maintained by careful control over the design of the stamps and the numbers of sets issued, so that they will continue to be sought by collectors whose purchase account for so much of the island revenue. From the standpoint of maintaining the economic wellbeing of the islanders and the integrity of the native ecosystems, postage stamps are an admirable resource: while they bring in a considerable amount of money, they have no undesirable effects upon the native biota or upon the human or natural environment. The production and sale of postage stamps demands design, printing, advertising and sales facilities that are quite outside the ability of the islanders themselves to provide, and the exploitation of this resource will have to remain in outside hands. Of the remaining ancillary resources, any large scale development of the strategic, communications or tourist resources on any of the islands would disrupt the insular ecosystems, but limited facilities on Tristan could benefit the community mainly through the demands that such facilities would create for goods and services from the islanders. With the exception of the existing weather station on Gough Island, and possible environmental monitoring facilities on any of the three smaller islands, it would be unwise from the point of view of maintaining their present ecological integrity, to allow facilities for anything more than temporary accommodation ashore on them. The islanders' present facilities on Nightingale pose little threat of settlement or permanent

man-induced ecological change to that island, because of the lack of drinking water there.

All the ancillary resources whether based on strategic, recreational or scientific interests, are external to the islands and only partially controllable by the islanders themselves, who do not fully share the outlook which make these features of value. As in many developing countries, were a conflict of interest to develop between the immediate economic needs of the islanders or the perceived development potential of the islands on the one hand, and the conservation of the insular ecosystems on the other, the island community might well be prepared to sacrifice wildlife and scientific interest displayed by outsiders to their own economic wellbeing. In these circumstances, conservationist arguments carry little weight unless money is available to compensate for alternative developments forgone in order to protect or conserve the biota. The main safeguard against such conflicts in the Tristan-Gough Islands lies in the ecological constraints that the islands display, and in the attitudes of the islanders towards their own future and especially in the sort of physical, biological and social environment that they want to enjoy.

6. 5. 2 Constraints. Climate, terrain and soils on the small islands are not favourable to settlement or agriculture. Inaccessible justifies its name, Nightingale has little level ground and no drinkable surface water, and Gough has an extremely rugged terrain with high rainfall, and peat bogs on the only level ground. On all three islands, settlement at anything more than a precarious subsistence level could hardly be viable, and stock ranching on them operated from Tristan would be beset by high losses and great difficulties in rounding up and extracting the produce.

There are different constraints on the development of the marine resources. Because the fishery demands continual movement around and between the islands, and continuous access to refrigeration for the catch, it has to be a ship-borne operation. The shore factory on Tristan, with the island fleet of small fibre-glass motorboats, operates only to process catches within a day's safe working range of the boat harbour at the Settlement. This effectively limits shore-based fishing to the waters around Tristan itself, and any expansion of the fishery (for example, to deeper waters) will involve the ship-based rather than the shore-based side of the industry. Capital to support this industry cannot be generated in Tristan, and while it is conceivable that the island community might in future obtain loans to enable it to own and operate the ships fishing in its waters, there would still be problems of marketing which requires the kind of base outside the islands which the present Company has in Cape Town.

All these constraints point to a simple conclusion. The Tristan community can maintain its standard of living and provide for limited population growth, and at the same time increase its economic stability by a policy of agricultural and forestry improvement on Tristan, careful management of the fishing industry, and some limited development for tourism and science. It can do this without destroying or threatening the resources on which these activities are based. Tristan will never be a 'boom' settlement: its prospects of economic or population growth are limited, and it will never be entirely independent of external economic influences, at least at anything approaching present standards of living. It will always have to steer a careful course within the constraints imposed by the isolation, ruggedness and small size of the islands, their ecology, and the restricted range of exploitable resources that they present. Suggested guidelines for the management of the islands, bearing these constraints in mind, follow in the next section.

Suggested Guidelines for Environmental management in the Tristan da Cunha Islands

7. 1 OBJECTIVES

In this section we suggest guidelines which might be borne in mind by the Island community and those responsible for advising them on the development of the natural resources of the group. As in any community, scientific knowledge and scientific considerations alone cannot be expected to determine management policy: social choice and economic constraints will always play a large, and sometimes a decisive part. But the Tristan-Gough group cannot be looked on as a site for any major industry or urban development: as a small rural community largely dependent on the biological productivity of land and ocean, the island population is therefore more likely than most to be constrained by ecological and environmental factors and to find it prudent to bear these in mind in managing their islands.

In our view, the chief aim of environmental management in the island group must be to provide for a sustained and satisfactory standard of living for the Tristan Islanders. A subsidiary aim should be to retain those features of the island group which make them unique in the world and hence of especial interest to scientists and naturalists outside Tristan. To this end, we suggest it is right to:

(a) manage, with the application of sound principles of conservation, all the extractive resources of the islands and their surrounding seas, notably the fishery, and marine mammals and the seabirds;

(b) maintain the highest practicable level of agriculture and forestry on the lowlands of Tristan;

(c) conserve the wildlife and natural habitats of the Tristan uplands and of Inaccessible, Nightingale and Gough Islands (see Appendix, p. 108).

On Tristan da Cunha these aims can be achieved by concentrating intensive agriculture and forestry in the lowlands while maintaining a substantially undisturbed wild area over the uplands. The primary objective of management of Inaccessible, Nightingale and Gough Islands should be the conservation of their existing ecosystems more or less intact. On Nightingale, and to a lesser extent Inaccessible, the result would be the safeguarding of the islanders' traditional, limited, wildlife cropping and also the value of these islands to the community as goals for recreational voyages. Such a policy is fully compatible with the retention of scientific interest and the attractiveness of these islands for research, which would be the predominant objective on Gough Island. Management objectives for the seas near the islands should be directed towards retaining their productivity for the primary benefit of the islanders on a basis of the indefinitely sustained yield of marine production.

From these general considerations, it would seem appropriate to adopt the following policies with respect to the different islands:

7. 2 TRISTAN DA CUNHA

7. 2. 1 Agriculture and forestry would have priority of land use on the **Settlement Plain** and a concerted effort should be made there to:

(i) increase the extent, variety and yield of crop plants, horticulture and forestry;

(ii) replace the present low yielding swards with more productive species, including both summer and winter growing fodder plants, and

(iii) diversify the range of stock kept on Tristan, and continue to improve those already there by selective breeding.

A long term plan should be drawn up including evaluations of fertilizer production from crayfish offal and kelp, proposals for the introduction of pasture and forestry species employing the climatically relevant expertise of agronomists and foresters in temperate South America, Australia and New Zealand (as well as from Britain and South Africa, as in the past), and subsidising or otherwise encouraging a group of islanders to specialise in horticulture, producing food for the rest of the community (6. 3. 1).

7. 2. 2 The use of the **other coastal lowlands** needs review. The pasture at Cave Point and around Stony Beach is poor, overgrazed and eroding: management to arrest its waning fertility would be a valuable long-term investment although it would probably involve drastic reduction in the numbers of cattle kept there. The Sandy Point lowlands are of proven fertility: their problem lies in their limited accessibility but they are a resource certainly worth retaining for meat production and perhaps some horticulture. These lowland areas should be carefully examined by an agricultural specialist and a long-term plan drawn up for them.

7. 2. 3 The **uplands** of Tristan, and the native fernbush above Sandy Point should be disturbed as little as possible, except for permissible cropping of seabirds (7. 2. 4) and possible grazing of some sheep on the Peak (6. 3. 1) (although difficulties of shepherding, and probably high stock losses may make this uneconomic, and it may be wisest to concentrate resources on the more effective management of the lower ground). The south eastern quadrant of the island (from Sandy Point to Stony Beach) should remain a wilderness area, and be managed as a reservoir for useful seabirds (such as mollymawks), a resource for tourism and scientific study, and as a yardstick against which to measure the impact of human effect on the environment and its biota elsewhere on Tristan. No roads giving access to wheeled vehicles should be constructed up to The Base without careful prior study of the possible environmental damage that might follow such construction (5. 2. 5). Transport up to The Base might be provided by mules, whose numbers would be easily controlled, and which would be useful also on the Settlement Plain.

7. 2. 4 **Wildlife cropping** on Tristan needs careful control. The small furseal colony at Cave Point should be encouraged to increase. This means that it must be protected from casual disturbance by dogs etc., as well as deliberate exploitation. This furseal colony could become a real asset to the islanders in future (5. 2. 3). There should also be stringent control over the number of albatrosses, penguins and other birds taken on Tristan. The present populations are much depleted, and although harvesting by the islanders for their own consumption is a sensible aim, there are insufficient data upon which to base any quotas for cropping. There is therefore an urgent need for research into the population biology of the breeding seabirds on Tristan to see what level of cropping can be maintained to allow a long term sustained yield to the islanders. Almost certainly this will confirm that any cropping in the near future should be at a low level to allow stocks to recover. There should be no commercialisation of such cropping, at least until stocks are greatly enlarged.

The albatrosses, penguins and furseals are some of the most spectacular and beautiful species in the islands and a great potential attraction to visitors. Management should therefore aim at allowing their numbers to increase in some protected sites within fairly easy access of the Settlement so that they can be seen and photographed at these places during their breeding seasons.

7. 2. 5 The present **quarantine** system guarding against the inadvertent introduction to the island of plant pathogens, weeds, and animal pests and diseases is of great importance to the island's agriculture. Such introductions are a serious potential threat to the island's productivity and wildlife. We recommend that the quarantine system be sustained and, where possible, strengthened and that:

(i) wherever possible, plants should be imported as seed, from sources that guarantee freedom from weed seed and seed-borne disease. This policy should be maintained even if it means that higher prices have to be paid for plant imports, since this is likely to be much cheaper in the long run. It is particularly important to exclude from the island any materials which may contain pests or pathogens of potatoes, on which the islanders rely so heavily for food (6. 3. 2). All plant imports should be considered from the standpoint of their known ecological performance when introduced into other parts of the world with a similar climate to Tristan. Species known to be aggressive in comparable situations elsewhere (such as those listed in section 5. 2. 5) should not be allowed on Tristan in any circumstances.

(ii) wherever possible, seed be raised within the islands from acclimatised and infection-free parents.

(iii) packing or other materials likely to harbour invertebrate pests of pastures, stored foods or timber, or species which could otherwise become a nuisance ashore, should be inspected carefully. Containers should be unpacked, wherever possible on a concrete floor able to be thoroughly sprayed, and packaging should be burned if it is suspected that the material contains unwanted species. Soil, and fodder for domestic animals should not be imported under any circumstances.

(iv) vertebrate animals should not be imported unless essential, and a system of isolation from domestic animals already on the island should be instituted for some period from the time of their landing. Certain species such as goats and rabbits, and all carnivorous mammals should be rigorously excluded, and the numbers of dogs should continue to be controlled as at present. Birds other than domestic poultry should be excluded, and all imports of these should be certified disease-free, and kept under observation in isolation on arrival (6. 3. 1). Importation even of such poultry to Gough Island should be reconsidered.

A record should be kept of all substantial imports of synthetic biocides to Tristan. It would be particularly important to keep the use of such substances to an absolute minimum, if the islands were to be used as baseline monitoring stations for pollutants, (including biocide residues) in the world environment (see below).

7. 2. 6 Because of its location, Tristan is a good site for **meteorological recording,** which might be extended by **environmental monitoring.** Weather observations during the period when the station on Tristan was operated in parallel to that on Gough Island permitted more exact plotting of the alignment

of fronts and a better base for general synoptic information on the South Atlantic than is possible at present with a weather station only on Gough Island. The South African Weather Bureau, at the time of our visit in 1968, made it clear that they would be considerably aided by the resumption of observations on Tristan, and although remote sensing from weather satellites may have helped to improve the position, surface observations still provide unique information.

Recent discussions (UNEP, 1974) suggest a relatively small network of background stations to monitor world atmospheric conditions, and Tristan was not among the stations initially selected. However, a regional station on the island would certainly have attractions, and could combine monitoring of atmospheric components, marine contaminants and residues accumulated in locally-feeding seabirds (like penguins) and marine organisms (like molluscs). Because of their very wide migration range, species such as great shearwater or yellow-nosed albatross would be less suitable as indicators of local marine contamination. A very small number of observations have revealed residues of persistent organochlorine pesticides in the endemic Tristan 'starchy', *Nesocichla eremita*, possibly derived from seabird eggs on which it feeds (Bourne, private communication to MWH), and these results confirm the need to examine residue levels in the eggs of seabirds which breed on the islands but forage over different oceanic zones.

7. 2. 7 An enquiry in 1965-68 showed that there would be world-wide interest were limited **accommodation for visiting scientists** provided at the Settlement. Such accommodation might consist of self-contained units for long term visitors, with a small adjacent laboratory. Those staying for short periods would be better accommodated with island families who were prepared to rent facilities for this purpose, and this might be the best initial arrangement. Accommodation might be inspected and licensed by the Island Council, who could establish a scale of charges.

The conservation and management of the islands demand some surveillance, and the community needs to keep records telling whether pests are increasing, whether productivity of agriculture and forestry is changing to keep pace with effort and money expended and changes of population, and whether wildlife stocks are increasing or declining. Such information needs to be gathered by a competent officer: an expatriate agricultural officer could do many of these tasks at present. As scientific interest in the islands develops, this and the meteorological and monitoring requirements could well justify the stationing of a fulltime scientific officer on Tristan, who could also advise the Island Council on management problems as they affect the wildlife or the environment. It is important that the scientific study of the islands should always be applied in this way for the welfare of the islanders. When an Administrator is appointed, it would also be relevant to consider the scientific interests and expertise of the applicants, in addition to purely administrative abilities.

7. 3 INACCESSIBLE ISLAND

7. 3. 1 The scientific value of the **conservation** of the undisturbed biota on this island far outweighs its possible use for agriculture or pasturage, especially since the island is close to Tristan (where visiting research scientists would be based) and is the only island in the group without either habitation or regular visits by man. Agricultural or pastoral activities on this island are unlikely to be profitable, and it is suggested that these are excluded and that no

plants or alien mammals (especially cats, rats or sheep) are allowed ashore. Any other disturbance of the habitat (including fires) should be avoided.

7. 3. 2 Although there is no absolute need to prohibit **wildlife cropping** on Inaccessible, there is much to be said for concentrating this activity (as at present) on Nightingale. **Scientific collecting** needs to be watched carefully; there should be complete prohibition on the taking of any wandering albatross from the uplands, and any taking of the endemic birds or plants for zoos or museums needs careful control by the Administration, advised by a competent ecologist.

7. 3. 3 Some shelter **and access** to the interior of Inaccessible should be provided. The huts by Waterfall Beach should be maintained as basic shelter for islanders and visitors, and a small supply of food kept there for emergency use. A safe route up the cliffs near the Waterfall should be established with fixed ropes or ladders over the most difficult points.

7. 4 NIGHTINGALE ISLAND

7. 4. 1 Visits to Nightingale are a valuable recreation for islanders wishing to get away from Tristan and the island should remain their principal outlet for this purpose. Cropping of the great shearwaters could continue, but the taking of mollymawks may need to be reduced for a while in order to allow stocks to recover, and to allow research to establish the frequency of breeding and likely sustainable yield. All taking of wildlife should be carried out only by the islanders for their own consumption, and should be under the general control of the Administration, which should keep records of the approximate numbers of each species taken (5. 4. 5).

7. 4. 2 The **scientific collecting** of endemic land birds for zoos, and the taking of any species of plant or animal for museums or other scientific purposes should be controlled by permit from the Administration, and severely restricted.

7. 4. 3 The importation of any **alien biota,** especially rats, mice, cats, rabbits, sheep and goats should be prevented, and habitat disturbance kept to a minimum. New Zealand flax should be finally eliminated from the island by pulling out all regrowth.

7. 4. 4 Existing **accommodation** on Nightingale should be maintained, but not extended. The islanders' huts are of great value to them, but none should be built elsewhere on the island. The Administration hut there could be enlarged and fitted with a small workbench for use by visiting scientists.

7. 5 GOUGH ISLAND

7. 5. 1 Although presenting the most formidable terrain and the most inhospitable environment of all the islands in the Group, Gough Island has the largest and most diverse seabird populations and undisturbed vegetation. Its land area is not used, nor is it likely to be used, by the islanders. Apart from its fishing and sealing resources, its greatest value to them is in its attraction of scientific visitors, and it should therefore be **conserved for scientific research** on its native biota. All forms of environmental disturbance, other than those essential to the functioning of the South African weather station in Transvaal Bay, should be avoided and no cropping of wildlife permitted. The removal

of plants and animals for zoos and other scientific use should be controlled by permit from the Tristan Administration and severely restricted.

7. 5. 2 The strongest control should be maintained over **the import of animals and plants,** and none should be allowed except possibly for poultry kept in enclosures at the weather station. If imports of such poultry are to continue (and there is much to be said for stopping them), particular care should be taken to ensure that imported birds are free of avian diseases which might spread to the native fauna (6. 3. 1). Consideration should be given to the building up of a disease-free breeding stock of enclosed poultry at the weather station so that imports can be stopped in future. Because of the plague of mice in the island (which are a nuisance at the weather station), particular care should be taken to see that no attempts are made to introduce cats, which might be thought of as a means of control but would be far more likely to establish a feral population preying on seabirds, as they have on Macquarie Island, Marion Island and elsewhere.

7. 5. 3 The South African weather station is a valuable scientific facility, and has a considerable amount of accommodation and laboratory space which it is hoped will be made available to visiting scientists. **Access** to the open uplands is comparatively easy from Transvaal Bay, but because of the danger from severe wind-chill on the mountains, (6.4. 2), care is needed over clothing, food and bivouac equipment if any long excursions are made. If visitors or members of the weather station visit the uplands then some rough shelters could be erected there for safety, and it might also be useful to cut some paths through the fernbush and to mark out tracks on the uplands with cairns. Only a few Tristan islanders know their way about on Gough Island: it would be prudent to increase the number by insisting that scientific visitors employ at least two islanders per party as general helpers.

7. 6 NEARBY SEAS

7. 6. 1 The need for careful **management** of the **crayfishing** around the islands has already been stressed (6. 2. 9). The employment of a full-time marine biologist with a senior professional adviser by Tristan Investments Ltd, is welcome, and it is important that his assessments and the data on which they are based are published for independent criticism and appraisal in scientific or technical journals. Exploitation of other marine resources, (and of furseals on shore 6. 2. 7) should always be subject to prior assessments of the cropping rates that they could withstand to produce a sustained yield.

7. 6. 2 It is important to emphasize that the **resources of the nearby seas, as well as those ashore, belong to the islanders.** The Administration must always be an active partner on behalf of the islanders, in discussion with the Company over fishing limits and procedures. Because of the limited resources available to the islanders, and their dependence on fishing, conservation of the marine resources should always take precedence over market pressures in reaching decisions on the size and nature of the crop taken.

These considerations would gain even greater weight if discussions on the Law of the Sea lead to extended jurisdiction over fishery in adjacent waters (there are already seabed rights). The resources within 200 miles of the shores of the islands should be surveyed on behalf of the island community and managed for their benefit, with the Island Council having an increasing say in management policy.

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Appendix

NEW CONSERVATION ORDINANCE FOR TRISTAN DA CUNHA

The following is the text of an Ordinance enacted on 2 April 1976, by His Excellency the Governor of St Helena (of which the Tristan da Cunha Islands are a Dependency) in Council. It replaces earlier and much less comprehensive measures. It will be noted that different degrees of protection are afforded to the environment, flora and fauna on different islands of the group, in a manner that accords with the traditional usages of the Islanders, recognizes the present concentration of agriculture and of human disturbance on the main island of Tristan da Cunha, and provides for the future concentration of development there. The measure has something in common in its basic approach with the Agreed Measures for the Conservation of Antarctic Fauna and Flora (Recommendation III-VIII of the Third Antarctic Treaty Consultative meeting: full text published by HM Stationery Office, London as Cmnd 2822), and subsequent measures adopted in the Falkland Islands Dependencies (Falkland Island Dependencies, No. D51, 1975). Flexibility, to take account of changing circumstances, is provided by the provisions under which the Administrator of Tristan da Cunha may vary the schedules dealing both with species receiving special protection on Tristan da Cunha and with the definition of sanctuary areas on that island.

The authors wish to express their thanks to HE the Governor of St Helena and to Miss M. E. Hunt of the Foreign and Commonwealth Office, London, for sanctioning the inclusion of the Ordinance here, and for providing copies of the text.

AN ORDINANCE
to make provision for the conservation of the fauna and flora of Tristan da Cunha

Enacted by the Governor of St. Helena and its Dependencies:

1. (1) This Ordinance may be cited as the Tristan da Cunha Conservation Ordinance, 1976.

(2) This Ordinance shall come into operation on such day as the Administrator shall notify to the public, in such manner as he may consider best for that purpose.

2. (1) In this Ordinance, unless the context otherwise requires:

"Administrator" means the Administrator of Tristan da Cunha;
"Administrator in Council" means the Administrator acting after consultation with the Island Council;
"Animal" means any member of the animal kingdom;
"Bird" means any member of the class Aves at any stage of the life cycle and includes eggs;
"Island Council" means the Island Council of Tristan da Cunha;
"Mammal" means any member of the class mammalia;
"Plant" means any member of the plant kingdom;
"Resident of Tristan da Cunha" means a person born in Tristan da Cunha Islands, the husband, wife or child of any such person and any person who has lived on the main island of Tristan da Cunha for a period of at least one year immediately preceding the date of the event in issue or, as the

case may be, the act or omission of which complaint is made but not including in that period any period during which his residence was authorised by a permit;

"Territorial waters" means a zone having for its inner boundary the low water line on the coast of the land area of Tristan da Cunha islands or any part thereof or any other baseline from which the territorial waters are measured and for its seaward boundary a line each point on which is three nautical miles from the nearest point on the aforesaid inner boundary and includes the air space above that zone as well as the seabed and the subsoil thereof;

"Tristan da Cunha Islands" means the main island of Tristan da Cunha, Gough Island, Inaccessible Island, Nightingale Island, Middle Island, Stoltenhoff Island and the islets belonging to any of those islands.

(2) In this Ordinance—

(a) any reference to a land area includes the area of the territorial waters of that land area; and

(b) a reference to a native animal or to a native plant shall be interpreted as meaning an animal or plant the presence of which in Tristan da Cunha Islands resulted from natural process of dispersal of the species to which the animal or plant belongs.

3. (1) No person shall wilfully within Tristan da Cunha Islands—

(a) set fire to any vegetation except for agricultural or horticultural purposes;

(b) spread, discharge or dump any noxious chemical except within a building or in a place approved by the Administrator for the disposal of such materials;

(c) spread by spray or other means any insecticide or pesticide except within a building or tent or for agricultural or horticultural purposes and except within the settlement of Edinburgh in the main island of Tristan da Cunha for public health purposes.

(2) No person shall wilfully within Tristan da Cunha Islands except with a permit and in accordance with the terms thereof—

(a) import any kind of live animal or plant not native to Tristan da Cunha Islands;

(b) liberate or disseminate any kind of live animal or plant not native to Tristan da Cunha Islands except in an area used for agricultural or horticultural purposes;

(c) engage in any action causing disruption of the soil or vegetation other than soil or vegetation in a garden or area used for agricultural or horticultural purposes.

(3) No person shall wilfully within Gough, Inaccessible, Nightingale, Middle or Stoltenhoff Islands, islets belonging to Tristan da Cunha or in any area in the main island of Tristan da Cunha for the time being declared to be a sanctuary under section 5 of this Ordinance except with a permit and in accordance with the terms thereof construct any house, hut, shed, jetty, landing strip, road or runway or erect any mast, pole, aerial beacon or any other installation or undertake any agricultural or horticultural activity.

(4) No person, not being a resident of Tristan da Cunha, shall in Inaccessible Island, except with a permit and in accordance with the terms thereof, wilfully pick, cut down, uproot or destroy any native plant.

4. Within the main island of Tristan da Cunha the birds and mammals specified in the First Schedule to this Ordinance are hereby declared to be protected species and no person shall, except with a permit and in accordance with the terms thereof, wilfully kill, capture or molest any bird or mammal of any species so specified.

5. (1) The Administrator in Council may at any time declare any area of the main island of Tristan da Cunha to be a sanctuary.

(2) Within any sanctuary under this Ordinance no person shall, except with a permit and in accordance with the terms thereof, wilfully kill, capture or molest any native bird or native mammal.

6. Within Inaccessible, Nightingale, Middle and Stoltenhoff Islands and islets belonging to Tristan da Cunha—

(1) No person, not being a resident of Tristan da Cunha, shall, except with a permit and in accordance with the terms thereof, wilfully kill, capture or molest or attempt to kill, capture or molest any native bird or native mammal;

(2) No resident of Tristan da Cunha shall, except with a permit and in accordance with the terms thereof, wilfully kill, capture or molest or attempt to kill, capture or molest any native bird or native mammal other than of a species specified in the Second Schedule of this Ordinance.

7. (1) Gough Island is hereby declared to be a wildlife reserve.

(2) Within a wildlife reserve no person shall, except with a permit and in accordance with the terms thereof,

(a) wilfully kill, capture or molest any native bird or any native mammal;

(b) pick, cut down, uproot or destroy any native plant.

8. (1) The Administrator in Council may from time to time vary—

(a) the first and second schedules to this Ordinance by adding or deleting any species of bird or mammal;

(b) the areas declared to be sanctuaries on the main island of Tristan da Cunha.

(2) Notice of any variation proposed to be made under subsection (1) of this section shall be posted publicly in such place in the Settlement of Edinburgh as the Administrator may direct and any resident of the main island of Tristan da Cunha who objects to the proposed variation shall be entitled within one calendar month of the posting aforesaid to give notice in writing addressed to the Administrator and delivered to his office that he objects to the proposed variation giving his reasons for such objection.

(3) The Administrator in Council shall as soon as practicable consider any objection under subsection (2) of this section and the Administrator shall decide thereafter whether the proposed variation shall or shall not be made and, if he decides that the variation shall be made, it shall come into force three calendar months after the date on which the Administrator so decides otherwise the proposed variation shall lapse.

9. (1) The Administrator may issue a permit to any person named in the permit—

(a) to do any of the things forbidden to be done without a permit by the provisions of this Ordinance;

(b) to take for commercial purposes the number of seals (Arctocephalus tropicalis) specified in the permit provided that the person to whom the person is issued is an employee of the South Atlantic Islands Development Corporation or its subsidiary Tristan Investments (Pty.) Ltd. and provided also that the permit shall lapse forthwith if that person ceases to be such an employee:

(2) A person to whom a permit is granted under paragraph (b) of subsection (1) of this section shall inform the Administrator within one month after the date of the expiry of the permit of the number of seals of each sex taken under the permit and shall, if required to do so, produce for inspection by the Administrator or person authorised by the Administrator in that behalf the skins or other products retained by the permit holder.

(3) A person to whom a permit has been granted under paragraph (a) of subsection (1) of this section or to whom oral permission has been given under subsection (4) of this section shall inform the Administrator from time to time and not later than one month after the date of the expiry of the permit or of the period specified when oral permission was given of anything he has done under the permit or oral permission, including the number of each species of bird or mammal taken by him by virtue of the permit or oral permission.

(4) A resident of Tristan da Cunha may for himself or for another resident but not for a person who is not a resident of Tristan da Cunha do any of the things forbidden to be done without a permit by sections 4, 5 or 6 of this Ordinance for which he has first obtained the oral permission of the Administrator or of the person authorised under subsection (6) of this section and of the Chief Islander: Provided that any native bird or native mammal taken under oral permission may not be disposed of to any person who is not a resident of Tristan da Cunha and provided that in any proceedings under this Ordinance in which a person claims that he has been given oral permission as aforesaid it shall be for that person to prove that he had such permission.

(5) A permit issued under this section or oral permission given under this section shall be for a period and shall be restricted to such area, in consideration of such payments and subject to such restrictions, terms and conditions as may be included in the permit or specified when the oral permission is granted.

(6) The Administrator may authorise a person to act on his behalf under this section either generally or for purposes specified in the authorisation.

10. Except to the extent to which it conflicts with any rights granted to the South Atlantic Islands Development Corporation by the Crown Agents for Overseas Governments and Administrations acting for and on behalf of the Governor of St. Helena, the provisions of this Ordinance shall apply to the said Corporation and its employees and its subsidiary Tristan Investments (Pty) Limited and its employees.

11. Records shall be kept by the Administrator or by his direction of all permits granted and all permission given including particulars of the period

and conditions thereof and of all activities conducted and of the numbers of each species of bird and mammal taken under permits issued or under oral permission given under the provisions of section 9 of this Ordinance and such records shall be made available for inspection by any member of the Island Council.

12. Any person who has in his possession any animal or plant which under section 3 of this Ordinance may not be imported, liberated or disseminated or has in his possession any native bird or native mammal killed or captured in contravention of this Ordinance shall be guilty of an offence and the animal, plant, native bird or native mammal shall be disposed of as the Administrator may direct.

13. (1) Any person who contravenes or attempts to contravene any of the provisions of section 3, section 4, subsection (2) of section 5, section 6 or subsection (2) of section 7 of this Ordinance or does not give the information required by subsection (2) or (3) of section 9 of this Ordinance shall be guilty of an offence.

(2) Any person guilty of an offence referred to in section 12 or in subsection (1) of this section shall be liable—

(a) if a resident of Tristan da Cunha, for a first offence to a fine not exceeding five pounds and for a second or subsequent offence a fine not exceeding fifteen pounds;

(b) if not a resident of Tristan da Cunha, for a first offence to a fine not exceeding twenty pounds and for a second or subsequent offence to a fine not exceeding one hundred pounds.

(3) In any proceedings under this Ordinance in which it is alleged that an animal or plant is or is not a native animal or a native plant the Court shall presume that the animal or plant is a native animal or a native plant unless the Court is satisfied that the presence in Tristan da Cunha Islands of the species to which the plant or animal belongs probably resulted from deliberate or accidental introduction by man.

14. Where any person has been convicted of an offence under section 13 of this Ordinance—

(a) any animal, plant or product thereof which has been the subject of such conviction shall be forfeited to the Administrator and the Court may, in addition to any penalty that may be imposed, order any firearm, machine, instrument, trap, net apparatus, article or material which has been used in the commission or concealment of the offence to be forfeited also to the Administrator;

(b) any such animal, if native to Tristan da Cunha Islands, shall, if alive, be released whenever possible in its appropriate habitat; and

(c) any such animal, if not native to Tristan da Cunha Islands and any such animal, if of a kind the import of which is contrary to subsection (2) of section 3 of this Ordinance or if its release would be impracticable or if it is dead or inanimate, and any plant and anything forfeited to the Administrator under this Ordinance shall be disposed of as directed by the Administrator and, if such animal, plant or thing as is referred to in this paragraph is sold, the proceeds thereof shall be applied for the benefit of and accrue to the funds of Tristan da Cunha.

15. (1) The provisions of this Ordinance may be enforced by conservation officers who for that purpose shall have the powers conferred by the next succeeding section of this Ordinance.

(2) The Administrator may appoint any person to be a conservation officer and every member of the police force shall also be a conservation officer.

16. A conservation officer shall have and may exercise the following powers—

(a) he may arrest without warrant or other process any person whom he has reasonable grounds to suspect of having committed an offence under this Ordinance;

(b) he may seize and detain pending its production in Court any animal, plant or thing in respect of which he has reasonable grounds to suspect that an offence under this Ordinance has been committed or which appears to him may be required as evidence in proceedings in respect of an offence or may have been used in connection with the commission or concealment of such an offence;

(c) for the purpose of exercising his powers under this section he may go aboard any vessel within Tristan da Cunha Islands and make such search thereof and such enquiries of any person thereon as he deems necessary to ascertain whether any offence under this Ordinance has been committed and to establish any fact relating thereto;

(d) if he suspects that there is on a vessel within Tristan da Cunha Islands any person whom he reasonably suspects of having committed an offence under this Ordinance, he may board that vessel and may bring that person before a competent Court and may detain him until the alleged offence has been adjudicated upon;

(e) if he reasonably suspects that any vessel which is within Tristan da Cunha Islands has been used in the commission of an offence under this Ordinance, he may board the vessel and may require the crew thereof in accordance with any directions given by him to bring the vessel to the nearest or most convenient port and the conservation officer may detain the vessel and crew until such suspected offence has been adjudicated upon by a competent Court.

17. No action shall lie against a conservation officer in respect of any act done or omitted to be done by him in the exercise or purported exercise of his powers under this Ordinance if there shall have been reasonable cause for such act or omission.

18. Any person who obstructs a conservation officer acting in the exercise of his powers under this Ordinance or who refuses or neglects to comply with any requisition or direction lawfully made or given by a conservation officer or who refuses or neglects to answer any question lawfully asked by a conservation office under this Ordinance shall be guilty of an offence and shall be liable to a fine not exceeding fifty pounds or to imprisonment for a term not exceeding three months or to both such fine and imprisonment.

19. For all purposes of and incidental to the trial and punishment of any person in respect of an offence under this Ordinance and to proceedings and matters preliminary or incidental to or consequential on his trial or punishment and for all purposes of and incidental to the jurisdiction of any Court or of any constable or conservation officer with reference to such offence, the offence shall be deemed to have been committed either in the place in

which it was actually committed or in any place in which the offender may for the time being be found.

20. The Wild Life (Tristan da Cunha) Protection Ordinance is hereby repealed.

Schedule I *Protected birds and mammals on Tristan da Cunha* (*Main Island*)

Tristan thrush or Starchy	*Nesocichla eremita*
Tristan Gallinule or Gough Island Gallinule or Island Cock	*Gallinula nesiotis* and *G. nesiotis comeri*
Wandering Albatross	*Diomedea exulans*
Fur seals	*Arctocephalus* species (all species)
Elephant seal	*Mirounga leonina*
Southern Right Whale	*Eubalaena australis*

Second Schedule: *Species permitted to be taken by residents of Tristan da Cunha on Inaccessible, Nightingale, Middle and Stoltenhoff Islands without a permit*

Great Shearwater or petrel	*Puffinus gravis*
Sooty Albatross or peeoo	*Pheobetria fusca*
Rockhopper penguin	*Eudyptes crestatus*