The arrival, establishment and control of alien plants on Gough Island

N. Wace
Department of Biogeography and Geomorphology
Research School of Pacific Studies
Australian National University, Canberra
Australian Capital Territory 2601

Twenty-three species of alien vascular plants had been recorded growing wild on Gough Island until November 1984. Eight species, which have all been present for at least 30 years, are naturalised and widespread. Five adventive species have been found only at sites of human habitation on the coasts. These 13 species are all forbs (7) or grasses (6) having C_3 photosynthetic carbon pathways, and they include no woody or large tussock-forming plants. A further 10 casual species have been found only once on the island: Five of these were discovered in October 1984 growing near a recently erected hut, and including two soft-woody shrubs recognised as weeds in South Africa, whence they came.

Burrowing and excreta-deposition by seabirds, and peat avalanches are the most important natural processes giving rise to regeneration sites, which are preferentially colonised by alien plants. There is very little human disturbance of the plant cover. Control of alien plants on Gough Island requires protection of the peat mantles and the native vegetation, especially from fire. Quarantine surveillance, to exclude the import of plants or animals (particularly rats), and regular surveillance of the plant life are most important in monitoring and maintaining the integrity of the native ecosystems, and thus excluding alien plants from the island in future.

Drie-en-twintig spesies vreemde vaatplante wat wild op Gough-eiland groei, is sedert November 1984 aangeteken. Agt spesies, wat almal reeds minstens 30 jaar daar voorkom, is genaturaliseer en kom algemeen versprei voor. Vyf adventiewe spesies is slegs aan die kus naby mense se verblyfplekke aangetref. Dié 13 spesies is almal òf weiveldkruide (7) òf grasse (6) met C_3-fotosintetiese koolstofroetes, en sluit nie houterige of groot polvormende spesies in nie. Nog 10 toevallige spesies is slegs een keer op die eiland aangetref en vyf hiervan is in Oktober 1984 ontdek naby 'n hut wat toe pas opgerig is. Onder dié plante was twee sagtehoutagtige struike wat in Suid-Afrika, waarvandaan hulle gekom het, as onkruid beskou word.

Seevoëls se agterlating van uitskeidings en die resultate van hul grawery, asook turflawines, is die vernaamste natuurlike oorsake van regenerasieterreine wat by voorkeur deur vreemde plante gekoloniseer word. Die mens versteur selde die plantbedekking. Vir die beheer van vreemde plante moet die turfmantel en die inheemse plantegroei op Gough-eiland beskerm word, veral teen brande. Kwarantyntoesig om te voorkom dat vreemde plante of diere (veral rotte) ingevoer word asook die gereelde waarneming van die plantlewe is uiters belangrik by die beheer en handhawing van die ongeskondenheid van die inheemse ekosisteme, en om vreemde plante in die toekoms van die eiland weg te hou.

Introduction

Along with the other two smaller islands of the Tristan da Cunha Group in the South Atlantic, Gough Island is probably the only remaining temperate oceanic island of any size and ecological diversity, which has retained its native plant and animal life more or less intact, and little affected by human activities. The few other oceanic islands in the Southern Hemisphere near the subtropical convergence zone, which support woody vegetation, have been settled by breeding and self-sustaining human populations, or had their native ecosystems variously modified by man (Holdgate & Wace 1961, Clark & Dingwall 1985).

This paper summarises what is known about the arrival and establishment of alien plants on Gough Island until the end of 1984; the degree to which the native vegetation has been disrupted by natural and man-induced processes (thus enhancing opportunities for alien species to become established); and the management that is necessary to prevent alien plants from establishing themselves in future as part of the naturalised flora. Records of the introduction and establishment of alien animals are also summarised, because of their possible effects on the native and alien flora of the island.

The arrival of alien plants

The only known introductions of domesticated plants and animals to Gough Island have been:

1. Cultivation of vegetables at various sites around the coasts, from about 1800 AD. The first documented accounts describe "potatoes and other vegetables" grown in 1811 by American sealers then living on the north coast (Tagart 1832). But Yankee sealers were known to be living ashore from 1804 (Wace 1969), and did so intermittently until the collapse of the industry by 1888, when potatoes were still noted as "growing wild" (Verrill 1895).
2. Some attempted cultivation of potatoes and vegetables (lettuce, carrots, cabbage, onions, radish) by N.M. Wace and J.J. van der Merwe from 1955-57; and at the present weather station in Transvaal Bay, between 1963 and 1970.
3. Attempts to keep sheep and poultry in small numbers during the first years of the South African weather station at The Glen (1956-57 – Van der Merwe, *in litt.*). Poultry were also kept at the Transvaal Bay weather station from 1963-1970. Some fodder was probably landed with the sheep, and the poultry were fed with imported grain at these times.

Except for potatoes, none of these intentionally introduced species has persisted or become naturalised on Gough Island. Since 1970, no alien plants or animals are known to have been taken ashore. Under the terms of the British lease of part of Gough Island to South Africa for use as a weather station (1984), no exotic plants or animals are allowed to be imported.

Apart from potatoes, all the plants introduced to Gough Island which later became naturalised, were brought in unintentionally. To the end of 1984, only eight species of vascular plants had become naturalised:

Stellaria media
Rumex obtusifolius
Plantago major
Sonchus oleraceus
Agrostis stolonifera
Holcus lanatus
Poa annua
Poa pratensis

A further 10 species were then (or had previously been) restricted to the vicinity of the old huts in The Glen, and/or the immediate vicinity of the weather station in Transvaal Bay:

**Cerastium fontanum*
Plantago lanceolata
**Verbena bonariensis*
Solanum tuberosum
Sonchus asper
**Agrostis castellana*
Agrostis lachnantha
Agrostis tenuis
Dactylis glomerata
**Rumex acetosella*

Four of these species (marked *) have been collected only once at one site, and have not been seen again at that site or elsewhere, although sought by the author during visits in October 1976 and 1984 and in May 1968. *Sonchus asper* may be more widespread on the island, but confused with *Sonchus oleraceus;* and the various species of *Agrostis* may be confused with *A. stolonifera.* Both *Sonchus oleraceus* and *Agrostis stolonifera* are widespread on the island. *Hypochaeris glabra,* allegedly collected at The Glen landing in 1904 (Rudmose Brown 1905) is now thought to be an erroneous identification of *Sonchus oleraceus* (Groves 1981, p. 366).

A further five species of alien vascular plants were found in October 1984, growing near the new magnetometer hut, beside the stream supplying drinking water to the weather station:

G401 *Conyza floribundus* (fleabane, Kleinskraalhans)
G402 *Lactuca serriola* (wild lettuce, wilde slaai)
G403 *Senecio burchellii* (Molteno disease Senecio, Burchell's senecio)
G404 *Lolium multiflorum* (ryegrass, raaigras)
G405 *Oenothera indecora* (evening primrose, nagblom)

These plants were all pulled out by a working party on 27 October, when only *Conyza* had mature fruits and showed signs of active spread, with young seedlings scattered around the new hut. The two soft-woody shrubs *(Senecio burchellii* and *Oenothera indecora)* were then up to half a metre or more tall, and spreading vegetatively, but *Lactuca* and *Lolium* were scarce, and appeared less aggressive. These five species are all common weeds in South Africa (Henderson & Anderson 1966). Their seeds probably arrived on Gough Island with sand or stone chippings from the Cape. After the hut was built, in April 1983, the surplus sand, which had been imported to make cement for the hut foundations, was spread about over the surface of the peat in the region round the hut which had been cleared of native vegetation. The seedlings of these imported plants thus had a chance to germinate, and to compete with the native species, just when the fronds of *Histiopteris incisa* were dying down in the autumn. The rapid spring growth and dense cover of *Histiopteris* must be important in preventing seedlings of alien plants establishing themselves near the weather station, where much seed must be accidentally imported. None of the above five species seen at the magnetometer hut was also present around the weather station, where the cover of *Histiopteris* and *Scirpus* remained little disturbed in 1984.

Present size and characteristics of the alien flora

The total flora of introduced vascular plants so far recorded from Gough Island thus consists of 23 species of flowering plants. These can be divided according to their performance and range on the island, into three groups:

Eight naturalised species which reproduce freely, and have been present at several places on the island for at least 10 years:

Stellaria media
Rumex obtusifolius
Plantago major
Sonchus oleraceus
Agrostis stolonifera
Holcus lanatus
Poa annua
Poa pratensis

Five adventive species, which have been found in several places on the island on a number of different occasions, but which do not seem to spread from these situations. This group includes persistent cultivated plants:

Plantago lanceolata
Solanum tuberosum
Sonchus asper
Agrostis tenuis
Dactylis glomerata

10 Casual species, which have been found only once, in one place on the island:

Cerastium fontanum
Rumex acetosella (agg.)
Oenothera indecora
Conyza floribunda
Lactuca serriola
Senecio burchellii
Agrostis castellana
Agrostis lachnantha
Lolium multiflorum
Verbena bonariensis

With the very small amount of botanical investigation of Gough Island, this can only be the most tentative grouping of the total alien flora. Some casual species may become adventive or even fully naturalised in future, and members of any group may become temporarily or permanently extinct on the island (e.g. ?*Rumex acetosella, Verbena bonariensis*).

Table 1

Remote islands of the Southern Hemisphere, 35 – 55° S. latitude. Basic geographical data, with indications of the degree to which their native ecosystems have been affected by human activities. Data drawn largely from Clark & Dingwall (1985). (Figures in brackets indicate no permanent self-sustaining human population)

	ISLAND or ISLAND GROUP	Number of Islands	Area (km²)	Maximum Elevation (m)	Mean Annual Air Temperature (°C)	GEOLOGICAL TYPE	Number of inhabited islands	Human population (temporary in brackets)	Vascular plants native:naturalised	SOVEREIGNTY	Additional references
ATLANTIC OCEAN											
37°	**Tristan Group**	3	103	2060	14.4	young & eroded volcanic	1	300	90:102	Britain	Wace 1967, 1986 Groves 1981
	Tristan altered by grazing, firing, wooding, feral cats & rats; Inaccessible & Nightingale little changed										
40°	**Gough**	1	68	910	11.3	eroded volcanic	(1)	(8)	60:8	Britain	Wace & Ollier 1984 Wace 1986
	Local and minimal human impacts; mice long-established, rats doubtfully present										
51-52°	**Falklands**	c.20	12000	705	5.5	metasediments, periglacial	2	2000	163:92	Britain/ Argentina	
	Most islands much altered by sheep grazing, peat cutting & firing; intact ecosystems on small offshore islets										
53-55°	**South Georgia**	1++	3756	2934	2.1	metasediments, icecap	(1)	(?20+)	26:19	Britain/ Argentina	Headland 1984
	Vegetation altered by introduced reindeer; birds reduced by rats; small islands intact										
54°	**Bouvet**	1	c.50	780	?-1.5?	volcanic, icecap	—	—	0:0	Norway	
	Inhospitable and probably uninhabitable island, no human impacts or introductions										
INDIAN OCEAN											
38°	**Amsterdam – St. Paul**	2	62	911	13.3	young volcanic, hot springs	(1)	(c.30)		France	Richards 1984
	Both islands much damaged by peat fires, cattle grazing, feral cats & rodents										
47°	**Marion – Prince Edward**	2	344	1230	5.1	young volcanic, lava flows	(1)	(c.20)	38:14	S. Africa	Gremmen 1982
	Cats on Marion devastated seabirds, Prince Edward little altered										
47°	**Crozet Group**	5	500	1090	4.4	volcanic, small icecaps	(1)	(c.20)		France	
	Feral cats and rodents on some islands; others probably free of introduced plants or animals?										
49°	**Kerguelen**	1++	c.7000	1850	4.1	volcanic, icecap, glaciers	(1)	(90)		France	
	Rabbits, feral livestock, cats have reduced birds and destroyed much vegetation; many exotic plants, but no recent census										
53°	**Heard & Macdonald**	2	380	2744	1.2	active volcano, icecap	—	—	8:0	Australia	Keage 1982
	Minimal human impact, no exotic plants naturalised										
PACIFIC OCEAN											
43°	**Chatham Group**	7	1973	270	11.2	old volcanic	2	700		New Zealand	Richards 1977
	Livestock grazing and peat fires devastated plant cover, peat mining now proposed. Rats have greatly reduced birds										
48°	**Bounty Group**	c.10	1	88	c.10	granite islets and rocks	—	—	0:0	New Zealand	
	Too small to carry land vegetation; largely unmodified										
50°	**Antipodes**	1+5	21	402	c.8	volcanic	—	—	64:1	New Zealand	
	Apparently unmodified, despite earlier feral livestock, no rats										
48°	**Snares**	3	3	152	c.11	granite	—	—	20:2	New Zealand	
	Largely unmodified, no rodents										
51°	**Auckland Group**	6	625	667	c.8	old eroded volcanic	—	—	228:41	New Zealand	
	Some islands unmodified, others affected by feral livestock; no rodents										
52°	**Campbell**	1	114	567	7.1	mostly old eroded volcanic	(1)	(10)	200:81	New Zealand	
	Modification by feral livestock now reversed with shooting and confinement of sheep; rats & exotic herbs persist										
54°	**Macquarie**	1	119	432	4.7	old volcanic, recent uplift	(1)	(15)	40:4	Australia	
	Rabbits, cats and rats modified vegetation and bird life; controls on rabbits reducing numbers										

The naturalised and adventive elements include no trees, shrubs, lianes or other woody species, and no scramblers, large tussock-formers or geophytes with spreading rhizomes – and no pteridophytes. Most of the naturalised and adventive plants are opportunist forbs and grasses which thrive in unstable habitats, and all except some species of *Agrostis* and the potatoes are native to Europe, but are now common weeds with widespread ranges in the temperate zones of both Northern and Southern Hemispheres.

All of the eight naturalised and five adventive species on Gough Island belong to genera with tricarboxylic acid (C3) carbon pathways in photosynthesis. This contrasts with some of the more aggressive naturalised species on the lowlands of Tristan da Cunha, where the volunteer alien plants include:

Cyperus congestus
Cyperus rotundus
Sporobolus capense
Cynodon dactylon
Paspalum dilatatum
Digitaria sanguinalis
Eleusine indica

These five species of grasses naturalised on Tristan, all belong to genera which are recorded as having C4 photosynthetic pathways elsewhere (Hattersley 1983 & pers. comm., Vogel *et al.* 1978). Both the above *Cyperus* specimens from Tristan have the Kranz-anatomy typical of C4 plants. None of the naturalised, adventive or casual species so far found on Gough Island belong to genera with C4 pathways else-

where. Specimens of the new arrivals *Senecio burchellii* and *Oenothera indecora* do not have the leaf anatomy typical of C4 plants. Amongst the native flora of the entire Tristan-Gough Group, only the large coastal tussock grass *Spartina arundinacea* has so far been found to have the typical C4 leaf anatomy.

Disturbance of the native ecosystems on Gough Island: enhanced opportunities for the establishment of introduced plants

It has long been assumed that even in the "disharmonic" ecosystems typical of oceanic islands (Carlquist 1974), some disturbance of their vegetation is essential if introduced plants are to establish themselves in competition with native species (Elton 1958, Wace 1967, Byrne 1980). Such disturbance may be natural, or brought about directly or indirectly by human activities. The major historical events leading to the disturbance of the native ecosystems in all the islands of the Tristan – Gough Group were summarised by Wace & Holdgate (1976). On Gough Island, parties of sealers, prospectors and scientists have lived ashore intermittently since *c.* 1800, and meteorological station personnel continuously since 1955. The hunting of fur seals, albatrosses, and other seabirds by sealers and the cultivation of vegetables at a few places on the coasts have been the most important human impacts on the native ecosystems in the island. Such activities have now ceased, and are prohibited under the lease agreement between Britain and South Africa. Shore parties now rely on imported supplies for their sustenance, supplemented by locally caught fish and crustaceans. So far as is known, no women have ever lived on Gough Island (and very few have ever landed there), and no attempts have ever been made to establish a settled, self-sustaining, breeding human population, with all the disturbance to the native ecosystems which that would inevitably entail.

This paucity of direct human disturbance of the native ecosystems by sustained activities such as agriculture, road-building or mining, is in marked contrast to the large scale and continuous *natural* disturbance of the native plant cover due to the burrowing of enormous numbers of ground-nesting seabirds, the open nest-building of albatrosses, and the colonial breeding of penguins and seals around the coasts. Eutrophication of the peat, (leading to what would be described as gross pollution of soils and soil water if it resulted from human or domesticated animal excreta) is a most important part of this natural disturbance of the native vegetation.

Much of the Gough Island vegetation is dominated by native plants whose growth forms are well adapted to withstand these burrowing activities of seabirds and the deposition of their excreta. The large tussock-forms of grasses *Parodiochloa flabellata* and *Spartina arundinacea,* and the hummock-meadows of *Scirpus sulcatus* are often associated with dense aggregations of seabirds, but the bare gaps between these native perennial plants are extensively colonised by introduced plants, notably *Poa annua, Stellaria media* and *Rumex obtusifolius.* On Nightingale Island, near Tristan da Cunha, which is dominated by *Spartina arundinacea* tussock grassland, and which has a similar but much smaller flora to that of Gough Island (Wace & Dickson 1965), seabird-induced pollution of the fresh water is so severe that the Tristan islanders who visit it are compelled to take their own drinking water with them from Tristan, or to rely on rainwater tanks fed by runoff from the roofs of their huts. Pleistocene peat more than 40 000 years old beneath tuffs and trachyte lavas on Nightingale, contains collophane nodules (Ollier 1984) indicating that eutrophication of the island peats there by seabird excreta is a long-standing feature of that island. The same is undoubtedly true of Gough Island. The overall effects of eutrophication of the Holocene peats on Gough Island by the enormous numbers of seabirds which still breed there today, must be considerable. Alien plants from the temperate zones that are well adapted to growth on wet organic soils in situations polluted by livestock might therefore establish and spread widely on Gough Island, if introduced.

In addition to this continuous natural eutrophication of both soil and water, and the disturbance of native vegetation by breeding seabirds and sea mammals, episodic and severe disruption of the native vegetation results from peat avalanching in the steep terrain. Peat accumulates rapidly in the wet temperate climate of Gough Island, and sodden peat avalanches down the steep slopes during heavy rains. The resulting scars in the peat and vegetation cover are a conspicuous feature of the fernbush and wet heath in the Glens, and in some of the tussock-covered precipices around the coasts. Such "peatslips" take place repetitively, especially where fed by seepage of water from above, dislodging both rock and peat to the valley bottoms. Slopes swept by such peatslips are recolonised by both native and alien plants (Wace 1961). It is notable that the first seed colonists of these shallow peats and rocky surfaces are the alien grasses *Holcus lanatus* and *Agrostis stolonifera,* and the dock *Rumex obtusifolius.* Native colonists spread into the disturbed area by vegetative growth from the surrounding fernbush, and *Histiopteris incisa* rapidly smothers these alien species by marginal ingrowth. Seedlings of the native *Spartina, Phylica* and *Empetrum,* and sporelings of *Lycopodium, Blechnum penna-marina* and other pteridophytes are the most conspicuous of the native colonists away from the margins of the peatslips. Peat avalanching is a most significant natural process disrupting and removing the mantle of peat and thus presenting open habitats on mineral substrates to colonising plants, many of the most successful of which are introduced species. Less spectacular peatslips take place naturally above the fernbush up to the highest points of the island, but at these higher altitudes, the conspicuous colonists of the disturbed areas are native species *(Agrostis carmichaelii, Agrostis magellanica, Grammitis magellanica, Lycopodium* spp, *Hymenophyllum* spp).

Above about 600 m, wind and water erosion of peat mantles, together with the deposition of alluvium and eroded peat, also provides fresh habitats for plant colonisation. *Sonchus oleraceus* has been seen on Tarn Moss in such situations, but apart from the ubiquitous *Poa annua,* alien plants are generally inconspicuous in these naturally disturbed situations at higher elevations.

The frequency of peat avalanching is greatly increased by human trampling, especially on the steepest slopes. Within the fern bush (below about 300 m altitude) and wet heath vegetation (*c.* 300-600 m altitude) the peat mantles are locally stripped off the rock along the route of much-used paths, and the resulting peatslips colonised by the alien grasses and *Rumex obtusifolius.* At higher altitudes, natural wind and water erosion of the thin sodden peat mantles often peels it off the rock, or causes local downslope slumping, as on the much-used paths leading to the summit of South Peak. *Poa annua* grows in such sites, but invasion by alien plants in such situations was not conspicuous in October 1984.

Volcanic activity has not occurred on Gough Island within

historic times. The youngest lava flow on the island (from the side of Edinburgh Peak) is thought to be about 20 000 years old (Ollier 1984), and is now mantled by wet peat. Apart from some local burning of the coastal tussock grassland in the 1950s by fishermen on the north coast, there are no accounts of fires in the vegetation or peat on Gough Island. Fires would produce open habitats for plant colonisation, and evidence of prehistoric fires in the peat is presently being sought by looking for charcoal fragments in lowland peat monoliths.

Introduced animals

Animals introduced to oceanic islands can have profound effects upon the native flora, because their activities may disturb the environment physically, and their food choices also alter existing food chains. Whether herbivores or carnivores, animals often mediate the terms of competition between endemic insular native plants (which are usually ill-adapted to grazing) and alien plants (which may be well adapted to the effects of herbivores in continental situations: Carlquist 1974).

On Gough Island, little is known of the abundance of alien invertebrates, or their impact on plants, but the spread of introduced slugs, earthworms, centipedes, woodlice, and various insects whose presence was noted in 1955-56 by Holdgate (1965) must effect the native plants differentially. The only species of mammal which has been unintentionally introduced is the house mouse *(Mus musculus)*. Mice were probably introduced by sealers early in the nineteenth century and were recorded as abundant by 1887 (Verrill 1895). They are now extremely numerous all over the island, and must have some effects, if only through seed predation, on the reproduction of both native and alien plants. The restricted range of some large-seeded plants (e.g. *Sophora microphylla*, whose lomenta were seen to be chewed in 1984), and the widespread chewing of the flowering and fruiting heads of the large native tussock grass *Spartina arundinacea*, are presumably due to mice. Amongst the alien plants, the fruiting spikes of *Rumex obtusifolius* were often seen at night being eaten by mice. The large seed production of this species, (and of *Plantago major* and *Holcus lanatus*) may provide them with a competitive advantage against the native colonising species when huge numbers of mice are present.

A rat (species undetermined) was sighted on Gough Island near the weather station in October 1983, but a systematic search a year later found no evidence of their presence (Bester *et al.* 1985, Wace 1986). Rats on Gough Island would have a very large effect on the flora (including the spread of alien plants), by their direct use of plants for food, and through their destruction of the huge populations of ground-nesting seabirds (Richardson 1984). It is notable that *Spartina arundinacea* is grazed down by black rats on Tristan, but that the same species forms large bamboo-like tussocks on Gough Island, as it does on Nightingale and Inaccessible, the other rat-free islands in the Tristan-Gough group. The more widespread distribution of alien plants on Tristan, as compared to the other islands, may be related to the spread of alien vertebrate animals on Tristan (rats, cats, dogs, sheep) which have not yet established themselves on the smaller islands.

Intentionally introduced mammals on Gough Island are few; a single known landing of a dog (as a companion to a Tristan islander) in 1957, sheep, and a goat (for milk) in 1958. These animals were landed at The Glen (Van der Merwe, *in litt.*). They were removed or destroyed shortly afterwards. Except for mice, and perhaps poultry, no introduced vertebrates have reproduced on Gough Island. No alien animals are now allowed to be landed, and stringent controls have been recommended to prevent the import of rats to Gough Island (Bester *et al.* 1985).

Management and control of alien plants on Gough Island

The following steps should be taken to ensure that alien plants do not become established on Gough Island:

1. Quarantine surveillance of imports

Prevention of the import of seeds or other plant propagules, whether these are introduced intentionally or accidentally (e.g. in packing material, with machinery, food, clothing or equipment). Quarantine inspection of fresh food imports landed at the time of the annual relief voyages, is particularly important to prevent the introduction of rodents, as well as alien plants.

Packing materials are likely to harbour the seeds of alien plants, and should be burnt or disposed of down the rubbish hole into the sea, rather than being left around the weather station. A dead rat was imported to the weather station with packing material in May 1968 (Wace & Holgate 1976, p. 69). The native ecosystems of Gough Island are particularly vulnerable to radical change if rats should establish themselves there (Atkinson 1985, Wace 1986). The vegetation, as well as the bird life of the island would be radically altered if rats should get ashore: the most stringent efforts must be maintained to exclude them. Standard quarantine procedures controlling the import of materials which may contain foreign organisms or their propagules, should be rigidly enforced at the assembly and packing centres in South Africa, aboard ship, and during the landing and unpacking of cargo shipped to the island. Some instructions on the importance of quarantine should be given to the members of the meteorological teams before they go to Gough Island, and a member of each team charged with responsibility to make sure that quarantine surveillance is maintained at the weather station.

2. Minimize disturbance of the native vegetation, and especially of the peat mantles

From the casual occurrence of alien species which have only been seen once or twice on Gough Island, it is likely that far more plants are arriving in a viable state than are succeeding in establishing themselves on the island. As in other isolated lands, barriers to the ingress of new species may be as much ecological as geographical (Wace 1985). Maintaining the integrity of the native vegetation, and preventing its disruption by physical disturbance, fire, or the import of alien animals, is therefore most important in preventing the establishment of alien plants.

Most of the ground near the weather station is mantled by peat several metres deep. This peat supports a dense cover of fernbush vegetation, which is dominated by *Histiopteris incisa* (bracken fern), *Scirpus sulcatus* (hummock sedge), and the scrambler *Acaena sarmentosa* ("dog catcher"), with thickets of *Phylica arborea* (island tree), *Blechnum palmiforme* (dwarf tree-fern, or "bog-fern" to the Tristan islanders), and numerous other ferns. Most of the herbage is formed by the *Histiopteris* fronds, which grow rapidly in the

spring to a height of a metre or more, casting a dense unbroken shade on the peat. This dense cover makes the establishment of seedlings of any intruding plants very difficult. Most colonising plants associated with human activities inhabit disturbed open sites on mineral soils, and are unlikely to be able to compete with the rapid vegetative growth of ferns on pure peat. Maintaining the integrity of the fernbush vegetation, and ensuring that the mantle of peat is not destroyed, especially in the vicinity of the weather station, is therefore the most effective way of preventing the establishment of alien plants.

Clearance of fernbush or tussock grass vegetation, if followed by the spreading of imported sand or gravel on the exposed peat, allows alien plants to become established, as it did in 1983-84 by the magnetometer hut. Any unused sand or stone chippings should therefore be kept in bags or returned to the weather station, and not spread around on the peat surface.

It is particularly important to prevent fire in the peat – especially in the coastal tussock grassland, which is underlain by dry peat and tussock stools on the steep free-draining precipices around the coasts. It is a mistake to imagine that the peat underlying fernbush or tussock grassland is too wet to burn. Accumulations of dry fibrous peat are common under rock ledges and in caves, even under the wettest conditions. Wildfires could persist and smoulder in such places for months, drying out the wetter peats as they burn through them. Peat fires burning for years in islands with wet temperate climates, have been recorded from Amsterdam Island in the Indian Ocean (Richards 1984), and Chatham Islands (Richards 1977) and Juan Fernandez (Skottsberg 1953) in the Pacific. Evidence of prehistoric fires in the peat formed by coastal tussock grasslands has also been described from the wet cold climate of Macquarie Island (Selkirk *et al.* 1983). The deep peat accumulations on Gough Island are extremely susceptible to fire, and burning them would immediately present open areas of exposed mineral substrate for plant colonisation. Alien plants would rapidly exploit such situations.

3. Maintain botanical surveillance of Gough Island, especially in sites disturbed by human activities

Alien plants will establish themselves on Gough Island in future, despite the best attempts to exclude them by quarantine controls and to minimise disturbance of the native vegetation and peat mantles. It is therefore important to have some people at the weather station, or visiting the island during the annual relief voyages, who have the botanical competence to identify plants, so that any intruding aliens can be detected and removed before they spread.

In October-November 1984, it was only by chance that one of the biologists ashore at the time knew the flora well enough to draw attention to the alien plants that were becoming established around the magnetometer hut. No one else ashore at the time, and none of the meteorological team, had enough knowledge of field botany to know which plants were native and which alien. If the intruding plants had not been pulled out at the time, it is likely that *Senecio burchellii* (a declared noxious weed throughout the Republic of South Africa: Henderson & Anderson 1966, p. iv), and some other alien species found there at the time, would now be spreading from this site of introduction. It is still essential to keep a watch on this site, to check for any regrowth of the alien species, but the South African authorities will be unable to keep the sections of their lease agreement with the British, in respect of excluding alien plants, unless a botanically competent person (who is specifically instructed as part of his/her duties to look for newly arrived alien species) is present at the weather station. Having such a person visit the island with the annual relief expeditions, is an unsatisfactory form of surveillance, because only those species which are conspicuous in the spring, when the annual relief takes place, are likely to be detected.

Conservation, or any other form of management of natural or artificial ecosystems, can not be undertaken without continued and informed observations of the changes that are taking place in the biota all the time. This is particularly important in the management of wilderness for the conservation of native plants and animals, whether the protected area is recognised as a "National Park", or protected (as is Gough Island) under some other protocol.

> "Ecological assessment of what is happening within national parks is growing as an art and a science, but is as yet insufficiently employed. Those who must manage and superintend, but are not ecologists, should realise that there can be no manual or handbook by which one can act by referring to page and paragraph. Every national park is unique, every problem is a different species, even if the genus is a big one. We are doing a detective's job all the time, recognising trends before they become torrents, finding indicators among plants and animals, or even communities of plants and animals, on what is going on in strata of the environment with which they are unfamiliar" (Fraser Darling & Eichhorn 1967, p. 102)

South African ecologists are themselves having to cope now, in their own country, with many "trends which have become torrents" in the invasion of their wildlands by alien plants (e.g. Stirton 1978, Macdonald & Jarman 1984, Wells *et al.* 1986). Particular care should be taken to detect and remove alien plants on Gough Island, because oceanic islands are especially prone to such invasion, and Gough Island is the last remaining temperate oceanic island of any considerable size and ecological diversity which has retained its native plant and animal life intact.

Acknowledgements

I am grateful to the National Geographic Society of Washington, USA; the South African Department of Transport and the South African Scientific Committee for Antarctic Research, Tristan da Cunha administration, and Tristan Investments Ltd., for assistance ashore and afloat. I thank Dr Paul Hattersley and Ms Jill Paterson for assistance with the identification of carbon pathway types in some Tristan and Gough Island specimens.

References

ATKINSON, I.A.E. 1985. The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas. *Int. Counc. Bird Preserv. Tech. Publ.* 3: 35-81.

BESTER, M.N., BREYTENBACH, G.J. & WACE, N.M. 1985. Gough Island rat investigation, Oct/Nov 1984 – Report to South African Committee Antarctic Research, Pretoria (28 pp, typescript).

BYRNE, R. 1980. Man and the variable vulnerability of island life – *Atoll Res. Bull.* 240.

CARLQUIST, S. 1974. Island biology – New York, Natural History Press.

CLARK, M.R. & DINGWALL, P.R. 1985. Conservation of islands in the Southern Ocean: a review of the protected areas of Insulantarctica. Gland, Switzerland & Cambridge, England; *Int. Union Conserv. Nat. Nat. Resour.* 193 pp.

ELTON, C.S. 1958. The ecology of invasions by plants and animals. London, Methuen.

FRASER DARLING, F. & EICHHORN, N.D. 1967. Ecological implications of tourism in National Parks, *I.U.C.N. publ.* 7(1): 98-103.

GREMMEN, N.J.M. 1981. The vegetation of the subantarctic islands Marion and Prince Edward. *Geobotany* 3: 1-149.

GROVES, E.W. 1981. Vascular plant collections from the Tristan da Cunha group of islands. – *Bull. Br. Mus. (Nat. Hist.)*, Bot. 8 (4): 333-420.

HATTERSLEY, P.W. 1983. The distribution of C_3 and C_4 grasses in Australia in relation to climate. – *Oecologia* 57: 113-128.

HEADLAND, R. 1984. The island of South Georgia. Cambridge University Press, Cambridge. 293 pp.

HENDERSON, M. & ANDERSON, J.G. 1966. Common weeds in South Africa. – Memoir 37, Dept. Agricultural Technical Services, S. Africa.

HOLDGATE, M.W. 1965. The fauna of the Tristan da Cunha Islands – *Philos. Trans. R. Soc. Lond., B.* 249: 361-402.

HOLDGATE, M.W. & WACE, N.M. 1961. The influence of man on floras and faunas of southern islands – *Polar Rec.* 10: 475-493.

KEAGE, P.L. 1982. The conservation status of Heard Island and the McDonald Islands – Univ. Tasmania, Environmental Studies Occasional Paper 13: 1-100.

MACDONALD, I.A.W. & JARMAN, M.L. 1984. Invasive alien organisms in the terrestrial ecosystems of the fynbos biome, South Africa. *S. Afr. Natl. Sci. Progr. Rep.* 85, C.S.I.R. Pretoria. 72 pp.

OLLIER, C.D. 1984. Geomorphology of South Atlantic volcanic islands. Pt. II: Gough Island – *Z. Geomorphologie* 28 (4): 393-404.

RICHARDS, R. 1977. Whaling and sealing at the Chatham Islands – Canberra, Roebuck Press.

RICHARDS, R. 1984. The maritime fur trade: sealers and other residents on St. Paul and Amsterdam Islands. Part II – *The Great Circle* 6: 93-109.

RICHARDSON, M.E. 1984. Aspects of the ornithology of the Tristan da Cunha group and Gough Island, 1972-1974 – *Cormorant* 12: 123-201.

RUDMOSE BROWN, R.N. 1905. The botany of Gough Island: phanerogams & ferns – *J. Linn. Soc. Lond. Bot.* 37: 238-250.

SELKIRK, D.R., SELKIRK, P.M. & GRIFFIN, K. 1983. Palynological evidence for Holocene environmental change and uplift on Wireless Hill, Macquarie Island – *Proc. Linn. Soc. N.S.W.* 107 (1): 1-17.

SKOTTSBERG, C. 1953. The natural history of Juan Fernandez and Easter Island, I (3), 89-192. Uppsale, Almqvist & Wiksells.

STIRTON, C.H. (Editor) 1978. Plant invaders: beautiful but dangerous – Dept. Nature & Environmental Conservation, Cape Town.

TAGART, E. 1832. A memoir of the late Captain Peter Heywood, RN. – London.

VAN DER MERWE, J.J. *in litt.* Letters dated 22/11/56 & 2/4/57 (Leader, South African weather station at The Glen, 1956-57).

VERRILL, G.E. 1895. On some birds and eggs collected by Mr George Comer at Gough Island, Kerguelen Island, and the island of South Georgia. – *Trans. Conn. Acad. Arts Sci.* 9 (2).

VOGEL, J.C., FULS, A. & ELLIS, R.P. 1978. The geographic distribution of Kranz grasses in South Africa – *S. Afr. J. Sci.* 74: 209-215.

WACE, N.M. 1961. The vegetation of Gough Island – *Ecol. Monogr.* 31: 337-367.

WACE, N.M. 1967. Alien plants in the Tristan da Cunha Islands – *I.U.C.N. publ.* 9 (3): 46-60.

WACE, N.M. 1969. The discovery, exploitation and settlement of the Tristan da Cunha Islands. *Proc. S. Aust. Brch R. geogr. Soc., Aust.* 70: 11-40.

WACE, N.M. 1985. Australia, the isolated continent. Chapter 1 in: Pests & parasites as Migrants. Eds A.J. Gibbs & R. Meischke – Australian Academy of Science, Canberra.

WACE, N.M. 1986. Rats on islands – research is needed – *Oryx* 20 (2).

WACE, N.M. & DICKSON, J.H. 1965. The terrestrial botany of the Tristan da Cunha Islands – *Philos. Trans. R. Soc. Lond. B.* 249: 273-360.

WACE, N.M. & HOLDGATE, M.W. 1976. Man and nature in the Tristan da Cunha Islands – *Int. Union Conserv. Nat. Nat. Resour. monogr.* 6: 1-114.

WACE, N.M. & OLLIER, C.D. 1984. Biogeography and geomorphology of the South Atlantic islands – National Geographic Society, Research Reports, 1975 projects, Washington DC.

WELLS, M.J., BALSINKAS, A.A., JOFFE, H., ENGELBRECHT, V.M., HARDING, G. & STIRTON, C.H. 1986. A catalogue of problem plants in Southern Africa – Mem. Botanical Survey S. Africa 53 (Botanical Research Institute, Dept. Agriculture & Water Supply, Republic of South Africa.