Introduction, present status and control of alien species at the Prince Edward islands, sub-Antarctic

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A total of 49 species of non-marine aliens (18 vascular plant species and 31 animal species, including domestic species) has been recorded at the Prince Edward islands to date. Twenty-five species are considered to have become naturalised. Two of the alien plant species, the forb Sagina apetala, *and the grass* Agrostis stolonifera, *are presently spreading at Marion Island. Two species of mammals have become naturalised aliens on Marion Island. Sealers accidentally introduced the house mouse* Mus musculus *to Marion Island in the early nineteenth century where they are now found in great numbers. In an attempt to curb the mouse problem the domestic cat* Felis catus *was introduced to Marion Island in 1949. They are now widely distributed over the island and attempts are underway to eradicate them. Only five alien species, annual bluegrass* Poa annua, *the spider* Myro paucispinosus, *the chironomid midge* Lymnophyes pusillus, *the hemipteran* Rhopalosiphum padi *and a species of fly, possibly* Psychoda *sp., have been recorded from Prince Edward Island. Strict measures are enforced to avoid any further introduction of aliens to this island.*

Altesaam 49 uitheemse nie-mariene spesies (18 vaatplantspesies en 31 dierespesies, waaronder huishoudelike spesies) is tot op hede op die Prins Edward-eilande aangeteken. Vyf-en-twintig spesies word as genaturaliseer beskou. Twee van die vreemde plantspesies, die kruid Sagina apetala, *en die gras* Agrostis stolonifera, *versprei tans op Marion-eiland. Twee uitheemse soogdierspesies het op Marion-eiland genaturaliseer geraak. Robbevangers het in die vroeë 19e eeu die huismuis* Mus musculus *per ongeluk op Marion-eiland vrygelaat waar hulle tans in groot getalle aangetref word. In 'n poging om die muisprobleem te bekamp,is die eerste huiskatsoort* Felis catus *in 1949 na Marion-eiland gebring. Ook hulle is nou wyd versprei oor die eiland en pogings om hulle uit te roei, is aan die gang. Wat Prince Edward-eiland betref, is slegs vyf uitheemse spesies, die eenjarige blougras* Poa annua, *die spinnekop* Myro paucispinosus, *die Chironomied-muggie* Lymnophyes pusillus, Rhopalosiphum padi *van die orde Hemipters en 'n vliegspesie, moontlik* Psychoda *sp. aangeteken. Streng maatreëls word toegepas om te voorkom dat enige verdere vreemde indringers op die eiland toegelaat word.*

Introduction

Most islands in the Southern Ocean have been affected by humans, whether by accident or deliberately. The ecosystems of these islands are particularly vulnerable to human disturbance and once they have been disturbed, either by direct destruction of native species or indirectly by the introduction of alien species, it is extremely difficult, if not impossible, to restore them to their natural state (e.g. Holdgate & Wace 1961, Holdgate 1967, 1970).

Marion du Fresne, French navigator and Captain of the frigate *Le Mascarin*, is attributed to discovering the Prince Edward islands (Marion and Prince Edward) in the sub-Antarctic Indian Ocean in 1772, although the Dutch may have sighted the islands in 1663 (Van Zinderen Bakker Sr 1971 and references therein). Exploitation of southern elephant seals *Mirounga leonina* and fur seals *Arctocephalus* spp. by sealers was carried out from at least as early as 1802 and ceased in November 1930, the sealer *Kildalkey* being the last to visit the islands (Marsh 1948, Rand 1962, Cooper & Avery 1986). The Prince Edward islands were annexed by the Union of South Africa in 1947-1948. Marion Island has been continually manned since annexation by meteorological teams of the South African Weather Bureau and also by teams of scientists since 1965. Prince Edward Island has always been uninhabited since annexation and is visited for short periods only by scientists.

The presence of man has seen the introduction, and, in a number of cases, the colonisation of the Prince Edward islands by alien plants, terrestrial invertebrates (spiders and insects only), freshwater fish, birds and mammals. This paper lists all known non-marine aliens (species introduced by man) recorded at the Prince Edward islands, gives details (where known) of their introduction and present status and discusses their control.

Methods

We have obtained information on aliens at the Prince Edward islands from four major sources: the published literature; reports and other unpublished documents now filed in the Niven Library, FitzPatrick Institute; information supplied by previous team members; and research recently conducted by ourselves and our colleagues at the Prince Edward islands.

Results

A total of 49 non-marine species thought or known to be aliens (18 vascular plant species and 31 animal species, not including man *Homo sapiens* but including domestic species) has been recorded at the Prince Edward islands to date. These species are discussed below under the heading of their major taxonomic groups.

Plants

Fifteen species of alien 'non-domestic' vascular plants have been recorded from the islands (Table 1). It appears that eight of the alien species on Marion were introduced by sealers during the 19th or early 20th centuries and seven since the establishment of the meteorological station in 1948 *via* packing material, sheep fodder or imported soil or sand (Huntley 1971, Gremmen & Smith 1981, Gremmen 1982, J.E. Crafford *in litt.*). Several species may have been introduced on more than one occasion (Gremmen 1982, Table 1). At Marion Island five of the 15 aliens are classed as transient (and no longer occur), one as persistent and nine as naturalised (Table 1).

Two of the alien species, the forb *Sagina apetala* and the grass *Agrostis stolonifera,* are presently spreading at Marion Island (Gremmen 1975, Gremmen & Smith 1981, Gremmen 1982, Table 1).

Alien plants have often established themselves in areas where the natural vegetation has been disturbed or destroyed. The initial spread of *Poa annua* in the vicinity of the meteorological station is attributed to the species' tolerance of trampling and grazing by domestic sheep (Gremmen 1975).

Only one alien plant species, annual bluegrass *P. annua,* has so far been recorded from Prince Edward Island where it is considered to be naturalised (Gremmen 1975, 1982). *Poa annua* was first recorded at Prince Edward Island in 1966 (Huntley 1971).

Poa annua has spread in the king penguin *Aptenodytes patagonicus* colony at Cave Bay on the eastern side of Prince Edward Island (Gremmen 1975). It has not been recorded on the western side of the island (J.E. Crafford pers. comm.). However, *Agrostis stolonifera* is able to invade undisturbed vegetation and can replace the native dwarf shrub *Acaena magellanica* (Gremmen & Smith 1981, Gremmen 1982, V.R. Smith pers. comm.); it probably being the biggest threat of all the alien plants at the Prince Edward islands.

In addition to the fifteen alien species recorded above, live trees from South Africa were imported to Marion Island in 1950 and 1951 and planted around the meteorological station. Cluster or maritime pine *Pinus pinaster,* Lawson cypress *Chaemaecyparis lawsoniana* and stiffleaved cheesewood *Pittosporum crassifolium* as well as vegetables (of unknown type) were planted in soil imported from South Africa but none survived for very long (La Grange 1952, 1954, Gremmen 1975). A greenhouse with imported soil existed in the past at Marion Island (Gremmen 1982). Radishes have been grown successfully on the island (La Grange 1962a). In 1972 lettuce, cabbage and tomatoes were planted in the greenhouse in island soil. The seeds germinated but did not progress past the seedling stage (V.R. Smith pers. comm.).

Invertebrates

A total of 18 species of alien macro-invertebrates has been recorded of which 14 are considered to be naturalised (Table 2).

Table 2

Animal species known or thought to be aliens recorded from Marion Island. Classification adapted from Walton & Smith (1973)*

Species	Common name	Present status
Invertebrates		
Myro kerguelenensis	spider	widespread, naturalised
*M. paucispinosus***	spider	"
*Limnophyes pusillus***	chironomid midge	"
Fannia canicularis	lesser house fly	"
Telmatoscopus albipunctatus	winged dipteran	"
Pericoma sp.	winged dipteran	"
Macrosiphum euphorbiae	hemipteran	"
*Rhopalosiphum padi***	hemipteran	"
Neomyzus circumflexus	hemipteran	"
Brachycaudus helichrysi	hemipteran	"
Heliothis armigera	American bollworm	transient
Agrotis ipsilon	cutworm	"
Blatella germanica	German cockroach	"
Psychoda sp.?**	latrinefly?	?
Scaptomyza sp.	fruitfly	naturalised
unnamed	thrip species	"
Plutella xylostella	diamond-back moth	"
Dendrobaena rubida	earthworm	widespread, naturalised
Fish		
Salmo gairdneri	rainbow trout	transient
S. trutta	brown trout	naturalised
Birds		
Gallus gallus var. *domesticus*	domestic fowl	transient
Anser anser	domestic goose	"
Psittacus erithacus	African grey parrot	"
Amazona sp.	Amazon parrot	"
Mammals		
Mus musculus	house mouse	widespread, naturalised
Felis catus	domestic cat	"
Ovis aries	Merino sheep	transient
Capra hircus	domestic goat	"
Sus scrofa	domestic pig	"
Equus asinus	donkey	"
Canis familiaris	domestic dog	"

*See text for references.

**also recorded from Prince Edward Island (Lawrence 1971, Crafford 1986, J.E. Crafford *in litt.*).

Table 1

Alien plants recorded from Marion Island. After: Huntley 1971, Gremmen 1975, 1981, Gremmen & Smith 1981, Gremmen 1982. Classification according to Walton & Smith (1973)

Species	Date first recorded, locality, present status	Comments
TRANSIENT ALIENS		
Avena sativa	1965-66, Meteorological station	All four species flowering 1965-66
Holcus lanatus	1953, April 1965 Meteorological station	
Hypochoeris radicata	1953, 1965-66 chicken run, Meteorological station	
Plantago lanceolata	1965-66, chicken run, Meteorological station	
	All the above species were not recorded during the 1973-75 survey. Presumably none has survived	
Unidentified thistle	1984, Van den Boogaard River and Meteorological station	31 plants removed, probably imported in building sand (J.E. Crafford *in litt.*)
PERSISTENT ALIENS		
Rumex acetosella	1953, no locality, 1965-66, Sealer's Cave, Meteorological station, Gentoo Lake	Seedlings at Gentoo Lake 1973-75 but chicken run population not survived. Sealer's Cave area not searched thoroughly
RESTRICTED NATURALISED ALIENS		
Alopecurus australis	Dec 1965, Feb 1975, Mixed Pickle Cove	Inflorescences observed. Spreading by vegetative means
Elytrigia repens	1966, Ship's Cove	Still present in 1981, no noticeable change between 1975 and 1981
Festuca rubra	1966, sealer's camp, Ship's Cove. 1973-75, sealer's camp, Ship's Cove with *Agropyron repens*. North Van den Boogaard River. Cliff near Meteorological station	In February seed was formed in abundance. Spreading mainly by vegetative means. No change between 1975 and 1981
Poa pratensis	1965-66, Meteorological station, Ship's Cove. 1973-75, seven localities between Archway Bay and Ship's Cove, occupying areas 10-30 m^2 in area. In 1981 two new stands were found	At old sites numerous inflorescences formed and seed was set. No seedlings observed. Seem to spread slowly by vegetative means
WIDESPREAD NATURALISED ALIENS		
Agrostis stolonifera	April 1965, Feb 1966, Jan 1975, Ship's Cove and Meteorological station 1981, northeastern lowland from Ship's Cove to Archway Bay	Largely restricted to drainage lines and stream sides. Forms large mats and flowers profusely. Able to invade undisturbed vegetation. Replaces *Acaena magellanica*. Previously mis-identified as *Agropyron repens* (Huntley 1971) and *Agrostis hergiana* (Gremmen 1975). Has increased greatly between 1975 and 1981. Thought to have been introduced in the 1950s or early 1960s at the meteorological station
Cerastium fontanum	1965-66, Meteorological station, Ship's Cove, Sea Elephant Bay, Mixed Pickle Cove, Kaalkoppie, Bullard Beach. 1973-75 at least 30 sites, perhaps as many as several hundred (V.R. Smith pers. comm.), between Cape Davis and Archway Bay areas, Mixed Pickle Cove, Kaalkoppie, Swartkop Point	Flowers and seeds produced in abundance. Seedlings observed frequently. Does not appear to compete strongly with natural vegetation. No important changes in distribution between 1975 and 1981
Poa annua	1948 no locality, 1965-66, 13 localities at old sealing bases or shipwrecks, 1973-75, 83 localities around perimeter of island. Present on the eastern side of Prince Edward Island	Does not colonise areas where animals are absent since seems to require some manuring. Occurs most often where trampling by penguins and seals is marked (V.R. Smith pers. comm.). Flowers and seeds present throughout summer. When growing in dense swards appears to be perennial. Spreads easily by means of seed. Little change in distribution noticed between 1975 and 1981
Sagina apetala	1965-66, Meteorological station. 1973-75, abundant from south of Gentoo Lake to Cabbage Point. 200-300 individuals mouth Van den Boogaard River. May 1975 single plant between Meteorological station and Trypot Beach	Abundant flowers and seeds during summer. Seedlings observed. Appears to invade natural vegetation by means of seed where trampling has occurred. Has increased rapidly between 1975 and 1981. Thought to have been introduced in the 1950s or early 1960s at the Meteorological station
Stellaria media	1873, northeast coast, Marion Island. 1965-66, 12 localities at old sealing bases or shipwrecks. 1973-75, 45 localities around perimeter of island, perhaps as many as several hundred (V.R. Smith pers. comm.)	Few colonies up to 5 m^2. Flowers and seeds observed throughout summer. Seedlings found at a number of sites. Does not compete aggressively with natural vegetation. No important changes in distribution between 1975 and 1981

Four species of spiders (Araneida) are known from Marion Island, two species, *Myro kerguelenensis* (first recorded 1952) and *M. paucispinosus* (recorded prior to 1947) may have been introduced by man, the evidence being more compelling for the former species (Lawrence 1971). The latter species has been recorded at Prince Edward Island at a number of localities (Lawrence 1971).

Six species of winged dipterans are thought to have been introduced by man to Marion Island (Séguy 1971, J.E. Crafford *in litt.*, S.L. Chown pers. comm.). It would appear that the chironomid midge *Limnophyes pusillus*, a widespread and abundant species on Marion, was introduced from Europe (Dreux 1971, Séguy 1971) and is the only insect to have successfully colonised the freshwater habitat on Marion Island (Crafford this volume). It was first collected on Marion Island in 1939 (Jeannel 1940, Séguy 1971). The lesser housefly *Fannia canicularis* was first recorded in 1956 and is thought to have been introduced by man (Dreux 1971, Séguy 1971). The flies *Telmatoscopus albipunctatus* and *Pericoma* sp., first recorded in 1965, are thought to have been introduced by man from Africa (Dreux 1971, Séguy 1971). An as yet unidentified species of fly, possibly a latrinefly *Psychoda* sp., was recently collected at Kildalkey Bay, Marion Island and at Prince Edward Island in May 1986 (J.E. Crafford *in litt.*). A fruitfly *Scaptomyza* sp., thought to be introduced, was first observed at Marion Island in 1984, but is now well established over the whole island (S.L. Chown pers. comm.).

An unidentified thrip (Thysanoptera) has recently been collected near the meteorological station, Marion Island and is thought to be an alien (J.E. Crafford *in litt.*).

Man may have been responsible for the introduction of four species of hemipterans, *Macrosiphum euphorbiae, Rhopalosiphum padi, Neomyzus circumflexus* and *Brachycaudus helichrysi*, to Marion Island, although it is possible that they were transported there by wind (Dreux 1971). These four species were first collected at Marion Island in 1965/1966 (Dreux 1971).

An earthworm *Dendrobaena rubida* is thought to be an alien (J.E. Crafford *in litt.*). The species was first collected at Marion Island in 1966 (Sims 1971).

It is likely that new species of invertebrates have been introduced by supply vessels visiting Marion Island since 1966. The cosmopolitan American bollworm *Heliothis armigera*, cutworm *Agrotis ipsilon* and the German cockroach *Blatella germanica* have been recently recorded from the meteorological station (J.E. Crafford *in litt.*). These were probably introduced with vegetable supplies. A single dead beetle (Carabidae) has recently been found in such vegetables at the island (J.E. Crafford *in litt.*). Only occasional individuals of the German cockroach have been seen and it is doubtful whether they have established a breeding colony (J.E. Crafford *in litt.*). Larvae of the diamond-back moth *Plutella xylostella* were first recorded at Marion Island in May 1986 feeding on the leaves and growing points of the Kerguelen cabbage *Pringlea antiscorbutica* causing extensive damage and stunted growth. This species was probably introduced with fresh cabbage supplies since its present distribution is downwind from the meteorological station (J.E. Crafford *in litt.*).

Very little is known about the presence of alien invertebrates on Prince Edward Island. *Limnophyes pusillus* has recently been recorded there (Crafford this volume) and in May 1986 the aphid *Rhopalosiphum padi* and a latrinefly was recorded at Prince Edward Island (J.E. Crafford *in litt.*).

Fish

There have been two deliberate introductions of trout *Salmo* spp. to Marion Island (Table 2). Rainbow trout *S. gairdneri* (unknown number) were introduced in November 1959 (R. Louw pers. comm.), most of the fish having died prior to introduction on the voyage to the island aboard the *Natal* (*The Cape Argus*, 14 November 1959). There was no evidence the fish introduced into "the streams" survived (C. Bredenkamp *in litt.* 1964). However, ten rainbow trout were accidentally killed in October 1962 when "chloride of lime" (calcium chloride) was added to a pond called "Dykes Pond" close to the meteorological station in order to purify the water for human consumption (M.C.L. van der Ven *in litt.* 1964). Although rainbow trout therefore survived at Marion Island for at least three years and are not known to have bred there, we classify them as transient aliens, rather than as naturalised aliens that are now extinct.

Approximately 130 brown trout *S. trutta* fingerlings were introduced in March 1964 into the lower part of the Van den Boogaard River at "Waterfalls", *c.* 750 m north of the meteorological station (C.T. Wiersma *in litt.* 1964, R. Louw pers. comm.). Two hundred fingerlings were taken to the island but approximately one-third died prior to the introduction (C.T. Wiersma *in litt.* 1964). In December 1970 trout were reported to be "numerous" (Anon. 1970.)

Twenty-seven brown trout were caught in the Van den Boogaard River by A. Berruti (pers. comm.) in April 1981. Their mean mass was 149 g and mean total length was 210 mm. Detailed analysis of these specimens will be published elsewhere. A.F. de Villiers caught several brown trout in 1973 and noted that their stomach contents included pebbles, earthworms and small trout (V.R. Smith pers. comm.). The 1981 collection was found to contain pebbles, snails, earthworms, spiders, larvae of the flightless moth *Pringleophaga marioni*, weevils and house mice *Mus musculus* in their stomachs (J.E. Crafford pers.comm., BPW pers. obs.). The larvae of the midge *Limnophyes pusillus* constitute the entire benthic fauna of the streams on Marion Island (Crafford this volume) but surprisingly none was recorded from the stomach contents of brown trout. At Kerguelen and Crozet islands the composition of the aquatic fauna has changed with the introduction of salmonid fish (Davaine & Beall 1982).

The 1981 collection was then presumed to have been the entire population (A. Berruti pers. comm.). However, on 19 May 1983, N.J. Adams and P.J.J. van Rensburg (pers. comm.) caught two trout; a third individual was seen but was not caught. In November 1984 a search of the Van den Boogaard River was made for trout by BPW but none was seen. The species may now be extinct at Marion Island, but this remains unproven. Trout have not been introduced to Prince Edward Island.

Birds

No birds have been introduced into the natural environment of the Prince Edward islands but four domestic species have been kept at the meteorological station at various times (Table 2).

As a supplement to the diet for members of the 1948 meteorological team, specially selected domestic fowls *Gallus gallus* var. *domesticus* from the Government experimental farm at Onderstepoort were sent to Marion Island. "The *Natal* ... put ashore eight black Australorp hens and two cocks. The hens began laying almost at once" (Marsh 1948). The success of this introduction is contradicted by Crawford (1982): "We imported a dozen laying hens, hoping to enjoy the luxury of an occasional fresh egg, but it was too cold for them and the experiment was not successful." It is not known whether or not the imported poultry was quarantined and/or vaccinated against diseases such as Newcastle Disease prior to their despatch from Cape Town. Later, Australorp chickens did very

well inside a protected cave, according to La Grange (1954) who spent several seasons at Marion Island. Live chickens were sent to Marion Island at least annually from 1950 until 1970 when the last batch of 70 or 75 was sent in February of that year (La Grange 1954, Volckman 1970, *The Cape Argus* 14 November 1959, D. J. van Schalkwyk pers. comm.). In October 1961 a hen hatched a few eggs (La Grange 1961a) so it can be assumed that chickens were then breeding on the island. In September 1964, 31 chickens were alleged to be laying 36 eggs a day (Anon. 1964a). In December 1968, 40 eggs were being laid a day and "breeding pens" had been built (Anon. 1968). Chickens were laying eggs on the island until at least June 1971 when the fowl run was repaired (Anon. 1971a, Anon. 1971b). A chicken cage was removed from 'Kapua Creek' (Prion Valley) in 1972: the first site of the grass *Agrostis stolonifera* (B.J. Huntley pers. comm.). It is not known how long chickens survived at Marion Island after June 1971, but none was present in April 1974 (A.J. Williams pers. comm.).

A.B. Crawford brought a small flock of domestic geese *Anser anser* from Tristan da Cunha to South Africa for Marion Island in 1948. Two of the geese died in transit in Cape Town, the remainder reaching Marion Island on board the H.M.S.A.S. *Good Hope* (Marsh 1948). A.B. Crawford (pers. comm.) has no recollection as to what became of these geese.

An African grey parrot *Psittacus erithacus* was present at the meteorological station in 1962 and used to sit on the back of the dog "Oubaas" then on the island (B. Sciocatti pers. comm.). It was taken back to South Africa by J. Nagel in March 1963 (P.A. le Roux pers. comm.). An Amazon parrot *Amazona* sp. was also present at the meteorological station in 1963. It is not known what became of this bird (B. Sciocatti pers. comm.).

No birds are known to have been introduced to Prince Edward Island.

Mammals

Two species of terrestrial mammals have become naturalised aliens on Marion Island, an additional five, introduced, domestic species no longer occur at the Prince Edward islands.

The only mammal inadvertently introduced to the islands is the house mouse. The sealer William Phelps of the *Pickering* ("Webfoot" 1871, Richards 1984) states that there were many house mice on Marion Island when he landed there in about August 1818, occurring on the beaches, in coves and "among the snows of the mountains". "Webfoot" (1871) considered that the mice had "been introduced from some sailing vessel, probably with the stores of the gang". This date is far earlier than that usually cited for the presence of mice (e.g. Moseley 1879, Gleeson & Van Rensburg 1982), and shows that mice must have arrived with the very early sealers. This species is now found in great numbers on Marion Island but, strangely, does not occur on Prince Edward Island.

Members of the first meteorological team in 1948 were plagued by mice. Crawford (1982) mentions that the temporary tarpaulin shelters within which they ate their meals soon acquired the name of "Mouse Inn". After a mouse had been found in the soup "Everything" was added to the name board. Anderson & Condy (1974) found mice occurring all over the coastal plains and up to the 300 m contour level on Marion Island. One sighting was reported by them at over 1 000 m near Jan Smuts Peak.

Gleeson (1981) gives the 450 m contour level on Marion as the upper survival limit for mice. The principal food supply of the mice is the larvae of the flightless moth *Pringleophaga marioni* with plant material (mainly grass seeds) being slightly more prevalent in summer (Gleeson & Van Rensburg 1982). Density of the mice varies greatly on the island due primarily to the availability of invertebrate biomass which is highest in biotically influenced areas (Gleeson 1981).

The mice do not seem to affect the vegetation on the island greatly and Gleeson & Van Rensburg (1982) suggested that due to the length of time that they have been present on Marion a dynamic ecological equilibrium exists between the mice and their invertebrate prey.

The first record of a domestic cat *Felis catus* on Marion Island is of one individual put ashore in late 1818 or early 1819 from the sealer *General Gates* ("Webfoot" 1871, Richards 1984). The cat, described as a "she", became feral after a few months and thereafter was sometimes seen "far inland" where it would "bound away" on being seen ("Webfoot" 1871). According to Marsh (1948), a kitten was borrowed from the guardship in 1948 in an attempt to curb the mouse problem. It is not known what eventually happened to these two individuals. From available information, Van Aarde & Skinner (1981) showed that there were only two further introductions of domestic cats *Felis catus* to Marion Island, the first early in 1949 comprised an orange striped tabby male and a black and white female; the second followed in August 1949 and comprised three siblings.

The first feral cat was seen in 1951 approximately 12 km west of the meteorological station (Van Aarde & Skinner 1981). Feral cats, or indications of their activities, were recorded all around the periphery of the island sixteen years after their introduction, thereby suggesting an average minimum dispersal rate of 2 km/year (Van Aarde & Skinner 1981).

Cats are now entirely feral and widely distributed over most of Marion Island and up to the 450 m contour (Van Aarde 1979). Distribution of cats seems to be influenced by the distribution of their avian prey, burrowing petrels, in particular the broadbilled prion *Pachyptila vittata,* which forms the principal prey (Van Aarde 1980, Van Rensburg 1985). It has been estimated that 455 000 burrowing petrels of seven species were killed by cats in 1975 (Van Aarde 1980).

Cat population estimates prior to attempted control have been given by the following authors: Van Aarde & Skinner (1981) 1973 : 1 500; Van Aarde (1980) 1974 : 1 693; Van Aarde (1979) 1975 : 2 139 ± 290.

The intrinsic annual rate of natural increase for the population in 1975 was estimated to be 17-23 per cent (Van Aarde 1980). Following a thorough investigation into various methods of control (Erasmus 1979), steps were then taken to reduce the cat population using the host specific, contagious feline panleucopaenia virus (FPL) which was introduced in March 1977 (Erasmus 1979, Howell 1984, Van Aarde 1984).

Density estimates for October 1978 (19 months after the introduction of FPL) were 54 per cent lower than the estimate for October 1976 (five months after the introduction). That for June 1980 (38 months after introduction) was 65 per cent lower than that for June 1976 (Van Aarde & Skinner 1981). FPL has resulted in a lowered fecundity and a change in the population age structure (a reduction in the number of subadults) as well as a decrease in population size (Van Rensburg this volume).

The 1982 population of 615 ± 107 feral cats is now showing signs of stabilising and/or recovering and FPL is now considered to be inefficient as a primary control measure due to the relatively low density of cats (Van Rensburg this volume). This reduced population was estimated to have killed 142 000 burrowing petrels of six species in 1982 (Van Rensburg 1985). It is therefore planned to attempt the eradication of cats at

Marion Island by intensive night shooting during their breeding season over the next few years. This secondary control measure, which has already been tested experimentally, will attempt to ensure the elimination of all female cats (Van Rensburg this volume). Cats have never been recorded at Prince Edward Island.

Five German Merino ewes *Ovis aries* in lamb were brought to Marion Island on board the frigate *Natal* in 1948 to supplement the diet of the meteorological team (Marsh 1948). A sheep pen was built in 1950 (La Grange 1952). In November 1959, 35 sheep were taken to Marion Island aboard the *Natal* (*The Cape Argus* 14 November 1959). Huntley (1971) reported that the sheep flock varied from ten to 60 individuals. In the 1950s and 1960s the practice was to send Merino sheep to Marion Island each year, so that animals could be slaughtered each month to supply the meteorological team with fresh meat (sheep had eartags and slaughterings were recorded in a log book), there being no deep freeze facilities at the base at that time (La Grange 1954, V.R. Smith pers. comm.). However, towards the end of the year the remaining sheep became pets and team members were reluctant to kill them (V.R. Smith pers. comm.). Sheep were obviously allowed to graze unpenned during the day, at least: "Loutjie de Beer, the medical man, developed a very successful secret call to entice the sheep to come running from wherever they are grazing to be locked up for the night" (Anon. 1964b). By December 1966 the sheep were reported to be wandering into the mountainous interior making it difficult to round them up (Anon. 1966). The last sheep were sent to Marion Island in February 1969 after which there were 22 present (D. J. van Schalkwyk pers. comm.). In October 1969 sheep were reported to be wandering far from their pens (Anon. 1969). By October 1971 only five sheep remained on the island and the sheep pen had been torn down (Anon. 1971c). A white sheep, obviously feral, was caught and "curtailed" in February 1972 (Anon. 1972). According to V.R. Smith (pers. comm.) three feral sheep were caught in February 1972: two were slaughtered and the remaining one died while trying to escape. Huntley (1971) states that only wethers (castrated males) were sent to Marion Island.

The last sheep seen alive at Marion Island was caught by A.F. de Villiers in the upper regions of Piew Crags (*c.* 2 km inland from the meteorological station) in April 1973, after administering a "haircut" to the animal so that it could see again it was released alive (Gremmen 1981, D.A. Gerneke pers. comm.). La Grange (1954) states that the wool of Merino sheep at Marion Island grew much faster than in South Africa. A.J. Williams (pers. comm.) found two sheep skulls at Marion Island during 1974 but saw no live animals. It would thus seem that the last feral sheep died between April 1973 and April 1974 when A.J. Williams first arrived at the island.

The presence of trampling and grazing sheep around the meteorological station was thought to have caused the establishment and spread of *Poa annua* and sorrel *Rumex acetosella*, both alien plants (Huntley 1971, Gremmen 1975), otherwise the direct effects of both domestic and later feral sheep on the natural vegetation seems to have been local and temporary. Sheep selectively grazed *Poa cookii* tussock grassland and caused its rapid destruction in the immediate vicinity of the meteorological station (Huntley 1971). From the late 1960s fodder was apparently sent to the island to supplement their diet (Huntley 1971). The sheep were found to lose mass after a few months ashore (La Grange 1954), who related this to "... the poor nutritional value of the grass."

Domestic goats *Capra hircus* (unknown number) were introduced to Marion Island prior to 1961 (La Grange 1961a): "A few years ago goats were released on the island and due to the damages done to the buildings they were chased away. The present relief party has found the meat a real delicacy." The goats became feral and spread to the western side of the island, their hooves becoming long and flat: presumably due to lack of wear in the wet terrestrial habitat. They were slaughtered in 1961 with the exception of one individual which managed to escape (P.A. le Roux pers. comm.). What became of this individual is unknown. It is not known whether goats actually bred on Marion Island.

A "couple" of hogs (domestic pigs *Sus scrofa*), presumably a male and a female, were left on Marion Island by the sealer *Pickering* prior to August 1818, at which time pigs were present on both the western and eastern sides of the island ("Webfoot" 1871, Richards 1984). Over the next two years, eight pigs (three were large boars) were killed and "we no doubt killed the whole stock" ("Webfoot" 1871). It can thus be assumed that the pigs had established themselves as a feral breeding population before their extinction by sealors from the *Pickering*. Domestic pigs (two to three individuals) were again introduced to Marion Island in 1950 and kept in a pig sty on Boulder Beach, below the meteorological station and were eventually eaten (King 1952, J.J. la Grange pers. comm.). The pig sty was "reconstructed" during 1950 (La Grange 1952).

A donkey *Equus asinus* was taken to Marion Island in November 1955 aboard the *Gamtoos* by PWD (Public Works Department) team members to assist in carrying pipes to obtain water for the meteorological station from the Van den Boogaard River. It was taken back to Cape Town at the end of the takeover period (J. Bothma pers.comm.). This same animal featured being transported on a raft in a film of the island (P.J.J. van Rensburg pers. comm.).

A domestic dog *Canis familiaris* was put ashore at Marion Island in late 1818 or early 1819 from the sealer *General Gates* ("Webfoot" 1871, Richards 1984). This dog, known as "Jack", and therefore probably a male, died after falling over a cliff after nearly a year ashore ("Webfoot" 1871). A dog known as 'Oubaas', a male ridgeback-cross (P.A. le Roux pers. comm.), was brought to Marion Island in April 1961 (La Grange 1961b, 1962). A volcanic cone on the island is named after this animal (Langenegger & Verwoerd 1971). Oubaas was removed from the island in March 1966 (B. Sciocatti pers. comm.). During October 1978 three female Jack Russell terriers were present on the island in order to assess their value as a means of cat control (Erasmus 1979). Terriers of one sex only were deliberately chosen to be sent to the island (W.R. Siegfried pers. comm.). These animals were removed from the island after the experiment.

No mammals are known to have been introduced to Prince Edward Island, which is therefore both mouse and cat free.

Discussion

Of the 49 species of aliens recorded at the Prince Edward islands (Tables 1 & 2), 26 are considered to have become naturalised (i.e. to be reproducing in the wild). All of these species are still present on at least one of the two islands and no naturalised species is known to have become extinct, with the possible exception of the pigs and brown trout. Active efforts to eliminate naturalised alien species at Marion Island to date have been restricted to domestic cats and brown trout, not counting the early elimination of feral pigs. No efforts have been made to remove the five known aliens from Prince Edward Island. It is unlikely that practical control measures

could ever be introduced to control or eliminate the majority of naturalised alien species, with the exceptions of brown trout and cats. However, stringent efforts (careful packing and sealing of containers, washing down of footwear and helicopter wheels, no fresh vegetables) are made to avoid introducing aliens from Marion Island to Prince Edward Island, especially the plants *Agrostis stolonifera* and *Sagina apetala* (Gremmen 1982) and the house mouse. Of concern here is that fishing vessels are alleged to have landed parties on Prince Edward Island at times (Clark & Dingwall 1985).

As far as is known, no efforts have been made (or are likely to be feasible) to control or eliminate naturalised alien plants and invertebrates at sub-Antarctic islands, although some success with plant control has occurred at cool temperate islands in the Southern Ocean (e.g. the successful removal of New Zealand Flax *Phormium tenax* from Nightingale Island (Wace & Holdgate 1976, Richardson 1984). Brown trout along with other salmonid species have been introduced to both Crozet and Kerguelen islands but no effort has apparently been made to control or eliminate them there (Lesel & Derenne 1975, Davaine & Beall 1982). Ten rainbow trout introduced to South Georgia in 1964 did not survive (Headland 1984). Cats are present at a number of sub-Antarctic islands (Leader-Williams 1985 and references therein) and control measures have been undertaken at several islands. However, to date, no established cat population on a sub-Antarctic island has been eliminated although a few failed introductions have occurred (Bonner 1984, Leader-Williams 1985).

Control efforts should also concentrate on avoiding new introductions, especially of Norway or brown rats *Rattus norvegicus* and black rats *R. rattus* which have never been recorded at the Prince Edward islands, but have become established at some other sub-Antarctic and cool temperate islands where they have affected burrowing seabird populations (Holdgate & Wace 1961, Holdgate 1967, Pye & Bonner 1980, Bonner 1984, Headland 1984, Atkinson 1985, Leader-Williams 1985 and references therein). In this regard, serious consideration should be given to eliminating the introduction of alien invertebrates *via* fresh vegetables to Marion Island.

It is interesting to consider whether any of the transient aliens, mainly domestic species, could ever have become naturalised at Marion Island. Based on information on aliens at other sub-Antarctic islands it seems most unlikely that chickens or geese could have survived in the feral state. Chickens and geese have not become naturalised at South Georgia despite a number of introductions of domestic birds (Headland 1984).

Sheep were kept in semi-captivity at Marion Island for several decades and a few animals eventually became feral. However, feral sheep captured were castrated males (wethers) and it is not known whether sheep have ever bred at Marion Island, where they no longer occur. Sheep are currently present at several sub-Antarctic and southern temperate islands, such as Kerguelen and islands south of New Zealand (Holdgate & Wace 1961, Lesel & Derenne 1975, Pascal 1982).

Whether sheep could ever have become established at Marion Island is a moot point. The very few feral animals had apparently become very "woolly", and it is of interest to note that Lesel & Derenne (1975) state that female feral sheep at Kerguelen could not become impregnated after one year of age due to the growth of their caudal fleece. However, sheep have become successfully established on several cool temperate islands farther north than Marion and Kerguelen (Holdgate & Wace 1961).

Goats have not become established at sub-Antarctic islands although they have at some southern temperate islands (Holdgate & Wace 1961, Leader-Williams 1985). Based on this, it seems unlikely that goats could have become established at Marion Island.

"Wild" pigs were abundant on Iles St Paul and Amsterdam in the early 19th century (Holdgate & Wace 1961), but these islands are cool temperate rather than sub-Antarctic in nature. Feral pigs occurred at sub-Antarctic Ile aux Cochons, Crozet islands in 1820 but were eliminated in the late 19th century because of the damage they caused both to vegetation and penguins (Holdgate 1967). Pigs do not presently occur on sub-Antarctic islands (Holdgate & Wace 1961, Bonner 1984). It is quite feasible that Marion Island would now have a feral pig population if the small nineteenth century feral population was not eliminated soon after its establishment.

Feral populations of dogs do not presently occur at sub-Antarctic islands (Holdgate & Wace 1961, Holdgate 1967, Lesel & Derenne 1975, Bonner 1984, Headland 1984, Leader-Williams 1985). Dogs are unlikely to have formed a sustained feral population, based on the South Georgia experience (Headland 1984). "Wild" dogs were present on Macquarie Island in 1821 but later died out and reports of wild dogs at Kerguelen Island in the early twentieth century are equivocal (Holdgate & Wace 1961). All five dogs known to have been present at Marion Island were domestic animals and four were later removed from the island. No dogs are known to have bred at Marion Island.

On Marion Island three species of burrowing birds, the greatwinged petrel *Pterodroma macroptera,* the softplumaged petrel *P. mollis* and the grey petrel *Procellaria cinerea,* are regarded as vulnerable due to predation by feral cats and one species, the common divingpetrel *Pelecanoides urinatrix,* is thought to have been exterminated as a breeding species by cats (Brooke 1984 and references therein). The greatwinged and grey petrels may well have been saved from extinction at Marion Island through the introduction of FPL (Van Rensburg 1985).

The deliberate introduction of plants and animals to Marion Island was carried out with apparently no concern of the risks of introducing alien diseases to the natural populations (for example Warner 1968). Because of this potential threat it is recommended that no further alien plants and animals be imported, as is the present policy. Introduced poultry are not known to have directly affected the indigenous avifauna of any sub-Antarctic island but findings indicate that penguins may risk infection from diseases of domestic poultry (Johnstone 1985). We recommend that this policy should be extended to cover the attempted rehabilitation of naturally occurring species, such as penguins and seals, to the Prince Edward islands. In May 1980 a single macaroni penguin *Eudyptes chrysolophus* was taken from South Africa to Marion Island although its place of origin was unknown (Cooper 1980). Plans were made in August 1985 to rehabilitate 10 king penguins and one rockhopper penguin *E. chrysocome* (places of origin again unknown) from South Africa to Marion Island (Steyn 1985). Fortunately, in our opinion, these plans were cancelled at the last moment.

The Prince Edward islands are essentially managed as a nature reserve equivalent to IUCN Category 1 (Scientific/Strict Nature Reserve) (Clark & Dingwall 1985). Although the islands are not legally protected, the Sea Birds and Seals Protection Act (1973) does give some specific protection to the fauna (Clark & Dingwall 1985). We recommend that the Prince Edward islands be given formal legal protection as a nature reserve.

We also recommend (following Van Rensburg 1985, this volume) that attempts to control and eventually eliminate cats at Marion Island should continue. We also recommend that a survey should be undertaken to ascertain whether brown trout

are extinct or not; if trout are still present they should all be removed. The presently practiced measures to avoid introducing alien plants and animals now present at Marion Island to nearby Prince Edward Island should continue to be strictly enforced. Newly recorded inadvertent introductions should be studied and where practicable controlled and the rates of spread of aliens already present at the Prince Edward islands should be monitored.

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