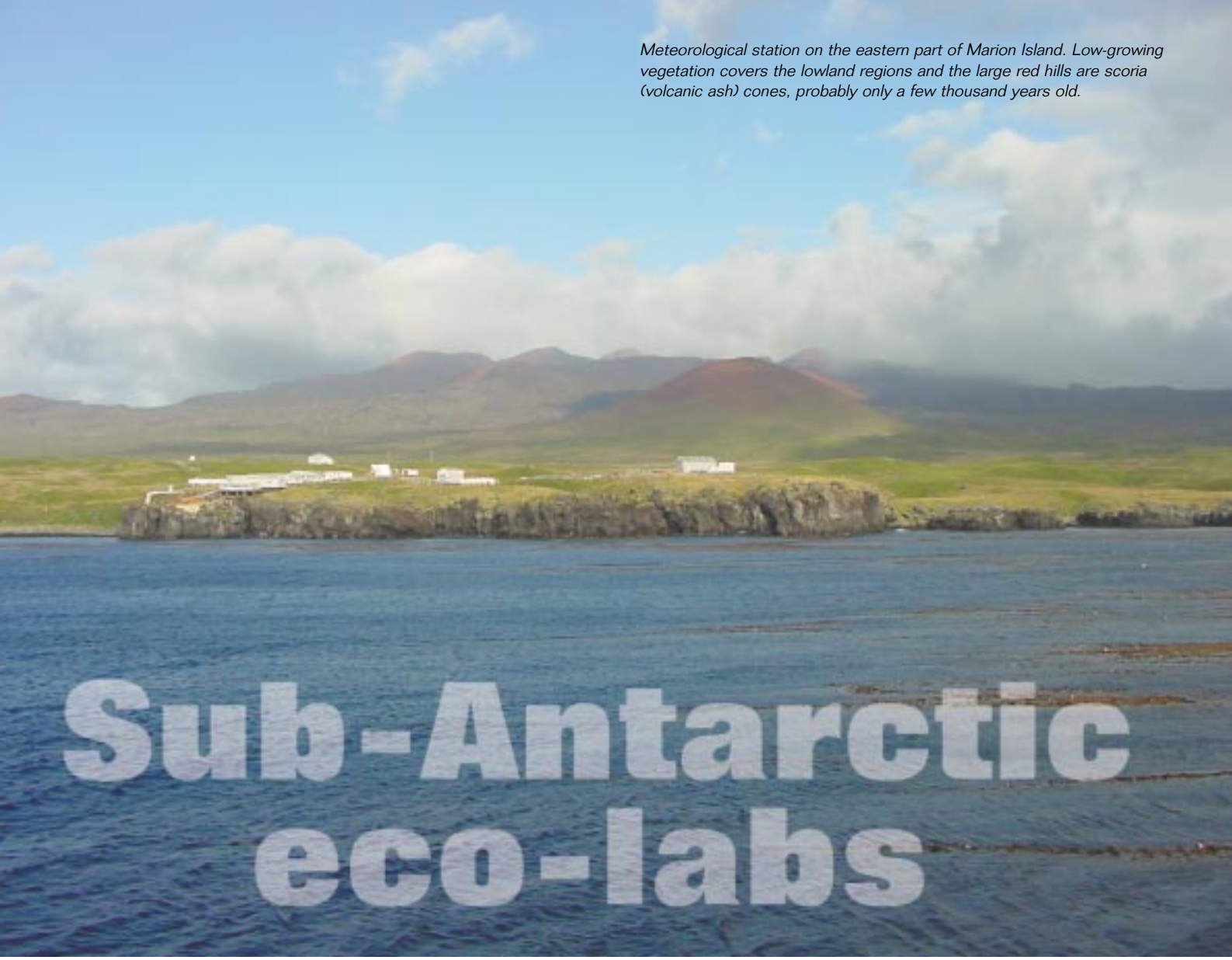
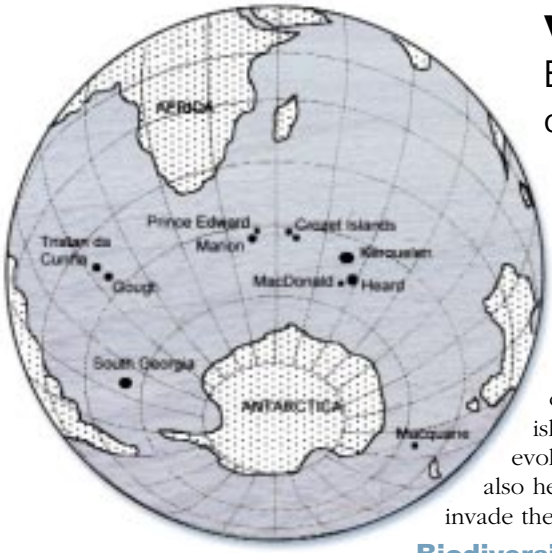


Meteorological station on the eastern part of Marion Island. Low-growing vegetation covers the lowland regions and the large red hills are scoria (volcanic ash) cones, probably only a few thousand years old.

Sub-Antarctic eco-labs



The sub-Antarctic region has six islands or island groups in an area of the Southern Ocean between about 45° and 55°S. They include the Prince Edward Islands, which are situated about 2 100 km south-east of Cape Town.

Map and photographs: Courtesy of Valdon Smith

Valdon Smith explains how South Africa's Prince Edward Islands help us to understand effects of climate change on ecological processes and whole ecosystems.

South Africa's two sub-Antarctic islands (Marion Island and, 22 km away, the smaller Prince Edward Island) are getting warmer, drier, and sunnier each year. The changing climate affects the islands' plants and animals, which evolved in cool, humid conditions. It also helps destructive alien species to invade the islands.

Biodiversity in island ecosystems

Ecosystems develop differently on oceanic islands than they do on continents. Continental ecosystems can draw on a large pool of species, whereas biodiversity on oceanic islands is low. Marion and Prince Edward Islands (together known as the Prince Edward Islands), for instance, were never connected to, or even near, any continent, so they have relatively few species of animals and plants, which somehow reached the islands over long distances across the ocean.

Many important functional groups of animals – such as cud-chewing buck and deer, and the predatory cats and dogs so characteristic of continents, especially Africa – are not indigenous to these islands. Nor are frogs, reptiles, rodents, or rabbits. Even the insect fauna is species poor, although in some habitats those few species that exist can reach high numbers.

How does this low biodiversity, and the absence of important functional groups such as herbivores and carnivores, affect ecological functioning on the islands?

Ecological functioning

The flow of energy and the cycling of nutrients determine an ecosystem's ecological functioning. Energy reaches an island as sunlight, which is fixed by plants and results in their growth.

The amount of vegetation growth each year (that is, the 'annual primary production') is high

Above: Rainbow over the south-east coast of Marion Island. The black lava rocks are surrounded by vegetation consisting of hardy fern species. The volcanic cinder cone in the background is Green Hill.

The Prince Edward Islands: some facts

The Prince Edward Islands (Marion Island and Prince Edward Island) originated as undersea volcanoes only about half a million years ago, long after the continent of Africa split from Antarctica and migrated north to its current position. They are among the warmest of the sub-Antarctic islands, with one of the most thermally stable climates on Earth.

Warmest month: February (7.8°C)
Coldest month: August (3.7°C)
Annual mean temperature: 5.6°C
Average difference between daily minimum and maximum temperatures: 1.9°C
Average annual total rainfall: 2 326 mm
Average daily sunshine: less than 4 hours
Winds: gales occur on about 100 days a year
Precipitation (rain rather than snow): high
Vegetation: well developed, including flowering plants; no trees or shrubs.

Above: The south-east part of Prince Edward Island. The vegetation in the foreground, called fellfield, consists of flat cushions of Azorella selago *on lava and volcanic ash.*

on the Prince Edward Islands because they have no dry season or bitterly cold weather to stop plants from growing, so substantial amounts of nutrients are needed. Climatic warming should increase plant productivity and the demand for nutrients. But will it?

In most ecosystems, herbivores eat the plants and excrete some of the nutrients – in this way they recycle nutrients and make them available for the plants to re-use. Without herbivores, nutrients taken up by growing plants remain trapped in the plant material, which dies to form plant litter. Decomposition of that litter releases the nutrients in a form that can be taken up by plants again. So nutrient recycling on the islands occurs mainly through decomposition, rather than grazing.

In cold, wet island soils, however, decomposition (and, therefore, nutrient release) is slow, unless helped in some way. Insects (especially the larvae of moths, weevils, and flies), snails, and earthworms assist by feeding on plant litter. This litter is partly broken down in the animal's gut and egested in a form that is easier for soil microorganisms, such as bacteria and fungi, to break down further. Insects and earthworms, therefore, are crucial to the processes of decomposition and nutrient cycling. On Marion Island, it has been estimated that they make available up to 88% of the nutrients needed by some vegetation types there.

The insects and earthworms are cold-blooded, so their activity depends strongly on temperature. The increasing temperatures occurring at the islands should bring higher rates of litter consumption and hence of nutrient release and plant production. But destructive alien predators can get in the way.

House mice

House mice show just how destructive an invasive alien organism can be to an island's biota and ecosystem. *Mus musculus* (the same species we find in most houses the world over), first recorded ▹▹

Climate change on Marion Island

- Annual rainfall has decreased: the 1990s was the driest of the five decades in which precipitation has been measured.
- Annual mean air temperature on Marion Island and annual mean sea temperature around it have increased by 0.04°C each year since 1969.
- Annual total sunshine hours increased by an average of 3.3 hours per year between 1951 and 2003.

Top right: Club-mosses, primitive plants that were dominant worldwide 360–380 million years ago.

Top left: Moss species occurring at higher altitudes on the islands, able to withstand the chilly drying wind.

Above: Small invertebrates.

Right: Kerguelen cabbage.

on Marion Island in 1818, was probably introduced by Danish sealing companies.

These mice feed mainly on adults and larvae of moths, weevils, and flies, and on earthworms and snails, the very same invertebrates that are so important in driving the island's ecosystem functioning. Mice can consume up to 194 g (dry mass) of these invertebrates per hectare each day. They can eat as much as between 1 and 6 times the average population of a particular prey species annually. These high consumption rates severely reduce the island's invertebrates, most of which take a long time to reproduce. The moth larvae, for instance, need several years to transform into adults.

We see the effect of the mice very clearly by comparing the invertebrate populations of Marion Island with those on nearby mouse-free Prince Edward Island, whose insect populations are far greater in size, structure, and composition.

Other species also suffer from the mouse predators. The maximum body size of certain weevils is diminished, for instance, because the mice feed preferentially on adults of a specific size. Another victim is the lesser sheathbill *(Chionis minor)*: the only non-migratory bird species on the island, it relies on soil macroinvertebrates as food in winter. From the mid-1970s to the mid-1990s, the sheathbill population on Marion Island decreased by 23%, whereas that on Prince Edward Island remained stable. Mice also affect the sedge *(Uncinia compacta)*, removing its seed long before it ripens. As a result, the sedge forms a far greater component of the vegetation on Prince Edward Island than on Marion Island.

More insidious, and probably even more profound, is the destructive effect of house mice on the ecosystem as a whole as they remove cardinal agents of energy flow and nutrient cycling on the island.

Ancient cabbages under threat

A victim of invasive alien species is the Kerguelen cabbage (*Pringlea antiscorbutica*), found on only four sub-Antarctic island groups, including the Prince Edward Islands. It is one of the last (perhaps the only) remaining relict* of a once extensive circum-Antarctic flora, and was eaten by sailors, sealers, and whalers to prevent scurvy. On Marion Island, its distribution and abundance has declined alarmingly over the past 20 years because of invasive alien biota:

- The European slug (*Deroceras caruanae*) was introduced to the island in the mid-1960s. Its population increased and spread widely in the 1990s. The Kerguelen cabbage is one of its favourite foods.
- The diamondback cabbage moth (*Plutella xylostella L.*), a major pest of crucifers (cabbages, cauliflower, Brussels sprouts), arrived in 1986. The cabbage is its only host plant on the island.
- *Botryotinia fuckeliana*, the fungus that causes grey mould rot in crucifers and other vegetable crops, arrived through vegetables sent as food for staff on the island (this practice has been discontinued). It has infected many stands of Kerguelen cabbage, and whole plants are collapsing into black slimy residue.

* **Relict** *n.* An animal or plant known to have existed in the same form in previous geological ages.

Definitions

Biota: the animal and plant life of a region.
Functional groups of plant and animal species are groups of species that 'do the same sort of thing' ecologically, e.g. herbivores, carnivores, floating plants, plants that climb over forest trees, succulents.
Biodiversity: species-richness.
Annual primary production: the amount of vegetation growth during a year.

We estimate, for instance, that predation by mice on moth larvae alone prevents the consumption of 1 000 kg plant litter per hectare per year, a decrease of about 40% compared with what would be consumed by more insects in the absence of mice. Since it was first studied in 1979/80, Marion Island's mouse population appears to have increased – in one habitat it doubled between 1979 and 1992 – possibly thanks to climatic warming and/or the eradication of the island's feral population of domestic cats in the early 1990s.

Increasing mouse populations translate into greater destruction of invertebrates and lower rates of nutrient cycling. This makes fewer nutrients available to plants and it lowers primary production. Even more important, it reduces the nutrient quality of the plant material, which, in turn produces low-quality litter that decomposes even more slowly.

Ecological laboratories

Marion and Prince Edward Islands are ideal 'ecological laboratories' for studying effects of climate change, because global warming is especially intense in the sub-Antarctic region and because their ecosystems are relatively simple and sensitive to change.

These two jewels in the sub-Antarctic research crown have already produced a South African research output of some 800 publications and 40 Ph.D. and master's theses. They will continue to play their part in the work of the new DST Centre of Excellence for Invasion Biology (see p. 45). □

For the origin, prehistory, biology and ecology of Marion Island, consult V.R. Smith, "The environment and biota of Marion Island", *South African Journal of Science*, vol. 83 (1987), pp.211–220, and for the most recent news of changing climate and its implications, see V.R. Smith, "Climate change in the sub-Antarctic: An illustration from Marion Island", *Climatic Change*, vol. 52 (2002), pp.345–357. The plants, animals, and geology of the island are described in the 37-chapter book, edited by E.M. van Zinderen Bakker, J.M. Winterbottom, and R.A. Dyer, called *Marion and Prince Edward Islands* (Cape Town: A.A. Balkema, 1971). You will find details of alien species, plants, and animals introduced to Marion Island in B.P. Watkins and J. Cooper's "Introduction, present status and control of alien species at the Prince Edward Islands, sub-Antarctic", *South African Journal of Antarctic Research*, vol. 16 (1986), pp.86–94.

A pair of grey petrels.

Domestic cats can destroy island ecosystems. **Valdon Smith** and **Marthan Bester** explain how Marion Island got rid of these dangerous predators.

Overcoming CATastrophe

First the house mice (*Mus musculus*) were brought to Marion Island, then the cats (*Felis catus*) to catch them. But instead of eliminating the mice, the cats hunted larger prey that they could catch more easily, such as burrowing seabirds. On all four of the six sub-Antarctic island groups where cats have arrived and multiplied, they have devastated seabird populations.

Domestic cats are among the worst of all invasive species and have caused a large proportion of global extinctions, especially on islands. We estimate that their hunting is responsible for the extinction of at least 33 bird species that occur on only a specific island or island group, as well as mammals and reptiles, including iguanas and the giant La Gomera lizard.

Cats are opportunistic predators with a varied diet. They breed prolifically and can live in very dense populations (for example, up to 14 cats per km^2 on Marion Island). Because island animals (and plants) have generally evolved without competitors and predators, they do not have the means to deal with them.

By decimating bird populations, cats upset the ecological functioning on islands. When seabirds feed in the sea and deposit their guano, eggshells, and moulted feathers on the island, they provide energy and nutrients (see box), so their destruction by cats has widespread implications. Burrowing birds are essential for maintaining the nutrients for several of the island's plant community types such as tussock grasslands. ▹▹

Penguin, Albatross & Giant Petrel Fertilizer Co.

We estimate that these surface-nesting birds bring the following to Marion Island each year:

- 3 600 000 kg guano*
- 512 000 kg nitrogen†
- 95 000 kg phosphorus
- 183 000 kg calcium

* This amount contains 52 billion kilojoules of energy = enough energy to heat 125 million litres of water from 0 to 100°C or energy in petrol to drive 35 medium-sized cars at 80 kph non-stop for a year.

† The amount of nitrogen in 8.2 million kg of 2:3:2 fertilizer.

A house mouse on Marion Island.

Photograph: Jan Crafford

The interior mountainous region of Marion Island showing the three main lava types. The black lava in the foreground formed the mountains and erupted after the last glaciers disappeared (about 11 000 years ago). The grey lava in the middle is more than a quarter of a million years old, and the red hills are cinder cones – volcanic ash deposits that erupted at the same time as the black lavas.

How did the cat problem start on Marion Island, and how was it solved?

1818/1819 – Female cat put ashore from the sealer, *General Gates*, and becomes feral (wild). That cat has no offspring and the island is cat-free for the next 128 years.

December 1947 – Occupation party, after annexation, borrows a cat from the ship that comes to relieve them; the cat snuggles up with the mice instead of eating them, so she's returned to the ship.

January 1948 – First meteorological observation team brings warm clothes, tinned food, gramophone and records, books, ping-pong table, and a radio to contact home once a month; they bring no cat to deal with the plague of mice.

March 1949 – Third team to the island imports an orange-striped tabby tomcat and a black and white female cat.

August 1949 – Team brings three sibling kittens.

1965 – Cats are common around the island edge.

1974–1976 – The South African Scientific Committee for Antarctic Research (SASCAR) begins a seven-phase cat eradication programme.

Phase 1: study of the cats' demography, breeding biology, and diet. First proper census in 1975 counts approximately 2 140 cats. The cats eat about 450 000 birds a year, mainly Salvin's prions (*Pachyptila vittata salvini*), soft-plumage petrels (*Pterodroma mollis*), Kerguelen petrels (*Pterodroma brevirostris*), great-winged petrels (*Pterodroma macroptera*), and blue petrels (*Halobaena caerulea*). Even penguin remains are found in stomach contents. Mouse remains are found in only 16% of the stomachs.

Phase 2: assessment of control methods. Scientists test biological control with feline panleucopaenia (FPL) virus, which produces gastroenteritis-type symptoms in cats and rapidly leads to death; it does not affect birds or seals.

1977 – Cat population reaches about 3 405, increasing by 17–23% a year.

Phase 3 begins in March, when 96 cats are inoculated with FPL and released from helicopters round the island.

Phase 4: monitoring the effect of FPL and testing other methods of control (such as trapping, poisoning, hunting with dogs, and shooting). Cat population decreases by 54% within 18 months.

1981 – *Phase 5:* further study of the cats. Pilot trial begins to test the time- and cost-effectiveness of hunting with shotguns.

1982 – SASCAR finds that cat population has declined by 26% a year; about 615 cats are left. They develop immunity to FPL, so there is no significant decline in 1983.

1986–1988 – *Phase 6:* full-scale, continuous, and intensive hunting at night by 8 two-man teams kills 458, 206, and 143 cats over three summers: hunting alone cannot eliminate all the cats.

1989 – *Phase 7:* experimental trapping and hunting. Trapping accounts for 54% of cats killed in 1989/90 season and 91% in 1990/91 season. Poisons are investigated, and sodium monofluoroacetate is chosen because it is odourless, tasteless, biodegradable, and results in quick death.

May 1991 – Large-scale poisoning campaign begins, plus hunting and trapping. First 12 000, then 18 000, day-old chicken carcasses injected with the poison are placed round the island.

July 1991 – The last cat is trapped.

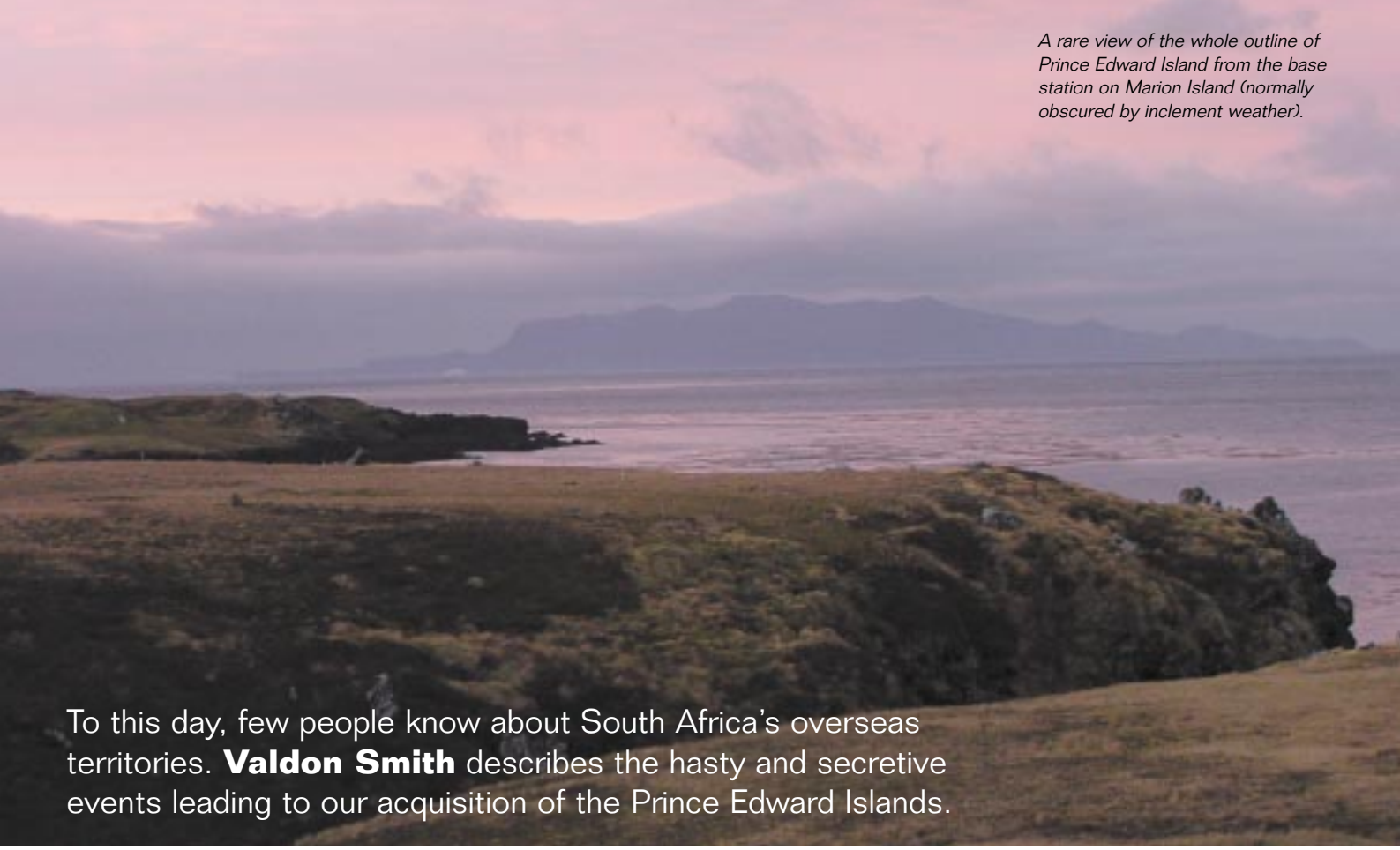
Marion Island, at 290 km^2, is by far the biggest of 48 islands from which cats have been eliminated (the next largest is the 28 km^2 Little Barrier Island off New Zealand; most are smaller than 5 km^2). The research accompanying the eradication programme, and hard-won practical experience and lessons learnt, are helping efforts to eradicate cats on other sub-Antarctic islands (for example, by the Australians on Macquarie Island and by the French on the Crozet Islands and some of the smaller islands off the Kerguelen Archipelago). The Marion Island ecosystem is far better off without cats – the breeding of the burrowing bird species has already improved and the tussock grasslands are expected to return. □

British pussy cats

In 1997, 986 tame cats were monitored for five months to see what prey they brought home. The results (excluding prey caught that was not brought home) show that an estimated 9 million British domestic cats bring home:

- 57 million mammals
- 27 million birds
- 5 million reptiles and amphibians.

For more on the problem of cats on 48 islands, read M. Nogales *et al.* "A review of feral cat eradication on islands", *Conservation Biology*, vol. 18 (2004), pp.310–319. For a detailed but easy-to-read review of the South African programme, consult M.N. Bester *et al.* "A review of the successful eradication of feral cats from sub-Antarctic Marion Island, Southern Indian Ocean", *South African Journal of Wildlife Research*, vol. 32 (2002), pp.65–73.



A rare view of the whole outline of Prince Edward Island from the base station on Marion Island (normally obscured by inclement weather).

To this day, few people know about South Africa's overseas territories. **Valdon Smith** describes the hasty and secretive events leading to our acquisition of the Prince Edward Islands.

How South Africa got its islands

Early sightings and namings

1663 – Barent Barentszoon Ham (Dutch East India Company) travels from the Cape of Good Hope to Java, sights the two islands, names the larger one Maerseveen and the smaller one Dina, but reports them as being almost 700 km north of their actual location. For a century nobody can find them.

1772 – French explorer/adventurer Marc Joseph Marion-Dufresne rediscovers the islands, names the larger one Terre de l'Espérance (Land of Hope), the smaller Île de la Caverne (Isle of the Cave), and, collectively, Îles des Froides (The Frigid Islands).

Four years later – Captain James Cook sees the islands. Not knowing they're the ones discovered by Marion-Dufresne, he names them the Prince Edward Islands.

Until the mid-20th century, nobody took much interest in the Southern Ocean islands, except the sealers and whalers who exploited them in the 18th and 19th centuries. They didn't advertise their harvesting areas, so we know little about who visited or inhabited our two islands in those early days. The first recorded landing on the larger one was in 1803 by sealers who found signs of earlier occupation, probably by other sealers. By the mid-19th century, sealers knew the pair as Marion Island and Prince Edward Island.

In the 19th and early 20th centuries, shipwrecked parties spent up to several months there. Best documented were the stays of an emigrant ship, the *Richard Dart*, and sealer ships such as the *Maria*, the *Solglimt*, and the *Seabird*. No country explicitly claimed ownership, however. It's been argued that Britain implicitly assumed ownership by granting leases to gather guano deposits (there never were any) there in the early 1900s, but, in fact, the British government was issuing licenses for whaling, sealing, guano and mineral collecting on almost all the Southern Ocean islands.

Tactical thinking

Developments in arms (especially missile) technology from World War II onwards made governments realize that long-range warfare encompassing the entire globe was now possible. Islands in the Southern Ocean became tactically significant. So did ownership. Britain, especially, was threatened, as Chile and Argentina disputed her right to occupy the Falkland Islands, South Georgia, and parts of the Antarctic Peninsula.

The then Union of South Africa owed allegiance to Britain, and their two governments realized that the Prince Edward Islands were vulnerable to foreign ownership claims. Flag-raising ceremonies on the other British islands in the Southern Ocean had at least indicated some claim to sovereignty, but no such event had been recorded on Marion or Prince Edward Island.

The sealing and guano-collecting concessions granted to English or South African companies had been abandoned, so no occupation of the islands supported any claim to possession. The late 1940s brought rumours of countries taking an interest. In December 1947 two ships of different nations with no previous record in Antarctica were known to be steaming south, and suspected of planning to claim occupation and legal possession of unoccupied territories in the area.

Hush-hush

High-level talks between South Africa and Britain culminated on 17 December 1947 when South Africa's prime minister, General Jan Smuts,

The research and supply vessel, the S.A. Agulhas, *which services South Africa's Antarctic and sub-Antarctic bases, seen here off Marion Island.*

ordered immediate annexation of both islands. Within 12 days, a naval frigate, the *HMSAS Transvaal*, was equipped and dispatched: proclamations of intent to annex were read out on Marion Island on 29 December 1947 and on Prince Edward Island on 4 January 1948.

So secret was the enterprise (known as Operation Snoektown) that, when the *Transvaal* left Cape Town, only the captain, Lieutenant Commander John Fairbairn, knew its destination and purpose. His crew was not told till they were at sea.

Back home, it also stayed top secret, despite three further ships going to the island, the hiring of personnel (from as far away as Tristan da Cunha) to build and man a base station on Marion Island, and the purchase of equipment. Though many people were involved, only a few top-ranking politicians, civil servants, and defence force personnel understood the true objective.

Press speculation and formal annexation

The press paid close attention. On 3 January 1948, a day before the proclamation, newspapers reported that Prince Edward had already been annexed. Press reports followed, on 6 January, of "an official" (unspecified) communiqué in London stating that Britain had authorized the Union government to occupy the islands.

Government confirmation came on 8 January, when Prime Minister Smuts answered questions from the press. Stating explicitly that there was no immediate military reason, he admitted to the annexations. These were formally announced by Governor-General G. Brand van Zyl when he opened parliament on 17 January. His reasons were the intensifying interest by other countries in the South Pole region, protection of the Union's future interests, and the need for weather stations.

The mystery continued, however. When the *Transvaal* returned on 10 January its company was sworn to secrecy before being allowed to disembark. When the coastal steamer *Gamtoos* left Cape Town with the base-building supplies on 12 January, her destination was not disclosed. Possibly the government was waiting for the party at the islands to proclaim the annexations formally, together with their intention to occupy the islands, which they did on 24 January.

The proclamation was published in the *Government Gazette* of 30 January and the annexations became effective in October with the Prince Edward Islands Act, Act 43 of 1948. Marion Island has been occupied permanently by South African research and logistic personnel since February 1948. There is no permanent occupation of Prince Edward Island. □

Professor Valdon Smith is in the Department of Botany and Zoology at the University of Stellenbosch. He has conducted research on the Prince Edward Islands since 1971.

For a popular account of the history and annexation of the Prince Edward Islands, by a maritime journalist who visited the islands shortly after their occupation, read J.H. Marsh's *No Pathway Here* (Cape Town: Howard B. Timmins, 1948). You'll find the text of the proclamation in "The South African Proclamation on the Prince Edward Islands", *South African Government Gazette Extraordinary* (30 January 1948) and also in *The Polar Record*, vol. 5, nos. 35/36 (1948), pp.243–244. The establishment of the weather station is described by the leader of the first team to winter on the island, Alan B. Crawford, in "Establishment of the South African meteorological station on Marion Island, 1947–48", *The Polar Record*, vol. 5, no. 40 (1950), pp.576–579.

The proclamation of provisional occupation of Prince Edward Island. This document was housed in a brass cylinder made from a Bofors anti-aircraft gun cartridge case and placed under a flagpole in a cairn of stones in front of a cave on the island. Since this photograph was taken in 1972, the document and the case have disappeared.