

**THE IMPACT OF FERAL HOUSE MICE AT SUB-ANTARCTIC MARION ISLAND
AND THE DESIRABILITY OF ERADICATION : REPORT ON A WORKSHOP
HELD AT THE UNIVERSITY OF PRETORIA, 16-17 FEBRUARY 1995**

S.L. CHOWN

Department of Zoology & Entomology, University of Pretoria, Pretoria 0002, South Africa

&

J. COOPER

*Percy FitzPatrick Institute of African Ornithology, University of Cape Town,
Rondebosch 7700, South Africa*

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EXECUTIVE SUMMARY

A workshop on the impact of feral house mice, *Mus domesticus*, at sub-Antarctic Marion Island was held because the draft Prince Edward Islands Management Plan (Rev. 7) requires that attention be given to the removal of aliens from the islands, and because a five-year programme concerning the impact of mice has provided considerable information on this topic and is nearing conclusion. Unpublished data were presented by various researchers on the demography of the mice and on their impact on the terrestrial ecosystem. Information on the eradication of rodents on various islands surrounding New Zealand, and a preliminary feasibility assessment for eradication of mice via aerial poisoning were also presented. It was concluded that feral house mice have reached a new, higher population level than was found in the 1970s and that mice are having a significant impact on macro-invertebrates, certain plant species, and therefore ecosystem functioning as a whole. However, considerable research is required, over a five-year period, to improve understanding of population fluctuations and the nature of the impact. Eradication of mice is feasible so long as research on the consequences of such a programme, and methods to reduce undesirable effects is undertaken. Control measures should also be investigated. Eradication is desirable, although only after baseline research on management issues and the impact of mice has been undertaken. A working group on mice at Marion Island should be established, under the auspices of the Prince Edward Island Management Committee of the South African Committee for Antarctic Research (SACAR), to oversee the research and management programmes. An eradication attempt is liable to enjoy a low national priority, and funding should be sought from international agencies, especially given the pristine condition of the Prince Edward Islands.

INTRODUCTORY REMARKS

The sub-Antarctic Prince Edward Islands lie approximately 2300 km south east of Cape Town and represent the coalescing peaks of a shield volcano. Marion Island is the larger of the two islands and has had a longer history of continuous human occupation than its smaller neighbour, Prince Edward Island (see Van Zinderen Bakker *et al.* 1971; Smith 1987). Although similar with regard to climate, geological history and native biotas, the islands differ considerably in terms of

introduced species. Marion Island has far more alien species than Prince Edward Island (Watkins & Cooper 1986). This situation presents ideal research opportunities in the context of the effects of alien invasive organisms on terrestrial ecosystems, especially in relation to the influence of global climatic change on ecosystem functioning (Smith & Steenkamp 1990).

Although long regarded to be *Mus musculus*, the house mouse at Marion Island may well be *Mus domesticus*. This conclusion is based on an on-going debate on the identity of house mice in Europe. Those in western Europe, from where the Marion Island population was derived, are thought to be *M. domesticus* (T.J. Robinson, University of Pretoria, personal communication). Feral mice were abundant on Marion Island by 1818 and were probably introduced shortly before this (the first known landing on Marion Island took place in 1804), although they have never been found on Prince Edward Island (Watkins & Cooper 1986). These feral mice have elicited comment from all visitors to the islands (e.g. Marsh 1948; Cooper & Headland 1991), and first formed the subject of research in 1975, when the late James Gleeson investigated the role of mice in the Marion Island ecosystem (Gleeson 1981; Gleeson & Van Rensburg 1982). Subsequently, Smith & Steenkamp (1990) proposed that climate change, particularly warming and drying of the islands, would have pronounced effects on the functioning of their terrestrial ecosystems. In particular, they argued that warming would enable house mice to produce more litters on Marion Island, increase their abundance, and thus have a greater impact on indigenous detritivores, their major dietary item (and possibly some native plants), than was the case in the past 100 years. The detritivores are responsible for the bulk of nutrient release from the large, dead standing crop of native plants on the islands. Smith & Steenkamp (1990) argued that if the nutrient release attributable to macro-invertebrate detritivores was diminished, substantial changes to vegetation structure and to ecosystem functioning would take place.

Based on this hypothesis, and some anecdotal evidence that mice seemed to be more abundant on Marion Island, an interdisciplinary research project was initiated in 1991 by the Department of Botany & Genetics, University of the Orange Free State, and the Mammal Research Institute, Department of Zoology, University of Pretoria. The aims of this project were to investigate the response of native plants and insects to changing abiotic conditions, and to investigate the population biology of feral house mice and their impact on indigenous plants and invertebrates, and to compare these data with those obtained by Gleeson almost 20 years earlier. The project was funded by the Department of Environmental Affairs and Tourism (DEAT) through the South African National Antarctic Programmes (SANAP), on the advice of the South African Committee for Antarctic Research (SACAR). This project has now entered its fifth year.

During this period, DEAT appointed a task group to draw up an environmental management plan for the Prince Edward Islands, which are to be declared Special Nature Reserves in terms of the Environmental Conservation Act of 1989. The plan aims to cover all aspects pertaining to the management of the islands including recommendations for the control or eradication of alien species. The management plan has now almost reached completion (seventh, and penultimate revision, released November 1994). In Part 3, Section 14 it is clearly stated that one of the sub-objectives of management is "To elucidate the ecological impact arising from the introduction of the House Mouse *Mus musculus* population to Marion Island and to make recommendations for its control".

Given the recommendations outlined in the management plan, and the fact that the

interdisciplinary research programme had run for four years, the Biological Sciences Task Group of SACAR, at its June 1994 meeting, recommended that a workshop on feral mice at Marion Island should be held. The task group recommended that the workshop should cover the current state of knowledge concerning the mouse population, its impacts on the Marion Island terrestrial ecosystem, and the desirability and feasibility of eradication or control of mice at the island. The task of organizing this workshop was given to ourselves and it was held over two days at the University of Pretoria. This report contains the conclusions reached by the delegates and their recommendations concerning research and management options over the short to medium terms.

WORKSHOP PROGRAMME

The full workshop programme is given in Appendix I, and a list of delegates is provided at the end of this document. Because the research programme on feral mice had only just emerged from the fieldwork phase, those participants who were directly involved in this programme were called on to present the data that they had collected over the past four years to provide delegates with a platform to work from. In addition, Dr. Marthán Bester was called on to present an overview of the successful feral cat eradication programme, which recently came to an end, to highlight logistic difficulties involved in large-scale management programmes at Marion Island. John Cooper had recently visited the Department of Conservation in New Zealand for a short sabbatical and was therefore requested to provide information on rodent eradication in New Zealand and to undertake a preliminary feasibility assessment for rodent eradication on Marion Island.

The first day of the workshop was devoted to the impact of mice on the terrestrial system. After the four presentations, the delegates split into two groups led by Perrin (Bester, Crafford, Smith, van Aarde, van der Merwe) and Nel (Avenant, Chown, Cooper, Ferreira, Rowe-Rowe, van Schalkwyk). The rapporteurs presented the findings of their groups which were summed up by Rowe-Rowe.

On the second day, John Cooper included a 30-minute video on rodent control on Chetwode Island, New Zealand in his presentation. The delegates split into two groups under the leadership of Crafford (Avenant, Chown, Ferreira, Nel, Smith, van der Merwe, Venter) and Cooper (Bester, Perrin, Rowe-Rowe, van Aarde, van Schalkwyk, Waters). The rapporteurs presented the findings of their groups, and Chown summarized the overall findings of the workshop.

PART I : THE IMPACT OF MICE ON THE TERRESTRIAL ECOSYSTEM

PRESENTATIONS

Bester : The success of any eradication programme rests on sound ecological knowledge of the target species as well as of the efficacy of the methods to be used. Once ecological knowledge of the species has been obtained a management decision has to be made. The choice available is between: i) no action, ii) regular control in perpetuity, iii) irregular control in perpetuity, iv) eradication. In the case of the Marion Island cat eradication programme, a biological control agent was shown to be successful for a reduction in numbers of feral animals and was therefore released. Once it had been established that the population had declined, it was decided to attempt eradication by hunting, trapping and poisoning. This eradication attempt was initiated and seen through until cats or their signs were no longer evident. It is of critical importance that the

political will and financial resources are available to complete an eradication programme. If this is not possible, the programme should not be undertaken given the logistic difficulties and concomitant expense of such an exercise. A detailed review of the programme is available in Bloomer & Bester (1992).

Van Aarde : Sampling of mice was carried out in exactly the same grid areas that Gleeson (1981) used. These were hummocky beach (biotic complex, Trypot Beach), vegetated lava (closed fernbrake, Nellie Humps) and dry mire (mire complex, Nellie Humps). Gleeson's raw data were re-analyzed to ensure more accurate comparisons because the sampling frequency in the more recent study was higher than that of Gleeson (1981).

Intra-annual variation in mouse population density showed similar trends in the three habitat types. Mean annual densities were significantly different in the three periods (1979/80, 1991/92 and 1993/94) in the vegetated lava and dry swamp habitats, but not in the hummocky beach habitat (Table 1). However, this appears to be due more to differences in late summer densities, than to those in winter (Table 2). High summer growth rates result in high densities at the end of summer, but high winter mortalities were also found. The trends in winter mortalities did not appear to be related to trends in minimum temperatures. Key factor analysis suggested that in high density areas (such as hummocky beach) there is undercompensating density dependence, which in turn suggests that there is a direct or indirect influence of density on mortality rates. There are forces which limit the size of the mouse population on the island, and an artificial reduction of the population would probably be followed by a rapid increase in population size through density-dependent factors. Further discussion can be found in Matthewson *et al.* (1994).

Table 1. Habitat-specific mean annual densities of feral house mice (no.ha⁻¹ ± S.D.).

Habitat	1979/80	1991/92	1993/4	ANOVA
Hummocky beach	105±44	100±59	123±45	P > 0.05
Vegetated lava	40±16	26±23	62±30	P < 0.05
Dry mire	34±20	32±17	75±49	P < 0.05

Table 2 Habitat specific mean annual densities of feral house mice (no.ha⁻¹ ± S.D.) on a seasonal basis.

Habitat	Hummocky beach		Vegetated lava		Dry mire	
	May	November	May	November	May	November
1979/80	127±18	70±6	62±7	23±3	65±14	11±2
1991/92	248±37	41±3	85±9	9	50±6	9±1
1993/94	179±19	62±6	107±13	31±5	115±19	17±2

Biomass of the flightless moth, *Pringleophaga marioni* Viette (Lepidoptera: Tineidae), the main prey item of mice, appears to have declined dramatically from a mean value of approximately 0.6 g.m⁻² in 1979/80 to less than 0.05 g.m⁻² in 1993/4. There also seems to be considerable fluctuation of densities between years, but with the lowest values recorded in the 1993/4 season. The percentage contribution of food items (weevil larvae and adults, moth larvae and adults, spiders, and "other") does not appear to have changed between 1979/80 and 1993/94. Mice must therefore be more efficient at locating their food resources than the sampling programme is at estimating densities of insects.

Avenant : Prey availability was sampled using a standard 8-cm diameter corer in the biotic zone as well as in mires in the 1992/93 season. In the biotic zone, it is clear that the biomasses of prey species have declined between 1976/77 (Burger 1978) and 1992/93 (Table 3), although not to the extent suggested by Prof. van Aarde's data. It is also noteworthy that the introduced slug, *Deroceras caruanae*, was never accepted by mice in laboratory palatability tests, and it is the only macro-invertebrate that increased in biomass over the 15 year period. Similar trends were found in the mires. These changes in densities imply that mice are now removing approximately 1.53% and 1.89% of the standing crop of moth larvae and weevil adults, respectively, on a daily basis. There also seems to have been a reduction of biomass of *Pringleophaga marioni* larvae on Prince Edward Island, although these data are derived from a single sampling event.

The percentage contribution of prey items to mouse stomach contents changed considerably between 1979/80 and 1992/93. *Pringleophaga marioni* larvae no longer contribute as much to the diet of mice as they used to, and weevil adults and larvae are of considerably greater importance. The incidence of other items has also risen considerably. This supports Chown & Smith's (1993) contention that mice are having a marked impact on weevil species on Marion Island. These authors have shown that mice are selective with regard to adult weevils, preferring the larger species and individuals. They have also demonstrated that there has been a significant reduction in the body length of prey species on Marion Island between 1986 and 1992, but no change has taken place in populations of the same species on Prince Edward Island. In addition, non-prey species on Marion Island have not changed over the six-year period and do not differ in body length from populations of the same species on Prince Edward Island.

Table 3. Mean biomass (g.m⁻²) of macro-invertebrates recorded by Burger (1978), Crafford (1990) and Avenant & Smith (unpublished data) in the biotic zone.

Prey item	1976/77	1983/84	1992/93
<i>Pringleophaga</i> larvae	0.97	1.19	0.79
Weevil larvae	0.75		0.46
Weevil adults	0.35		0.14
Slugs	0.09		0.74
Spiders	0.29		0.05
Earthworms	43.14		11.05

These data suggest that mice are having a marked impact on their invertebrate prey species at Marion Island. Steenkamp & Smith (1990) showed that invertebrates are responsible for the bulk of the nutrient release from litter on Marion and Prince Edward Islands. If invertebrate densities are depressed by the mice, there is liable to be a significant impact on ecosystem structure and functioning on the island. Data provided by Chown & Smith (1993) also show that mice are having a significant direct effect on vegetation structure. The area covered by the sedge, *Uncinia compacta*, has increased at Prince Edward Island over the past 20 years, but has not done so at Marion Island. Mice remove seed heads of the sedge and most of these are absent by the start of winter, shortly after mouse population density has peaked. Mice may be having a similar effect on *Acaena magellanica* (Rosaceae), and seem to have a pronounced impact on the major peat-forming species, *Azorella selago* (Apiaceae), as a result of their predilection for burrowing in this cushion plant.

Smith : The climate is changing at Marion Island, as has been shown in papers by Smith & Steenkamp (1990) and Chown & Smith (1993). The most important of these changes, with regard to both the mice and the terrestrial ecosystem as a whole, are the increase in temperature and duration of sunshine, and the decrease in rainfall. The entire climate is becoming warmer and drier over the short term. When warming is expressed in terms of summed degree-days above 0°C, this is reflected in a 20% increase in "warmth" between the 1949-1970 period and the 1971-1992 period. Whether these trends will remain consistent in the long term is difficult to know, but this seems likely given current scenarios of global climate change.

Enhanced growing season warmth, and reduced precipitation has considerable ramifications for nutrient cycling through both plants, macro-invertebrates and bacteria, and this has been dealt with extensively by Smith & Steenkamp (1990). Enhanced growing season warmth should also have a marked effect on the survival of mice and the numbers of litters that can be produced per season. Should this be the case, and should mice be having an enhanced impact on macro-invertebrates as suggested by Avenant, it seems likely that ecosystem functioning will be altered considerably, particularly if warming continues.

One of the most important questions that remains to be addressed is the nature of the climate prior to 1949. Data on southern hemisphere temperature means for the 1949-1992 period are available and there is a good correlation between these means and those found at Marion Island. Extrapolation of this data to years prior to 1949 is liable to show a cooling trend, but more accurate data would be more valuable. Unfortunately, the pollen record at Marion Island does not have sufficient resolution to provide insight into short-term temperature changes, particularly those that have taken place since 1818.

GROUP CONCLUSIONS

Perrin

1. The Marion Island terrestrial ecosystem is abiotically stable in terms of temperature and rainfall, but is subject to longer-term climate change. The system is biologically productive and forms a spatially dynamic mosaic. It shows high resilience in the short term but appears to be more dynamic in the longer term.

2. Summer mouse population densities are at a new and higher equilibrium state. Food resources for the mice are available throughout the year, but a reduction in quantity of resources over winter may lead to enhanced winter mortalities of mice.
3. Mice are having a direct impact on vegetation via seed predation and perhaps other activities, which is leading to a change in germination of species and to plant composition/vegetation structure.
4. Mice are having a direct effect on macro-invertebrates via predation. They are affecting densities and the genetic diversity of invertebrates in the system.
5. The nature of the impact of mice on the invertebrates is seasonally variable, with largest effects in April/May. However, additional data are required to determine the full extent of the impact.
6. The structure and functioning of the ecosystem at Marion Island are being significantly affected as a result of the impact of mice on vegetation and the detritivores which are responsible for nutrient release.
7. The terrestrial ecosystem may be in a non-equilibrium stable state. However, the long term cumulative impact of mice could bring about critical changes to the system.
8. There is a need for both medium-term and short-term research on the impact of mice on the system. The following research should be undertaken: i) Long term low-key (once yearly in April/May) monitoring of mouse population density; ii) Investigation of impact of mice vs. changing climate on invertebrates, Prince Edward Island to serve as a control; iii) Effects of cold and wetness on survival of mice; iv) Effect of food availability on mice via enclosure studies; v) Extent of seed predation by mice and the effects of burrowing on peat formation by plants; vi) Effect of moisture and temperature on decomposition of litter; vii) Patchiness of insects in terrestrial habitats; viii) Transit times of insects in gut and likelihood of chitin and cellulose digestion; ix) Determination of medium-term (180 yr) climate change since mice were introduced; x) Foraging time and foraging methods of mice.
9. Marion Island is a typical example of a sub-Antarctic island and should be used as an outstanding environmental laboratory.

Nel

1. There are clear intra-annual changes in population densities of mice at Marion Island, but inter-annual changes may be due to natural variability.
2. Macro-invertebrates are declining and the terrestrial ecosystem is consequently changing. However, the contribution of climate vs. mice to these changes in macro-invertebrate density need to be addressed. The impact of Lesser Sheathbills, *Chionis minor*, on invertebrates also requires attention.

3. There is a need for further research. The following work should be undertaken: i) Determination of climate change over the 180 yrs mice have been present on the island, cores from the ice-plateau may be of some value in this regard; ii) Monitoring of mouse population fluctuations; iii) Determination of the impact of mice vs. climate on invertebrates; iv) Determination of geographic variability of climate on the island; v) Determination of effects of prey availability on mice; vi) Comparative analysis of scat vs. stomach content analyses for assessment of the diet of mice.

CONCLUSIONS AND RECOMMENDATIONS

1. The population density of feral mice at Marion Island is at a new, higher level than what it was at the time of Gleeson's study. However, the extent of natural population fluctuations is unknown. Annual sampling in known grids should be continued for at least five years.
2. Mice are having a considerable impact on arthropods, vegetation and ecosystem processes. This is reflected in differences in macro-invertebrate densities and plant cover between the early and mid 1970s and the 1990s. However, the following studies are required: i) An investigation of the impact of changing abiotic conditions vs. the impact of mice on macro-invertebrates. ii) The effect of abiotic variables on litter decomposition and mouse survival. iii) Knowledge of the spatial and temporal variability of food availability, and its effect on mice. iv) The effect of abiotic variables on digestion in mice.
3. Macro-invertebrate populations have changed over time both in terms of densities and composition. Knowledge of this variation over a further five-year period is required. Key species are *Pringleophaga marioni*, earthworms and the *Ectemnorhinus*-group of weevils.
4. The climate is changing at Marion Island. However, longer term data from the past 180 yrs are required, as well as information on intra-island variability in climate. Microclimate stations should be deployed around Marion Island and on Prince Edward Island.
5. The Lesser Sheathbill is an important component of the interaction between introduced and alien species because it subsists mainly on invertebrates in winter months. This species may be used as an indicator of changes in the system because of the ease of monitoring these birds and because baseline studies have already been undertaken by A.E. Burger in the 1970s (e.g. Burger 1982).
6. There is a need for a five-year research programme to address the above issues. This programme will not only address management issues on the islands, but is also liable to produce high quality research which is in line with the International Geosphere Biosphere Programme (IGBP), Global Change in Terrestrial Ecosystems (GCTE) and Biological Investigations of Terrestrial Antarctic Systems (BIOTAS) programmes, and which is directly relevant to all studies of biological invasions. Such invasions are liable to become increasingly important in South Africa as economic contacts with other nations are renewed.

PART II: THE DESIRABILITY AND FEASIBILITY OF ERADICATION

PRESENTATIONS

Cooper : New Zealand Programme : The New Zealand Department of Conservation (NZ-DOC) leads the world in eradicating rodents from islands and in testing poisons for use as rodenticides (Eason 1991; references in Table 1). New Zealand expertise and knowledge are now being utilized worldwide to rid islands of rodents. In the 1980s efforts were ground-based, by using baited traps, bait stations or ground broadcast of poisoned bait (e.g. McFadden 1992). These techniques were labour-intensive, slow and sometimes failed to achieve eradication and were only feasible on small (< 100 ha) islands (I. McFadden, NZ-DOC, personal communication). On heavily vegetated islands paths had to be cut to dispense bait and this was expensive and caused environmental damage. More recently, single or double (approximately two weeks apart) aerial applications of poisoned bait from "monsoon buckets" suspended from helicopters has been very successful in eradicating rodents (usually Polynesian Rats or Kioie, *Rattus exulans*) on at least nine New Zealand islands up to 770 ha in size (Table 4). Bait is spread in a 80-100 m swath at 60 knots at a density of $5-18 \text{ kg} \cdot \text{ha}^{-1}$. Flying time is approximately $100 \text{ ha} \cdot \text{h}^{-1}$. The buckets can carry up to 900 kg and are suspended from small helicopters (Aerospatiale Squirrels and Bell Jet Rangers) by a 5-6 m line. The poison of choice is the second-generation single-dose anticoagulant Brodifacoum (formulated as pellets at 20 ppm), which is also toxic to birds.

Substantial research is first conducted on both target and non-target species. For some islands, animals may be taken into temporary captivity to avoid being poisoned. Future New Zealand efforts may take island size at which rodent eradications are attempted to over 10 000 ha (such as Campbell Island) and efforts to rid islands up to 3 000 ha of rodents are planned for the next few years (Clout 1992; McFadden 1995; Table 4). The New Zealand aerial baiting experience is being adopted by the French Antarctic Programme (TAAF) to rid St. Paul Island (700 ha) of rodents and rabbits in 1995/96, with international funding from the European Union (Patel 1994).

Cooper : Feasibility for Marion Island: Marion Island, at 29 000 ha, is far larger than any New Zealand island from which rodents have been eradicated, or for which plans have been made to do so (Clout 1992). However, New Zealand opinion is that island size mainly effects costs and that given sufficient funding aerial baiting could be used successfully on large islands (I. McFadden, NZ-DOC, personal communication). Generally, the larger the island, the greater the likelihood of their being non-target species which could be affected, since larger islands tend to support more species.

A very preliminary calculation suggests that 20 000 ha of Marion Island would need to be aurally treated with poisoned bait, and that this would require 100 tonnes of bait (current cost in South Africa, c. 2.75 million Rand) at $5 \text{ kg} \cdot \text{ha}^{-1}$ for a single application and 2000 hrs of flying time. It is evident from these calculations that it will be an expensive undertaking. There will be a requirement to preplace bait in weatherproof containers around the island to save on flying time. One likely problem is bad weather interrupting the complete coverage of the island, and this could possibly allow mice to re-invade treated areas and re-establish themselves.

Because of the need to reduce incidental mortality of scavenging birds occurring at Marion Island, such as Subantarctic Skuas, *Catharacta antarctica*, Kelp Gulls, *Larus dominicanus* and Lesser

Sheathbills, which are likely to take both bait and poisoned mice, it would be desirable to dispense poison in winter. Few skuas are present at this time. However, the Lesser Sheathbill is both an endemic subspecies and a resident, so it will be necessary to investigate ways of reducing mortality of this species, such as taking birds into temporary captivity, using baits of no or low toxicity to birds, or colouring or chemically treating baits to make them less attractive. It will be necessary to conduct applied research in this field, since only one poisoning effort (ground-baiting for rabbits) has been made at two small islands in the Kerguelen archipelago where sheathbills, skuas and gulls could have been affected (Chapuis 1994). On Enderby Island (Table 4), at least two-thirds of the skua population was killed by taking poisoned bait directly (Torr 1993).

GROUP CONCLUSIONS

Cooper

1. The desirability and feasibility of eradication or control should be treated as two distinct issues.
2. Control (below "threshold of excessively deleterious effects") or eradication is desirable for the following reasons: i) Philosophical - mice do not belong in the system; ii) The Prince Edward Islands Management Plan states that wherever possible, alien species are to be removed from the islands; iii) Mice are having deleterious effects on indigenous species and ecosystem processes; iv) Eradication may provide an unparalleled opportunity for a study of the recovery/resilience of a sub-Antarctic ecosystem.
3. Eradication or control may be considered undesirable because mice have been present on Marion Island for 180 years and therefore present excellent research opportunities to study the effects of biological invasions over the long term and under scenarios of global change.
4. The options are to do nothing, to control the mice, or to attempt eradication. The Prince Edward Islands Management Plan effectively excludes the "do nothing" option.
5. Before any option is finally decided on additional research is required. This should include the following: i) Research on the system as indicated in Part I (above); ii) An investigation of the efficacy and desirability of various control measures vs. eradication; iii) The effects of eradication via aerial bait dispersal on non-target species; iv) The nature of the rodenticide to be used, and its behaviour under field conditions on the island.
6. The feasibility issue cannot be separated from the economic needs of the country. There are other, higher priorities such as the environmental requirements of the Reconstruction and Development Programme.
7. Eradication via aerial bait drops appears to be feasible. However, a 4-12 day weather window is required, and considerable information needs to be gathered on the possibility of taking non-target species, especially sheathbills, into captivity, the most suitable time for eradication, bait toxicity and the possibility of using other techniques such as chemosterilants, diseases and/or lethal genes.

Table 4. Removal of rodents from New Zealand islands by aerial baiting from helicopters.

ISLAND	YEAR	SIZE (HA)	SPECIES	REFERENCE
SUCCEEDED				
Burgess	1990	73	Polynesian Rat	McFadden & Greene 1993
Stanley	1991	100	Polynesian Rat	Towns <i>et al.</i> 1993
Red Mercury	1992	225	Polynesian Rat	Towns <i>et al.</i> 1994
Tiritiri Matangi	1993	220	Polynesian Rat	I. McFadden, pers. comm.
Middle Chain	1993	40	Polynesian Rat	I. McFadden, pers. comm.
Watapuke	1993	100	Polynesian Rat	I. McFadden, pers. comm.
Inner Chetwode	1993	240	Polynesian Rat	I. McFadden, pers. comm.
Enderby	1993	770	House Mouse	Torr 1993, 1994
Lady Alice	1994	136	Polynesian Rat	I. McFadden, pers. comm.
RECOMMENDED OR PLANNED				
Big South Cape		939	Black Rat	Clout 1992
Mayor		1277	Norway & Polynesian Rat	Clout 1992
Codfish		1396	Polynesian Rat	Clout 1992
Ruapuke		1525	House Mouse	Clout 1992
Motutapo		1560	Norway, Black, Polynesian Rat	Clout 1992
Great Mercury		1860	Black Rat	Clout 1992
Kapiti		1970	Norway & Polynesian Rat	Clout 1992
Antipodes		2025	House Mouse	Clout 1992
Rangitoto		2321	Norway, Black, Polynesian Rat	Clout 1992
Raoul		2938	Norway & Polynesian Rat	Clout 1992, Veitch 1994
Little Barrier		3083	Polynesian Rat	Clout 1992
DESIRED				
Campbell		11 330	Norway Rat	A. Cox, pers. comm.

8. Control is feasible but at an extremely high long-term cost. Diseases and genetic manipulation appear preferable to chemosterilants.
9. Conclusion: Management research on the possible effects of eradication and/or control is necessary. Research to establish a baseline for the system prior to control, and with which to assess post-control changes is necessary. A watching brief on international developments in rodent control should be kept. This topic could be usefully revisited in a second workshop after five years of research.

Craft ord

1. Eradication via aerial poisoning is feasible. However, it is liable to enjoy a low, national priority. Given the importance of Marion Island as an almost pristine sub-Antarctic system, international agencies should be approached by the responsible authority for funding for an eradication programme.
2. Although eradication is considered to be feasible, considerable research concerning the behaviour of the rodenticide under local conditions is required. In addition, research on the effects of secondary poisoning, and the half-life of the rodenticide is also required. Furthermore, data on the genetic variability of the sheathbill populations on both Marion and Prince Edward Islands are required to ascertain the "acceptable" levels of population reduction.
3. In terms of the desirability of control, there is a dilemma. From a scientific point of view, the presence of mice on Marion Island, but not on Prince Edward Island present incomparable research opportunities for assessing the effects of invasive organisms on natural ecosystems during a period of climate change. However, from a conservation point of view, control or eradication is obligatory, given the unique value of the system.
4. Over the short term, control may be easier to "sell" at a national level, than eradication.
5. Conclusion: Although eradication could be considered both desirable and feasible, considerable research is required on the impact of mice on the ecosystem, as set out in Part I above, and on management aspects such as those outlined in points 1 and 2. A five-year research programme should be implemented to address these issues.

CONCLUSIONS AND RECOMMENDATIONS

1. Eradication of feral house mice at Marion Island is feasible. However, considerable management research on secondary poisoning, the toxicity of the rodenticide to be used, logistic requirements, and the minimization of impact on non-target species is required. Five years is required to establish the nature of mouse population fluctuations and the impact of mice on the system as outlined in Part I. This will also provide an opportunity to establish a baseline for monitoring changes should an eradication attempt be made.

2. Eradication is desirable. However, local ecological research is required (Part I) and management research concerning possible options for control and the effects of eradication must be undertaken.
3. A watching brief on global developments in rodent eradication should be kept.
4. The research programme should be subdivided into two components, one dealing with the impact of mice on the system, the other with issues relating to management of the feral mouse population and its consequences.
5. It is suggested that the Prince Edward Island Management Committee establish a working group on mice at Marion Island. This group should address the recommendations set out in this report and monitor global advances in rodent control. The group should consist of permanent representatives from the Department of Environmental Affairs and Tourism, permanent representatives from local universities who **are not** involved in the research programmes, a permanent representative from the rodenticide industry who is **not** liable to supply rodenticides if eradication is attempted, a permanent representative from a conservation-minded, non-government organization, such as the World Wide Fund for Nature, and temporary members who are either involved in research programmes or who may be involved in an eradication programme. It is suggested that an impartial chair (non-rotating) be elected from within the Prince Edward Islands Management Committee. The Working Group will also advise the South African Committee for Antarctic Research on funding with regard to applied and basic research concerning feral house mice on Marion Island.

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REFERENCES

- Bloomer, J.P. and Bester, M.N. 1992. Control of feral cats on sub-Antarctic Marion Island, Indian Ocean. *Biological Conservation* **60**: 211-219.
- Burger, A.E. 1978. Terrestrial invertebrates: a food resource for birds at Marion Island. *South African Journal of Antarctic Research* **8**: 87-99.
- Burger, A.E. 1982. Foraging behaviour of Lesser Sheathbills *Chionis minor* exploiting invertebrates on a sub-Antarctic Island. *Oecologia* **52**: 236-245.

- Chapuis, J.-L. 1994. Eradication of the rabbit (*Oryctolagus cuniculus*) on Verte Island in Kerguelen Archipelago by poisoning. *SCAR Sixth Biology Symposium, Antarctic Communities: Species, Structure and Survival*. Venice, 30 May - 3 June. Abstract Volume p. 50.
- Chown, S.L. & Smith, V.R. 1993. Climate change and the short-term impact of feral house mice at the sub-Antarctic Prince Edward Islands. *Oecologia* 96: 508-516.
- Clout, M.N. 1992. Rodent eradication strategy for large islands for period 1992-1996. New Zealand Department of Conservation, unpublished report.
- Cooper, J. & Headland, R.K. 1991. A history of South African involvement in Antarctica and at the Prince Edward Islands. *South African Journal of Antarctic Research* 21: 77-91.
- Crafford, J.E. 1990. *Patterns of energy flow of the dominant insect consumers on Marion Island*. PhD thesis, University of Pretoria [unpublished].
- Eason, C.T. 1991. A review of the advantages and disadvantages of existing rodenticides and rat baits. New Zealand Forest Research Institute. Contract Report FWE91/46.
- Gleeson, J.P. 1981. *The ecology of the house mouse, Mus musculus, Linnaeus, on Marion Island*. MSc Thesis, University of Pretoria.
- Gleeson, J.P. & Van Rensburg, P.J.J. 1982. Feeding ecology of the house mouse *Mus musculus* on Marion Island. *South African Journal of Antarctic Research* 12: 34-39.
- Marshall, J.H. 1948. *No Pathway Here*. Hodder and Stoughton, Cape Town.
- Matthewson, D.C., Van Aarde, R.J. & Skinner, J.D. 1994. Population biology of house mice (*Mus musculus*) on sub-Antarctic Marion Island. *South African Journal of Zoology* 29: 99-106.
- McFadden, I. 1992. Eradication of Kiore (*Rattus exulans*) from Double Island, Mercury Group in northern New Zealand. *New Zealand Department of Conservation Scientific Research Internal Report* 130: 1-12.
- McFadden, I. 1995. Rodent eradication from New Zealand Islands. *Aliens* 1: 15.
- McFadden, I. & Greene, T. 1994. Using Brodifacoum to eradicate Kiore (*Rattus exulans*) from Burgess Island and the Knights Group of the Mokohinau Islands. *New Zealand Department of Conservation Scientific Research Series* 70: 1-18.
- Patel, T. 1994. French declare war on rats and rabbits of seabird isle. *New Scientist* 17 December 1994.
- Smith, V.R. 1987. The environment and biota of Marion Island. *South African Journal of Science* 83: 211-220.
- Smith, V.R. & Steenkamp, M. 1990. Climatic change and its ecological implications at a subantarctic island. *Oecologia* 85: 14-24.
- Torr, N. 1993. An interim report on Enderby and Rose Island rabbit eradication programme following expedition 9 February - 8 May 1993. New Zealand Department of Conservation, unpublished report.
- Torr, N. 1994. The second interim report on Enderby and Rose Island rabbit eradication programme following expedition 20 January to 19 February 1994. New Zealand Department of Conservation unpublished report.
- Townes, D., McFadden, I. and Lovegrove, T. 1993. Offshore islands co-operative conservation project with ICI Crop Care Division: Phase One (Stanley Island). *New Zealand Department of Conservation Scientific Research Internal Report* 138: 1-24.
- Townes, D., McFadden, I., Thomson, P., Robertson, H. and Colbourne, R. 1994. Offshore islands co-operative conservation project with ICI Crop Care Division: Phase Two (Red Mercury Island). *New Zealand Department of Conservation Scientific Research Internal Report*

142: 1-12.

- Van Zinderen Bakker, E.M., Winterbottom, J.M. and Dyer, R.A. (eds) 1971. *Marion and Prince Edward Islands. Report on the South African Biological and Geological Expedition 1965-1966*. A.A. Balkema, Cape Town.
- Veitch, C.R. 1994. Raoul Island May to August 1994. A report to the Regional Conservator, Auckland Conservancy, following a visit to Raoul Island. New Zealand Department of Conservation, unpublished report.
- Watkins, B.P. & Cooper, J. 1986. Introduction, present status and control of alien species at the Prince Edward Islands. *South African Journal of Antarctic Research* 16: 86-94.

LIST OF DELEGATES

Mr. N.L. Avenant, State Museum, Bloemfontein
Dr. M.N. Bester, Dept. Zoology & Entomology, University of Pretoria
Prof. S.L. Chown, Dept. Zoology & Entomology, University of Pretoria
Mr. J. Cooper, FitzPatrick Institute, University of Cape Town
Dr. J.E. Crafford, Dept. Zoology, University of Venda
Mr. S. Ferreira, Mammal Research Institute, University of Pretoria
Dr. F. Hanekom, Dept. Environmental Affairs and Tourism*
Prof. J.A.J. Nel, Dept. Zoology, University of Stellenbosch
Prof. M. Perrin, Dept. Zoology & Entomology, University of Natal
Dr. D.T. Rowe-Rowe, Natal Parks Board
Prof. V.R. Smith, Dept. Botany & Genetics, University of the Orange Free State
Prof. R.J. van Aarde, Dept. Zoology & Entomology, University of Pretoria
Mr. M. van der Merwe, Dept. Zoology & Entomology, University of Pretoria
Mr. D. van Schalkwyk, Directorate: Antarctica & Islands, Dept. Environmental Affairs and Tourism
Mr. L. Venter, Hoechst Schering AgrEvo (Pty) Ltd*
Mr. H. Waters, Hoechst Schering AgrEvo (Pty) Ltd*

* Delegates present on the second day only.

APPENDIX I - WORKSHOP PROGRAMME

THE IMPACT OF FERAL HOUSE MICE AT MARION ISLAND AND THE DESIRABILITY OF ERADICATION

THURSDAY 16TH FEBRUARY 1995

THE IMPACT OF MICE ON THE TERRESTRIAL ECOSYSTEM

09H00-09H15:	WELCOME
09H15-09H30:	WORKSHOP OUTLINE
09H30-10H00:	Historical background to alien vertebrates and control programmes at Marion Island. DR. M.N. BESTER
10H00-10H30:	Mouse population biology and the nature of the impact. PROF. R.J. VAN AARDE
10H30-11H00:	**TEA**
11H00-11H30:	The impact of mice - an invertebrate perspective MR. N. AVENANT
11H30-12H00:	The possible influence of climate change PROF. V.R. SMITH
12H00-13H00:	DISCUSSION I - THE NATURE OF THE IMPACT Session split into two groups: Leaders: Prof. M. Perrin & Prof. J. Nel
13H00-14H00:	**LUNCH**
14H00-14H30:	DISCUSSION I CONTINUED
14H30-15H00:	REPORT I: THE NATURE AND EXTENT OF THE IMPACT
15H00-15H30:	**TEA**
15H30-16H00:	REVIEW OF FINDINGS DR. D.T. ROWE-ROWE
16H00-17H00:	FINAL DISCUSSION : CONCLUSIONS TO BE DRAFTED NATURE AND EXTENT OF IMPACT
17H00:	***BRAAI***

FRIDAY 17TH FEBRUARY 1995

THE DESIRABILITY AND FEASIBILITY OF ERADICATION

- 08H30-09H00: Rodent eradication on other sub-Antarctic islands.
MR. J. COOPER
- 09H00-09H30: Rodent control via aerial distribution of rodenticides
VIDEO
- 09H30-10H00: Feasibility for Marion Island.
MR. J. COOPER
- 10H00-10H30: ****TEA****
- 10H30-11H30: DISCUSSION II - DESIRABILITY AND FEASIBILITY OF
ERADICATION Leaders: Mr. J. Cooper and Dr J.E. Crafford
- 11H30-12H00: REPORT II - ERADICATION : OPTIONS
- 12H00-12H30: REVIEW OF FINDINGS
DR. J.E. CRAFFORD
- 12H30-13H00: FINAL CONCLUSIONS TO BE DRAFTED:
DESIRABILITY OF ERADICATION
- 13H00: CLOSE

PROGRAMME FOR A WORKSHOP ORGANIZED BY S.L. CHOWN & J. COOPER; HELD AT THE DEPARTMENT OF ZOOLOGY & ENTOMOLOGY, UNIVERSITY OF PRETORIA, 16-17 FEBRUARY 1995.

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