The impact of rabbit and goat eradication on the ecology of Round Island, Mauritius

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Abstract Round Island (169 ha) holds the only populations of several reptiles and plants that formerly occurred on Mauritius. Eradication of introduced goats (*Capra hircus*) by 1978 and rabbits (*Oryctolagus cuniculus*) by 1986 was predicted to allow increases in abundance of threatened species. Subsequent surveys have revealed the first substantial recruitment of three main tree species for over 100 years. The extent of ground vegetation increased slightly but is now dominated by non-native species and large unvegetated areas remain. Of three reptiles confined to Round Island, two showed no sustained increases but one increased dramatically. In the short term the general, predicted effects of eradication (increases in plant biomass and tree recruitment) were upheld. However unpredicted effects (differential population responses of reptiles and increasing rates of establishment and influence of non-native plants) have occurred. As a result new ecological communities are likely to develop on Round Island.

Keywords Impacts of eradication; rabbits; goats; plants; reptiles.

INTRODUCTION

Round Island (169 ha), 20 km NE of Mauritius, supports the only populations of several plants and reptiles that used to occur on the mainland. It is rodent-free, and one of the most important seabird islands in the western central Indian Ocean. Early reports indicate that a giant tortoise (*Cylindraspsis* sp.) was present. This native 'large herbivore' was replaced by rabbits (*Oryctolagus cuniculus*) and goats (*Capra hircus*) introduced in the early 19th century (Cheke 1987). The mammalian herbivores prevented tree recruitment, destroyed a hardwood forest, encouraged the open character of the vegetation and promoted the progressive ecological degradation described by many authors (e.g. Vinson 1964; North and Bullock 1986).

In terms of vegetation and non-avian species the significance of Round Island has largely been because of its relative 'naturalness' and as a refuge for threatened species. Despite the mammalian herbivores it has retained the last significant remnant of an open palm-rich forest, which supports 14 threatened plant taxa. The herpetofauna is similarly outstanding: Eight species (nine including *Cylindraspsis* sp.) are recorded, of which seven are Mascarene endemics and four are now confined to Round Island. However, within the last few decades the adverse impact of the rabbits and goats has caused the probable extinction of the snake, *Bolyeria multocarinata* last seen in 1975, reduced a hurricane palm *Dictyosperma album* var *conjugatum* endemic to Round Island to one individual, and reduced several other species to very low numbers (Bullock 1986; North *et al.* 1994).

In 1975/76 there were between 10 and 20 goats and the combination of a shooting expedition and a cyclone had temporarily reduced the rabbit population. By 1978 the few remaining goats (<5) had been shot out but by 1982 the rabbit population had recovered and the response of the vegetation was limited (North and Bullock 1986). In 1986 rabbits were eradicated (Merton 1987) and in 1989 the following short term changes were being observed or anticipated (North *et al.* 1994) increases in: ground vegetation (i.e. vegetation other than mature trees); the number and abundance of non-native plant species; regeneration and recruitment of palms and other trees; invertebrate abundance; habitat availability for, and population sizes of, arboreal *Phelsuma* geckos and the saurivorous snake *Casarea dussumieri*. After an initial pulse of tree regeneration, decreases in recruitment rate were expected as the availability of open seed bed habitats declined. Decreases were also observed or anticipated in the abundance of plants favoured by the presence of rabbits, goats or open ground. The projected loss of open ground was also expected to reduce optimum habitat availability for skink by reducing open basking areas, leading to their local decline.

After rabbit and goat eradication, and anticipated increases in two of the largest reptiles, *Casarea* and *Phelsuma guentheri*, reptile biomass was expected to increase. Reptile biomass is often exceptionally high on other seabird islands where food availability is enhanced by nutrient inputs from guano, plus carcasses and eggs. For example, on Cousin Island (Seychelles), the combined biomass of

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three lizard species has been reported as at least 96 kg/ha, close to the maximum recorded for reptiles (Cheke 1984). In the short term, at least, there was no reason to expect fluctuations in the breeding populations of seabirds to be influenced by eradication of rabbits and goats. An increase in reptile biomass on Round Island after eradication would be expected only if habitat or food availability had been limiting when the mammalian herbivores were present.

In this paper, predicted and observed changes are compared using the results of surveys before and after the removal of rabbits and goats. Much valuable restoration management work has been conducted on Round Island since 1986, including the planting of Mauritian endemic trees. In this paper the focus is on describing unaided responses of threatened species and their habitats to eradication. The eradications are therefore regarded as an opportunity to gain understanding of ecological processes on Round Island (as suggested in Myers *et al.* 2000) and to place them in the context of the overall ecosystem (Zavaleta *et al.* 2001). Particular attention is paid to the influence of unpredicted processes in the short term (i.e. a decade after eradication of mammalian herbivores) on the long-term restoration of the island.

Scientific names and the status (non-native/native) of all plant species from 1975 to 2000 are given in Appendix 1. It is frequently difficult to separate long established introduced species from those that are native. This is especially so for pan-tropical species such as *Portulaca oleracea*, which here is considered to be native.

METHODS

Vegetation

In 1975 the most vegetated slopes of Round Island were divided into 12 study Areas (totalling *c.*102 ha) within which vegetation and reptile populations were recorded. These Areas formed the basis of comparable surveys in subsequent expeditions (1978 - partial surveys only, 1982, 1989 and 1996). Survey methods have been described previously (Bullock 1986; North and Bullock 1986). Individual *Latania loddigesii* and *Pandanus vandermeerschii* trees were assigned to one of seven and five size classes respectively where the largest (and presumably oldest) were Class 1 (see Fig. 1 and 2). Trees were counted and ground vegetation measured using cover estimates along transects in two Areas, 3 (8.7 ha) and 11 (11.2 ha). These Areas were chosen to represent trends on the western and south-eastern slopes respectively but it should noted that they were amongst the most vegetated parts of the island. In addition, the frequency and percentage cover of plant species in 15 permanent quadrats distributed across the island was recorded. Particular attention was also paid to tracking trends in the status of threatened species, including the palm *Hyophorbe lagenicaulis*, and non-native species.

Reptiles

For reptiles, direct standardised daytime counts of at least two Areas (Area Counts) in each sample year, plus timed searches at night (to give Encounter Rates) and transects (one each in Areas 3 and 12 - west and south-east slopes respectively - walked during the day and at night) were used. Visual counts provided indices of population density and were always underestimates. In 1996 mark-recapture sessions (10 in each of Areas 3 and 11) used to estimate population sizes indicated that in Area Counts between 5% and 55% of individuals were recorded, depending on the species. Reptile biomass was estimated from population estimates and mean weights of caught samples of all species.

Invertebrates

In 1989 and 1996, the relative abundance and taxonomic diversity of invertebrates was sampled in two gullies on the south-eastern slopes and two sites in Area 3 using pitfall traps (10 set for 24 h) and sweep nets (150 sweeps) during daylight. Catches were sorted to Order and the proportions of soft-bodied taxa preferred as prey by lizards (Arachnida, Dermaptera, Dictyoptera, Orthoptera, Lepidoptera, Diptera, Phasmida, Coleoptera) separated from non-preferred prey (such as Hymenoptera (mainly ants) and Isopoda).

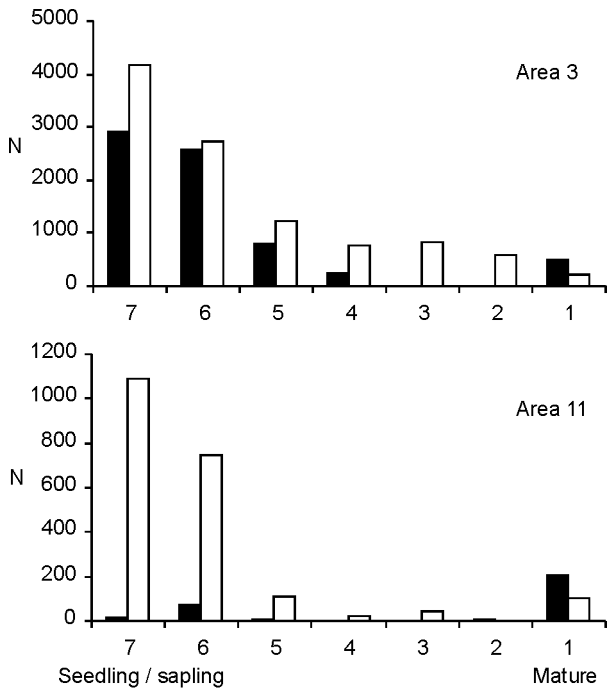

Fig. 1 Size structure of *Latania loddigesii* in Areas 3 and 11 of Round Island in 1975 (black bars) before browsing mammal eradication and 1996 (white bars) after browsing mammal eradication. Size class categories: 7, seedling; 6, >0.1 m - 0.6 m; 5, >0.6 m – 1.2 m; 4, >1.2 m – 1.8 m; 3, >1.8 m – 3.0 m; 2, >3.0 m, <2.0 m of trunk; 1, usually >3 m of trunk and 90 yrs. old. N = number of individuals.

RESULTS

Tree populations

Between 1975 and 1996 the number of Class 1 or equivalent individuals of the three main species declined. However, removal of the mammalian herbivores allowed large pulses of recruitment that are now beginning to replace losses of adult trees.

Latania loddigesii

Latania is by far the most abundant tree species on Round Island. After rabbit/goat eradication, the numbers of *Latania* in six smallest size classes dramatically increased. Eradication resulted in the first major recruitment phase to occur for at least 100 yrs. Between 1975 and 1996 the numbers of Class 1 *Latania* declined by 62% (Fig. 1). Assuming no change in the rate of decline, this cohort was estimated to disappear by 2009. If the mammalian herbivores had not been removed, by 2010 *Latania* would probably have disappeared, along with key habitats of several reptile species and a major component of the island's ecology.

In permanent quadrats, the density of *Latania* seedlings (Class 7) in the lower western, upper western and south-eastern slopes was similar within years but declined from a mean density of 8.2/m^2 in 1975 to 1.1/m^2 and 1.6/m^2 in 1989 and 1996 respectively. For quadrats on the lower western slopes, the decline between 1975 and 1989/1996 was significant ($F_{2,9}$ = 11.08, $P < 0.01$ on $\log_{10}$(x+1) transformed data). As the quadrats were located in the areas of highest tree density, these results may therefore reflect localised self thinning.

Hyophorbe lagenicaulis.

In 1975 there were 15 mature palms on the island, only two of which were alive by 1996. However, recruitment increased markedly after 1986 with six newly-mature individuals in 1996, together with at least 42 young plants (over 1 m tall) and abundant seedlings in several locations. All these were the result of natural regeneration rather than planting as part of restoration programmes. Were mammalian herbivores still present, *Hyophorbe* would be close to extinction in the wild.

Pandanus vandermeerschii

On the south-eastern slopes, where *Pandanus* is most frequent, regeneration and recruitment increased after rabbit/goat eradication with, however, a decline in the numbers of trees in the oldest cohort (Fig. 2).

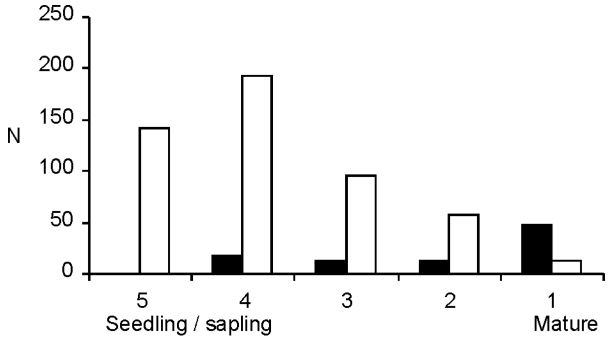

Fig. 2 Size structure of *Pandanus vandermeerschii* in Area 11 of Round Island in 1975 (black bars) before browsing mammal eradication and 1996 (white bars) after browsing mammal eradication. Size class categories: 5, >0.1 m – 0.6 m; 4, >0.6 m – 1.8 m; 3, >1.8 m – 3.0 m; 2, >3.0 m and vigorous; 1, >3.0 m showing signs of dieback. N = number of individuals.

Table 1 Changes in the ground vegetation cover in Areas 3 and 11 of Round Island between 1975 and 1996 based on point samples along transects. Goats were eradicated by 1978; rabbits were eradicated in 1986.

Vegetation/substrate type	% Cover Area 3				% Cover Area 11			
	1975	1982	1989	1996	1975	1982	1989	1996
Boulder, gravel, sand	21.1	5.9	3.0	4.5	3.7	2.8	5.5	7.1
Rock slab	62.8	73.3	63.3	56.9	41.8	37.3	37.2	33.8
Creeper	4.2	6.4	7.1	9.9	45.5	48.8	44.2	28.2
Exotic grasses	0.1	0.1	9.8	12.3	0.1	0	1.6	11.1
Native grasses	3.8	9.3	5.8	3.5	2.5	5.1	1.2	2.4
Tall herbs	0.1	0.1	1.8	2.8	6.6	5.1	8.5	9.8
Boerhavia spp.	0	0	0.9	1.0	0	0.1	1.4	2.8
Achyranthes	0	0	0	0.9	0	0	0	2.5
Latania	7.7	3.9	7.8	7.6	0.3	0.5	0.4	1.3
Pandanus	0.2	0.5	0.6	0.7	0.4	0.6	0.1	1.0
N point samples				3637				2942
Total vegetation cover	16.1	20.3	33.8	38.7	55.4	60.2	57.4	59.1

Table 2 The frequency and abundance of "important" plant species (species with >10% cover in any quadrat in any year) in 15 permanent quadrats on Round Island between 1975 and 1996. The number of quadrats in which the species was recorded (frequency) is followed, in parentheses, by the number of quadrats in which it was >10% cover (a measure of abundance). Species in bold are introduced (non-native). Responses in bold are major changes in frequency and/or abundance.

	1975	1982	1989	1996	Responses to eradication	
					Goat	Rabbit
Passiflora	15 (8)	15 (3)	13 (7)	12 (6)	Unclear	Unclear
Tylophora	13 (5)	14 (11)	15 (11)	9 (5)	Increase	**Decrease**
Vetiveria	7 (5)	8 (5)	8 (4)	5 (0)	?Increase	**Decrease**
Portulaca	7 (3)	9 (0)	10 (0)	3 (0)	Unclear	Decrease
Ipomea	7 (0)	8 (2)	8 (5)	10 (7)	Increase	**Increase**
Ageratum	6 (2)	13 (0)	11 (1)	5 (1)	Unclear	Decrease
Nicotiana	6 (0)	7 (2)	0	0	?Increase	**Decrease**
Commelina	5 (1)	7 (1)	11 (3)	11 (1)	Unclear	Increase
Withania	2 (0)	0	0	1 (1)	Unclear	Unclear
Boerhavia	1 (0)	0	13 (0)	13 (2)	Unclear	Increase
Digitaria	1 (0)	0	6 (0)	7 (1)	Unclear	Increase
Chloris filiformis	1 (1)	1 (1)	1 (1)	1 (1)	Unclear	Unclear
Latania	0	1 (1)	6 (1)	7 (6)	?Increase	**Increase**
Abutilon	0	1 (0)	1 (0)	9 (7)	Unclear	**Increase**
Chloris barbata	0	0	10 (6)	13 (4)	None	**Increase**
Lycopersicon	0	0	1 (1)	0	None	Increase*
Amaranthus	0	0	2 (0)	5 (2)	None	Increase
Cenchrus	0	0	1 (0)	9 (4)	None	Increase
Achyranthes	0	0	0	13 (4)	None	**Increase**
Desmodium	0	0	0	2 (1)	None	Increase

***** Subsequently decreased

Ground vegetation

In Area 3, total vegetation cover along transects increased between 1975 and 1996, particularly between 1982 and 1989. In Area 11, where vegetation cover was much higher, there have been no substantial changes. In both Areas, a high percentage of the ground remains unvegetated a decade after rabbit eradication. In terms of changes in proportional abundance the most striking has been the increase in exotic grasses (*Chloris barbata, Cenchrus echinatus, Dactyloctenium ctenoides, Digitaria horizontalis)* and young *Latania.* Since the removal of rabbits/goats, vegetation dominated by *Boerhavia* spp., *Abutilon indicum* and *Achyranthes aspera* has increased, whilst native grasses (predominantly *Vetiveria arguta)* have declined. Creeper (*Tylophora coriacea, Ipomea pes-caprae, Passiflora suberosa*) cover increased in the more open Area 3 but declined in the more vegetated Area 11 (Table 1).

Non-native plant species

Of 72 vascular plant species recorded on Round Island since 1975, 37 (51.4%) are non-native (Appendix 1). The cumulative number of non-native species is increasing, but because of (re)discoveries of native species the native:non-native ratio has changed little. However, non-native species have had an increasing influence on the composition and structure of the ground vegetation. This effect is most marked for the present post-eradication period (Table 2).

The percentage of "important" species (see Table 2 for definition) which were non-native rose from 43% in 1975 to 75% in 1996. These non-native "important" species are those which are likely to be significant agents of change in the developing vegetation of Round Island.

The fate of individual non-native species on Round Island is hard to predict as shown in the breakdown of 37 species tracked to date:

Twelve species have become "important" components of the vegetation in one or more 15 permanent quadrats.

Four species have been "important" (*Lycopersicon esculentum* and *Nicotiana tabacum*) or common *(Tetragonia tetragonioides* and *Chenopodium murale)* but are now rare or have disappeared.

Six species are considered to be "potentially important" components. Three (*Cymbopogon excavatus, Solanum nigrum* and *Dactylotenium*) are common or frequent but have not yet reached >10% cover in any permanent quadrat. A further three (*Desmanthus virgatus, Heteropogon contortus* and *Chromolaena odorata*) have the potential to be invasive but to date have not

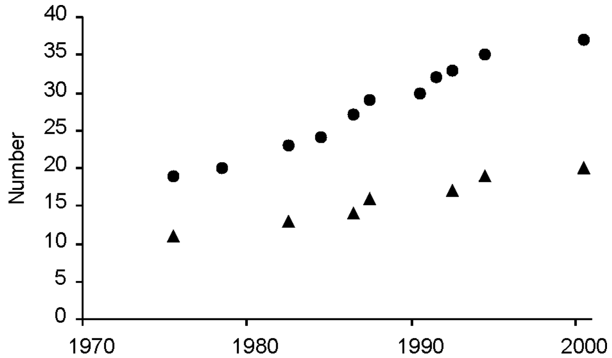

Fig. 3 The cumulative increase in non-native plant species recorded on Round Island between 1975 and 2000 based on Merton *et al.* 1989, North *et al.* 1994, Strahm 1994, pers. obs. The regression equations for all species (circles), and the subset of "potentially important" plus "important" species (triangles) are, respectively: y = 0.8165 – 1594.5, $F_{1,9}$ = 284.10, p <0.001; y = 0.3867 – 753.04, $F_{1,5}$ = 111.74, p <0.001. N = number of species.

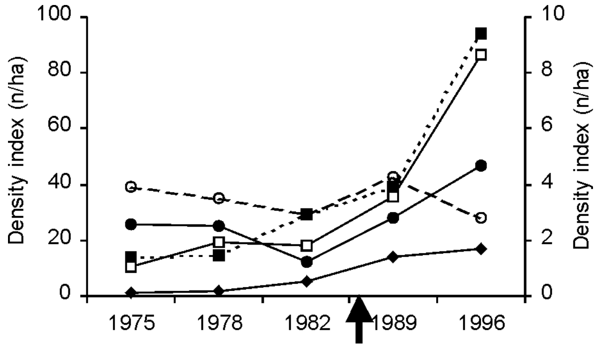

Fig. 4 Changes in the mean densities (n/ha) of the reptile species *Casarea dussumieri* (black diamonds, right axis), *Gongylomorphus bojerii* (white squares) and *Leiolopisma telfairii* (black squares), *Phelsuma guentheri* (black circles, right axis), *P. ornata* (white circles) recorded in daytime Area Counts on Round Island. Arrow denotes the year of rabbit eradication.

been recorded in permanent quadrats and are controlled by weeding or spraying.

Eight species have become (and remain) common but their influence on vegetation cover appears to be minimal and they are not believed to be significant agents of change.

Seven species which were never common have died out.

The number of non-native species recorded on Round Island increased linearly between 1975 and 2000. The rate of establishment increased after rabbit/goat eradication (Fig. 3) but not significantly so ($F_{1,7}$ = 0.83, p>0.05). For "important" species the rate did not change. Between 1975 and 2000 a new non-native species was recorded approximately every 1.4 years; a new "important" or "potentially important" species was recorded every 2.8 years.

Native plant species

Two native species, *Phymatodes scolopendria* and *Lobelia serpens*, have not been recorded since 1975. Changes in the populations of 15 further species which are largely or wholly confined to Round Island (Appendix 1) have been as follows: Five, *Latania, Hyophorbe, Pandanus, Gagnebina pterocarpa* and possibly *Lomatophyllum tormentorii*, increased in response to eradication of the mammalian herbivores. Four, *Dictyosperma, Fernelia buxifolia, Asparagus umbellulatus* and *Phyllanthus revaughanii*, have not responded and their populations remain critically low. Two, *Selaginella barklyi* and *Dichondra repens*, are low-growing and shade tolerant and remain widespread showing no obvious trend. Two, *Chloris filiformis* and *Aerva congesta*, remain confined to open and exposed habitats and their status has not changed. Two, *Vetiveria* and *Phyllanthus mauritianus*, appear to have declined since eradication.

Table 3. Comparisons of population indices of reptiles on Round Island. Comparison of Area Counts (day) and Encounter Rates (night) for before (1975, 1978, 1982) and after (1989, 1996) rabbit eradication. t tests used on $\log_{10}$ transformed counts. Transects, trends from counts in 1988 (from Merton *et al.* 1989), 1989 and 1996 are given for Area 3/Area 12 transects. '—' denotes species inactive.

	Area Count (day)	Encounter rate (night)	Transect Day	Transect Night
Phelsuma guentheri	No change	Increase P<0.01	No change/no change	No change/no change
Phelsuma ornata	No change	—	No change/decrease	—
Nactus serpensinsula	—	No change	—	Decrease/decrease
Leiolopisma telfairii	Increase P<0.01	Increase P<0.01	No change/increase	No change/increase
Gongylomorphus bojerii	No change	—	Decrease/no change	—
Casarea dussumieri	—	No change	—	Increase/decrease

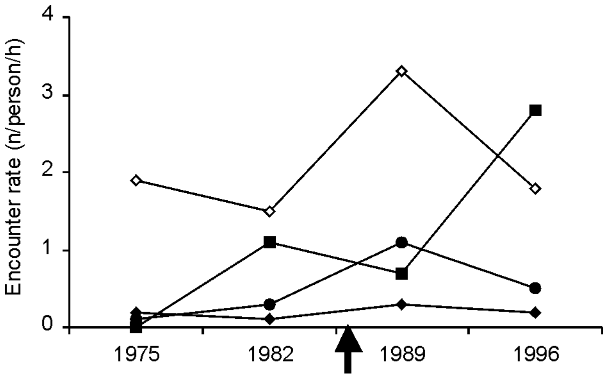

Fig. 5 Changes in the Encounter Rate (n/person/h) at night of reptiles on Round Island. Symbols as Fig. 4 but including *Nactus serpensinsula* (white diamonds). Arrow denotes the year of rabbit eradication.

Reptiles

Geckos

The large *Phelsuma guentheri* is now confined to Round Island where it has always been recorded as uncommon with a total population of <5000. Comparison of population indices from 1975 to 1996 indicates that overall this species has probably not increased in abundance, except at night when the Encounter Rate was significantly higher after rabbit eradication. Population indices of the nocturnal *Nactus serpensinsula* at night and the diurnal *Phelsuma ornata* during the day showed no evidence of sustained increases following eradication of rabbits (Table 3, Fig. 4 and 5).

Skinks

In contrast to the geckos, the large omnivorous *Leiolopisma telfairii* increased spectacularly after rabbits were eradicated. The small skink, *Gongylomorphus bojerii*, showed the same trend but the mean Area Counts from before and after rabbit eradication had high associated variances and the difference was not statistically significant (Table 3, Fig. 4 and 5). A third skink *Cryptoblepharus boutonii*, which has a wide tropical distribution, is largely confined to coastal rocks where its abundance does not appeared to have changed between 1975 and 1996.

Snakes

There is no evidence of a sustained increase in the abundance of *Casarea* as a result of rabbit eradication (Table 3, Fig. 4 and 5). However, the percentage of immatures found increased significantly from 22.0% in 1975 – 1982 to 50.5% in 1989-1996 (Chi square = 15.72, $p < 0.001$, df = 1) suggesting increased recruitment.

Relationships between vegetation and reptile abundance in 1996

The density of all *Latania* >1.8 m tall (Classes 5, 4, 3, 2 and 1) was a strong determinant of density of *P. ornata* ($r^2 = 90.2\%$). Similar regressions for other reptile species showed much weaker relationships. Interestingly, the regression for trees and the arboreal *P. guentheri* explained less of the variation ($r^2 = 41.4\%$) than did the one for the terrestrial *Leiolopisma* ($r^2 = 51.4\%$). The latter is also strongly dependant on cover of litter, much of which was fallen *Latania* leaves ($r^2 = 55.3\%$).

Changes in reptile biomass

Population estimates from between 1970 and 1975, based on tree:gecko ratios, mark- recapture and extrapolation from transects (Bullock and North 1976; Vinson 1975), indicate that reptile biomass on Round Island was relatively low at *c.* 4 kg/ha prior to goat/rabbit eradication. In 1996, using the same range of methods to estimate population sizes, biomass was approximately an order of magnitude higher at >40 kg/ha. Mean masses of reptile species had not changed (unpub. data), and the difference was principally due to an increase in *Leiolopisma*, together with increases in *P. guentherii* and *Nactus serpensinsula*. In 1996, *Leiolopisma* contributed 82.1% to the estimated reptile biomass.

Invertebrates

Comparison of catches in standardised pitfall and sweep net catches on Round Island in 1989 and 1996 showed no significant differences in either the diversity of invertebrate taxa sampled or number of soft-bodied "prey" species. Compared with other islands off Mauritius, such as Gunner's Quoin, samples from Round Island contained proportionately more soft-bodied prey. The unusually-high abundance of Dictyoptera on Round Island does not appear to have changed dramatically since 1975.

DISCUSSION

Responses of the tree populations

The imminent extinction of the oldest cohorts of *Latania* and *Hyophorbe* (and the decline in *Pandanus*) combined with negligible recruitment had mammalian herbivores still been present, indicates how close the palm-rich forest and its associated species had come to disappearing altogether. Increased regeneration and recruitment of woody species is a well-documented response to removal of grazing pressure. Despite the apparent adaptations of the three main tree species to deter herbivory, such as spiny seedlings and heterophylly, all were grazed by rabbits and/or goats. The recovery of the populations of *Latania*, *Hyophorbe* and *Pandanus* is the basis for restoring key processes such as accumulation of organic matter, soil retention and interspecific interactions. However, by 1996, recruitment of *Latania* seedlings in permanent quadrats had declined due to reduced seed bed availability, self thinning or interspecific competition. One or more of these factors is limiting future recruitment potential as predicted in North *et al.* (1994).

Responses of the ground layer vegetation

Three processes appear to be involved in changing the character of the ground vegetation post eradication, some of which were expected: 1. Observed declines in species of open, disturbed habitats that benefited from grazing pressure were expected. Such species are avoided by rabbits (e.g. *Nicotiana),* intolerant of competition (e.g. *Portulaca)* or tolerant of grazing (e.g. *Brachiaria* sp.). 2. The expected colonisation of bare areas has occurred but has been slow, because of the degree to which the island is subject to wind and the natural processes of sheet and gully erosion. 3. Where vegetation cover is high and the substrate stable, successional changes have occurred as expected. Annual species intolerant of shading (e.g. *Vetiveria, Portulaca, Nicotiana)* have declined whilst tall annuals/ biennials/perennials (e.g. *Abutilon, Solanum, Achyranthes, Boerhavia)* have increased. Non-native species have become an increasingly important influence on the structure and composition of the vegetation. This pattern has been described for other islands where introduced rabbits or goats have been eradicated (reviewed in Usher 1989; Zavaleta *et al.* 2001).

Observations suggest the following successional stages and their key constituent species (non- native species in bold):

a. Open vegetation, shade intolerant, grazing tolerant. Mainly annuals. *Vetiveria, Portulaca,* ***Nicotiana, Ageratum conyzoides, Passiflora,*** *Brachiaria, P. mauritianus.*
b. Closed vegetation, shade intolerant, grazing intolerant. Mainly annuals. ***Cenchrus, C. barbata, Digitaria.*** Potentially ***Dactyloctenium, Heteropogon.***
c. Closed vegetation, grazing intolerant. Low perennials including creepers. ***Boerhavia*** **spp.*, Commelina benghalensis, Desmodium incanum,*** *Tylophora.*
d. Closed vegetation of low scrub. Tall annuals, perennials, woody herbs/shrubs. ***Abutilon, Achyranthes, Solanum, Withania somnifera, Desmanthus,*** *Gagnebina.*
e. Palm/*Pandanus* thicket. Mature trees with thickets of younger trees. *Latania, Hyophorbe, Pandanus, Dictyosperma.*

Community type ‘a’ was extensive in 1975 but scarce by 1996 as ground cover and plant biomass increased. By 1996, ‘b’, ‘c’ and ‘d’ were widespread in vegetated areas but it is not yet clear how these changes will affect regeneration and recruitment of native tree species, especially *Latania,* which make up the characteristic landscape of Round Island and hold key habitats for the reptiles. The increasing influence of non-native woody herbaceous species has occurred on other Mauritian islands such as Ile aux Aigrettes (Dulloo *et al.* 1997) and was expected. However, only one woody shrub, *Desmanthus,* has become established on Round Island and that has been controlled by weeding. The effectiveness of control of *Desmanthus,* or other woody species, will be an important factor in the future development of the island’s vegetation.

Between 1975 and 2000 the cumulative increases in the numbers of new non-native species recorded on Round Island and the subset of “potentially important” plus ”important” species were linear (Fig. 3). This was despite wide fluctuations in mammalian herbivore density (in the case of rabbits from *c.* 2000 in 1985 to 0 in 1986), the number of human visitors (generally increasing over time) and the introduction of phytosanitary measures in 1986 (Merton *et al.* 1989).

Effects of eradication on populations of threatened native plant species

Five of the 15 native plant species which were threatened because of their induced restricted distribution and/or grazing, increased in response to the eradication of mammalian herbivores. These were all perennials and mostly trees. The remaining 10 showed no response. Either their populations were so low and they need a longer time to recover (and are perhaps genetically impoverished), or present conditions are unsuitable. Two species, *Vetiveria* and *P. mauritianus*, declined after rabbit eradication. Both are constituents of open vegetation community type ‘a’. In the absence of grazing, their persistence, along with that of two other species that thrive in open, salt-sprayed habitats, *C. filiformis* and *Aerva,* relies upon the intrinsic and natural instability of substrates, and exposure.

On Round Island there have been projected declines and losses of some key native plant species that can be directly attributed to the impact of mammalian herbivores. These, together with an apparent absence of impact on the rate of colonisation of non-native plant species indicates a differential “top down” control of vegetation. Goats, and especially rabbits, had much more overall influence on the presence or absence of native than non-native plant species.

Effects of eradication on populations of threatened reptile species

Except for *Cylindraspsis* sp. and *Bolyeria,* which were extinct or effectively extinct by 1975, no species appear to have declined. Of the threatened reptiles confined to Round Island, two types of response to the removal of rabbits were observed: Two species (*P. guentheri* and *Casarea)* do not appear to have increased. A third, *Leiolopisma,* has increased dramatically. Thus predictions of increases in arboreal reptiles (especially *Phelsuma* geckos) and possible declines in terrestrial reptiles have not been upheld. The estimated population sizes of *P. guentheri* and *Casarea* are in the low thousands and low hundreds, respectively, and these species remain vulnerable to extinction. Both are large, specialist reptiles with low reproductive rates; they are wholly or partly saurivorous, forage at night on the ground and also use above-ground vegetation. *Leiolopisma* is omnivorous and is seen with increasing frequency foraging at night. During the hottest part of the day it hides amongst litter. Its population appears to have benefited from the increased availability of litter produced as more *Latania* palms mature.

Reptile biomass is estimated to have increased ten-fold between 1975 and 1996 and is now approaching that of other seabird islands in the Indian Ocean such as Cousin Island, Seychelles. This change is mostly due to the increased population density of *Leiolopisma* between 1989 and 1996. In the absence of any known changes in the seabird populations the increase in *Leiolopisma* is attributed to increases in food or habitat availability after rabbit eradication. The abundance of invertebrates in 1989 and 1996 was similar, but neither pitfall traps nor sweep nets adequately sampled cockroaches (Dictyoptera), which are probably a major prey item for lizards that hunt at night, including *Leiolopisma*.

In the short term two skink species have responded positively to the ecological changes on Round Island induced by rabbit eradication. The high and apparently increasing population of *Leiolopisma* may serve to dampen increases in the other reptile species by way of predation and competition. This response of one native vertebrate species to the possible (short-term?) detriment of others has not been properly documented. It may represent an additional adverse trophic interaction to those already described for post eradication events (Zavaleta *et al*. 2001). In the longer term, density dependent factors may limit *Leiolopisma.* Increased availability of mature palms and *Pandanus* will provide more key habitat for *Phelsuma* geckos, and we expect the population of *P. guentheri* to respond positively to these changes.

Short-term and long-term consequences of eradication

Rabbits and goats were on Round Island for at least 150 years and their removal profoundly altered its ecology. The eradication of one of the mammalian herbivores (goat) led to a limited recovery (North and Bullock 1986). Whilst there are demonstrable benefits arising some 10 years after eradication of both goats and rabbits, we have also documented an increasing influence of non-native plant species. Of particular concern in the long term is the potential impact of non-native species on regeneration of tree species. In the context of Mauritius, Round Island is considered to have three key features: It is the best example of palm-rich forest (i.e. with a high proportion of native species); it has a large area of native vegetation; it is a refuge for species that now do not occur elsewhere. Notwithstanding eradication of goats and rabbits the increasing importance of non-native plants is reducing the value of the first two attributes. Furthermore, if tree regeneration is inhibited by non-native species then the value of the palm-rich forest as a refuge for threatened plants and reptiles may also decline.

All the data indicate that Round Island is experiencing a period of rapid changes. Some are successional, and the process is predictable; others, such as the rapid increase in the skink *Leiolopisma*, were not anticipated. Both types of response emphasise the value of continuing to measure the changes taking place on Round Island into the long term. Without further measurements of this “experiment” the ecological processes will not be understood in sufficient detail to inform management decisions on Round Island and similar islands elsewhere.

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Appendix 1. Plant species list for Round Island. Observed abundance levels in 1975, 1982, 1989 and 1996. Common C, locally common L, frequent F, rare R, not recorded 0. *= Non-native species. # = Native species for which Round Island is of particular conservation importance (based on Merton *et al.* 1989; Strahm 1994; pers. obs.). Native/non-native status and nomenclature from Antoine *et al.* 1976

FAMILY	TAXON	ABUNDANCE	COMMENTS
Polypodaceae	*Phymatodes scolopendria* (Burm.f.) Ching	R O O O	Last seen 1975
Pteridaceae	*Adiantum rhizophorum* Sw.	F F F F	
	Pityrogramma calomelanos (L.) Link*	R R O O	Last seen 1986
	Pteris vitatta L.	O O R R	First found 1986
	Acrostichum aureum L.	R R R R	
Nephrolepidaceae	*Nephrolepis* sp. ? *	O O O O	Only seen in1986
Selaginellaceae	*Selaginella barklyi* Baker #	F F F F	
Thelypteridaceae	*Christella dentata* (Forsk.) Brownsey and Jermy	O O R R	First found 1986
	Thelypteris sp.?	O R R R	
Psilotaceae	*Psilotum nudum* (L.) Beav.	O O R R	First found 1987
Aizoceae	*Tetragonia tetragonioides* (Pallas) O.Kuntze*	C R O O	Last seen 1993
Amaranthaceae	*Aerva congesta* Balf.f. #	L L L L	
	Achyranthes aspera L. var. *aspera* L.*	O O O C	First found 1992
	Amaranthus viridis L.*	O O F L	First found 1986
Asclepediaceae	*Tylophora coriacea* Marais	C C C C	
Campanulaceae	*Lobelia serpens* Lam.	O O O O	Only seen in 1978
Caricaceae	*Carica papaya* L.*	R R R O	
Chenopodiaceae	*Chenopodium murale* L. *	C F F R	
Commelinaceae	*Commelina benghalensis* L.*	C C C C	
Compositae	*Ageratum conyzoides* L. *	C C C C	
	Bidens pilosa L. *	O O O O	First found 2000
	Chromolaena odorata (L.) King and Robinson*	O O O O	First found 2000
	Conyza canadensis (L.) Cronq. *	O O C C	First found 1986
	Crassocephalum rubens (Juss. ex Jacq.) S. Moore*	O O O O	Only seen 1990
	Eupatorium sp. *	O O O O	Only seen in1991
	Gamochaeta purpurea (L.) Cabrera * (formerly *Gnaphalium pensylvanicum* Willd.)	R R O O	Last seen 1982
	Sonchus asper (L.) Hill *	O O F F	First found 1984
	S. oleraceus L. *	F F R F	
	Tridax procumbens L. *	O O O F	First found 1991
Convolvulaceae	*Dichondra repens* J.R. and G.Forster #	F F F F	
	Ipomea pes-caprae (L.) R.Br.	C C C C	
Cyperaceae	*Cyperus rubicundus* Vahl.	L F F F	
	Fimbristylis cymosa R.Br.	L L L L	
Euphorbiaceae	*Euphorbia prostrata* Aiton *	? ? OO	Found 1978 and 1986
	E. thymifolia L.	F F F F	
	Phyllanthus amarus Schum. and Thonn *	O R F F	First found 1982
	P. mauritianus H.H. Johnston #	C C F R	
	P. revaughanii Coode #	O O R R	First found 1986
Gramineae	*Brachiaria* sp. (possibly *serpens* (Kunth) Hubbard)	C C R R	
	Cenchrus echinatus L. *	O O L C	First found 1987.
	Chloris barbata Swartz *	R F C C	
	C. filiformis (Vahl.) Poir.#	L L L L	
	Cymbopogon excavatus (Hochst.) Stapf *	R R R F	
	Cynodon sp (probably *dactylon* (L.) Pers.)*	R O O O	Last seen 1975
	Dactyloctenium ctenoides (Steud.) Lorch ex Bosser*	O O O F	First found in 1994/5
	Digitaria horizontalis Willd. var *porrantha* (Steud.) Henrard *	R R R F	
	Heteropogon contortus (L.) P.Beauv. ex Roem.& Schult. *	O O O R	First found 1994
	Lepturus repens (G. Forster) R. Br.	O O R R	First found 1989
	Sporobolus virginicus (L.) Kunth.	R R R R	
	Stenotaphrum micranthum (Desv.) C.E.Hubbard	R O R R	
	Vetiveria arguta (Steud.) Hubbard #	C C C C	

continued next page

Appendix 1. continued

Leguminosae (Mimosoideae)	*Desmanthus virgatus* (L.) Willd. *	O R L L	First found 1982
	Gagnebina pterocarpa (Lam.) Baillon #	O R R R	First found 1978
Leguminoseae (Papilionoideae)	*Desmodium incannum* DC. *	O O L F	First found 1987
Liliaceae	*Asparagus umbellulatus* Bresler #	O O R R	First found 1978
	Lomatophyllum tomentorii Marais #	L L L L	
Malvaceae	*Sida pusilla* Cav.	O O R R	First found 1986
	Abutilon indicum (L.) Sweet *	R F F C	
Nyctaginaceae	*Boerhavia coccinea* Mill.	F C C C	
	B. diffusa L. * (= *B. repens*)	R O F F	
Palmae	*Dictyosperma album* (Bory) H.Wendl. and Drude var *conjugatum* H.E.Moore and L.J.Guého#	R R R R	
	Hyophorbe lagenicaulis (Bailey) Moore #	R R R L	
	Latania loddigesii Mart. #	C C C C	
Pandanaceae	*Pandanus vandermeerschii* Balf.f. #	F F F F	
Passifloraceae	*Passiflora suberosa* L. *	C C C C	
Portulacaceae	*Portulaca oleracea* L.	C C F F	
Rubiaceae	*Fernelia buxifolia* Lam. #	O R R R	First found 1982
Solanaceae	*Nicotiana tabacum* L. *	C C C R	
	Physalis peruviana L. *	C F F F	
	Lycopersicon esculentum Mill. *	O L C R	First found 1982
	Solanum nigrum L. *	C F C C	
	Withania somnifera DC*	R F F F	

Number of species in each year of survey

	1975	1982	1989	1996	Total 1975-2000
Total	43	46	56	59	72
Native	24	26	33	33	35
Non-native *	19	20	23	26	37
Index of introduction (Usher 1988)	44.2	43.5	41.1	44.1	Overall = 51.4

Deliberately (re)introduced species (e.g. *Dracaena concinna, Argusia argentea*, *Scaevola taccada*, *Tarenna borbonica*) have not been included.