The morphology, distribution and conservation implications of introduced rats, *Rattus* spp. in the granitic Seychelles

M. J. Hill, T. Vel and N. J. Shah

Nature Seychelles, Victoria, Mahé, Republic of Seychelles

Abstract

There are no native land mammals in the Seychelles archipelago other than bats. Introduced rats have reduced the conservation value of most islands. This paper compares the results of rat-trapping carried out on eight islands in the granitic Seychelles, between July 1999 and April 2000. Trapping was carried out in both the dry and wet seasons. Three introduced rodent species were caught, including two species of rat (ship rat *Rattus rattus* Linnaeus and Norway rat *R. norvegicus* Berkenhout), but only one *Rattus* species occurred on each island. Both rat species were smaller than European or Asian conspecifics, and there were variations in the size and appearance of rats on different islands. Inter-island differences in size and pelage colour are discussed.

Key words: alien species, islands, rats, Seychelles

Résumé

Il n'y a pas d'autres mammifères terrestres natifs de l'Archipel des Seychelles que les chauves-souris. Des rats introduits ont réduit la valeur de conservation de la plupart des îles. Cet article compare les résultats des piégeages de rats réalisés sur huit îles des Seychelles granitiques, entre juillet 1999 et avril 2000. Les piégeages ont eu lieu en saison sèche et en saison des pluies. On a attrapé trois espèces de rongeurs introduits, dont deux espèces de rats (le rat des navires *Rattus rattus Linnaeus* et le rat de Norvège *R. norvegicus* Berkenhout), mais une seule espèce de rat s'est retrouvée dans les huit îles. Les deux espèces de rats étaient plus petites là que les rats de même espèce vivant en Europe et en Asie, et il y avait des variations de taille et d'apparence des rats sur les différentes îles. On discute les différences de taille et de couleur du pelage selon les îles.

Correspondence: M.J. Hill, Nature Seychelles, P.O. Box 1310, Victoria, Mahé, Republic of Seychelles.
E-mail: nature@seychelles.net

Introduction

The central Seychelles is a group of around 40 granitic (and two coralline) islands in the Western Indian Ocean (see Fig. 1). The islands are relatively small (only four exceed 1000 ha, all others are smaller than 300 ha each) and isolated and only support two native mammals, both of which are bats (Racey & Nicoll, 1984). A number of introduced mammal species have become established, including three species of rodent: ship rat (or black or roof rat) *Rattus rattus;* Norway rat (or brown rat) *R. norvegicus;* and house mouse *Mus musculus* Linnaeus. *Rattus norvegicus* is not mentioned by Racey & Nicoll (1984), and today a relatively restricted distribution within the granitic islands suggests that it may be a recent introduction. *Rattus rattus* is more widespread, and in the past was considered an important pest of coconut plantations, climbing palms to feed on flowers and nuts. Its wide distribution and pest status made it the target of unsuccessful biological control measures when barn owls *Tyto alba* (Scopolia) were introduced from east Africa in 1949–52 (Blackman, 1965). In the Seychelles, as on other oceanic islands, introduced rats have important conservation implications: they have long been thought to contribute to the local extinction of endemic birds (Newton, 1867; Diamond, 1984), although domestic cats (*Felis catus* Linnaeus) may also be a significant predator. It is difficult to separate the effects of rats and cats because (on most islands) both are present – cats were often introduced in an attempt to control rats.

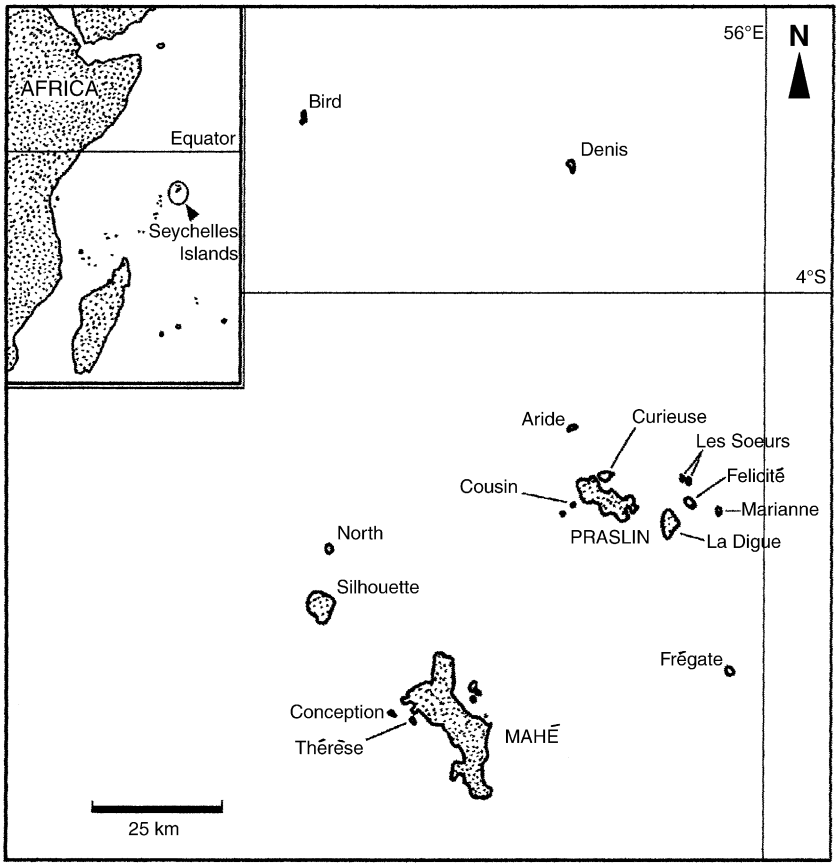

Fig 1 Location of the central (granitic) Seychelles Islands.

Methods

Techniques used were similar to standardized 'index trapping' techniques developed by the Ecology Division, Department of Scientific and Industrial Research, New Zealand (D. Merton in litt., Cunningham & Moors, 1996). The traps used were locally available cage traps, baited with roasted coconut. Snap-traps were not used to minimize the danger of trapping native animals.

On each of eight islands (see Fig. 1), traps were laid out in two trap-lines. Each trap-line was restricted to a single habitat type and trap-lines were placed to reflect broad ecological variation on the island: thus, on most granitic islands, one trap-line was placed on the coastal plateau, one on the granite hill. For islands without a significant area of plateau habitat (Conception, Marianne, Félicité), both trap-lines were situated on the hill. Open habitats and sites close to inhabited buildings were avoided (to reduce bias in trapping rates) all trap-lines were situated in scrub, woodland or intermediate habitats. Trap-lines normally followed existing paths, for ease of servicing, but traps were laid off the path itself.

Each trap-line was made up of fourteen traps, in seven pairs. Within each pair, traps were placed 1 m apart. Traps were not laid on open pathways but no special effort was made to locate traps on rodent runs. Pairs of traps were spaced at a distance of 30 m, so that each complete trap-line measured 180 m.

Traps were baited and opened at around 17.00 hours each evening, Every morning at 07.00–08.00 hours, traps were checked and each trap recorded as:

1 open, bait present;
2 open, bait gnawed or removed;
3 closed, bait present;
4 closed, bait gnawed or removed;
5 closed with rat, or closed with crab or other animal.

Traps containing rats were removed and the rats killed by drowning. Other animals caught unintentionally were

released alive. Wherever bait had been removed, it was replaced and all traps were replaced at their original positions on the trap-line with doors closed. Traps were opened again at 17.00 hours (to reduce by-catch during the day).

Each rat caught was identified to species and gender. Animals were classified as adult or juvenile, according to a combination of body size and the prominence of sexual characteristics (nipples, testes). Biometric and breeding data were gathered. Measurements of head and body length (HB), tail length (*T*) and hind foot excluding claws (HF) were made using a metal rule and calipers. For all rats, belly colour was recorded. Adult female rats were tested for lactation (by applying pressure to the nipples). All measurements were made by the author. Further details of trapping methods used are given in Hill (1999).

Where possible, rat trap-lines were maintained for five consecutive nights, giving 140 trap-nights per island (70 per habitat type) in each of ten assessments. For four assessments, 112 trap-nights were carried out. Trapping was carried out between July 1999 and April 2000.

For each trapping period, data were expressed as numbers of rats per 100 trap-nights. In addition, an index was calculated correcting for the number of traps closed for, at least part of the night (D. Merton, in litt., Cunningham & Moors, 1996). For each night, the corrected number of trap-nights was arrived at by adding all the traps that were closed in the morning (categories 3–6 above). This figure was halved (assuming that, on average, these traps had been shut for half the night) to give the total number of trap-nights lost. The corrected number of trap-nights was calculated as total trap-nights minus trap-nights lost. Thus, the corrected index of abundance = captures × (100/corrected trap-nights).

On five islands, trapping was carried out twice to investigate seasonal variation in abundance. The two distinct seasons of Seychelles are the dry season dominated by South–East trade winds (around June–September, but with variation between islands and seasons) and the wetter North–West monsoon (around December–March: Walsh, 1984). Fieldwork occurred in July–September 1999 (called SE in this paper) and January–March 2000 (NW). Where trapping was carried out twice on the same island, trap-lines were placed in the same locations in each season. Data were analysed using the statistical package MINITAB.

Results

Overall, 1846 trap-nights were carried out, in a range of habitats (see Table 1). Three different rodent species were caught. Non-target species caught included the crabs *Coenobita* spp. (on most islands) and *Cardisoma carnifex* (Herbst) (on Curieuse) *and F. catus* (on North and Félicité).

By far, the most widespread rodent trapped was the ship rat (total of 476 rats were caught). The house mouse (six caught) and the Norway rat (123 caught) were each trapped on one island (although the house mouse was observed on a second island, Bird Island). Table 2 shows the distribution of species by island and the index of

Table 1 Trap-nights carried out per island

Island	Habitat	SE	NW
Conception	Hill Woodland	140	112
Curieuse	Plateau Woodland	70	56
Curieuse	Hill Scrub	70	56
Denis	Plateau Woodland	140	139
Félicité	Plateau Scrub	56	–
Félicité	Hill Glacis	56	–
Grande Soeur	Plateau Coconut	140	–
Marianne	Hill Woodland	140	112
North	Plateau Coconut	70	70
North	Hill Woodland	70	70
Thérèse	Plateau Scrub	69	70
Thérèse	Hill Woodland	70	70
	Total	1091	755

Table 2 Rodent distribution, and index of abundance for rats on islands assessed

Island	*Mus* present	*Rattus* species present	Corrected index of abundance	
			SE	NW
Bird	†	–	ns	ns
Conception		*R. norvegicus*	88.65	59.76
Curieuse	‡	*R. rattus*	30.14	20.57
Denis	†	*R. rattus*	64.94	34.46
Félicité		*R. rattus*	33.33	ns
Grande Soeur		*R. rattus*	99.45	ns
Marianne		*R. rattus*	25.20	19.80
North		*R. rattus*	33.77	3.82
Thérèse		*R. rattus*	17.47	63.22

†*Mus* present; ‡*Mus* reported; ns: not surveyed in season.

Species	Sex	*n*	Mean HB (mm)	SEM	*n* (*T*)	mean *T* (mm)	SEM
R. norvegicus	M	60	186.10	1.71	107	171.92	1.40
	F	51	178.63	1.59			
R. rattus	M	199	167.16	0.99	330	201.95	1.10
	F	171	158.02	1.06			

Table 3 Biometrics of adult rats from Seychelles Islands

Sample size differs for HB and *T* measurements as tails occasionally damaged by traps.

abundance for the *Rattus* species on each island. No index is given for house mice on Denis, as very few individuals were caught (six individuals in total, over both trapping periods).

While indices of abundance varied greatly between islands and sample periods, all but one island (Thérèse) showed a higher index in the July–September period (SE) than in the period January–March (NW). On average, the corrected index of abundance by island in the SE was 253.7% of that in the NW. However, due to the small number of replicates, the difference was not statistically significant ($T = 6$, $P > 0.1$, Wilcoxon's test for matched pairs).

Although more males than females were caught, this sex bias was not statistically significant. For the ship rat, the ratio male:female was 1.16 (with Yate's correction for continuity, $\chi^2_1 = 2.33$, not significant). For Norway rat, the ratio was closer to parity (1.05) (with Yate's correction for continuity, $\chi^2_1 = 0.03$, not significant).

Nine lactating females were trapped: in October 1999 (five individuals, 15.6% of adult females trapped); November 1999 (two individuals, 16.7% of adult females trapped); and in February and April 2000 (one individual each). Juveniles were trapped in every month (of the 9 months in which trapping occurred), usually forming between 13.4 and 21.0% of individuals trapped. In November, however, the proportion of juveniles was considerably higher (42% of rats caught).

The two rat species showed significant differences in size, measured as head + body HB ($z = 13.66$, $P = 0.0000$) and tail *T* ($z = -16.91$, $P = 0.0000$). *Rattus norvegicus* have a greater mean HB, while mean *T* is greater in *R. rattus* (see Table 3). Within each species, there were differences in measurements of HB by sex (for *R. norvegicus*, $z = -3.20$, $P = 0.0018$; for *R. rattus*, $z = -6.31$, $P = 0.0000$), but measurements of *T* showed no significant difference by gender (for *R. norvegicus*, $z = -1.22$, $P = 0.22$; for *R. rattus*, $z = -0.76$, $P = 0.45$).

For *R. rattus*, populations on different islands differ in mean HB ($F_{6,246} = 17.16$, $P = 0.000$ one-way ANOVA). Because of the small number of islands involved, it is impossible to control for effects of colour phases on different islands (white-bellied rats seem to be larger than grey-bellied: see below). However, if only one colour phase is considered (grey belly) there is still a significant difference in the mean HB of *R. rattus* from different islands ($F_{6,246} = 7.01$, $P = 0.000$ one-way ANOVA). Pairwise comparison (Tukey test) reveal significant differences in 6 of 21 cases (see Fig. 2). The most distinct populations are those of Curieuse and North Island.

Rattus rattus was found in three different colour morphs with the grey-bellied form being by far the most widely distributed. On four of seven islands, only grey-bellied individuals were found. On the other three, all three forms were found. White and white + grey were never found in the absence of grey individuals, and wherever

Island	Mean HB	Curieuse	Denis	Félicité	Gd Soeur	Marianne	North
Curieuse	152.98						
Denis	161.62	**					
Félicité	154.80						
Gd Soeur	157.77						
Marianne	157.95						
North	175.25	**			*	**	
Thérèse	165.78	**				*	

Significance level:** = p < 0.01, * = p < 0.05

Fig 2 Grey-bellied *R. rattus*: mean HB for different island populations and significant differences.

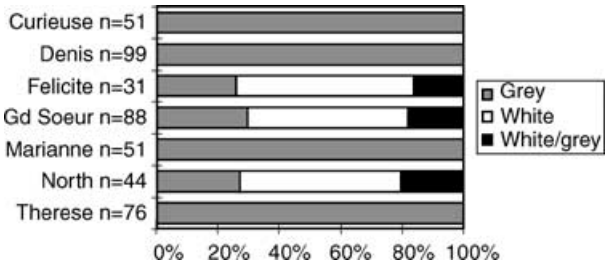

Fig 3 Proportion of total rats of different colour morphs, by island data for SE and NW combined.

the three morphs coexisted, the proportions of each morph in the overall rats captured was similar (see Fig. 3).

There was a significant difference in the mean size (HB) of adult rats by colour although in part this may have been an island effect (see above). The white and grey-bellied morphs were distinctly different in size, while the white + grey morph showed intermediate mean size and greater variance in HB length (see Table 4). The size of colour morphs is not constant across islands. However, in two of three islands where white-belly and grey forms coexist, the white form is larger.

Rats of both species trapped in the granitic Seychelles were smaller than those caught in Thailand (Lekagul & McNeely, 1971) and in the U.K. (Racey & Nicoll, 1984) (see Table 5).

Table 4 Size of adult rats (*R. rattus*) of three different colour morphs

Belly colour	*n*	Mean HB (mm)	SEM
Grey†	253	160.32	0.84
White†	62	166.45	1.81
White + grey	27	163.59	3.65

†Significantly different mean: $F_{2,339} = 5.06$, $P = 0.007$.

Discussion

Species distribution

Mice and rats coexist in semi-natural habitats on at least one of the islands surveyed (Denis), and mice are, probably more widespread in purely anthropogenic habitats (they were reported to be present on Curieuse, and are found on many other islands in the granitic Seychelles). However, none of the islands visited had more than one species of rat. It appears that the only islands of the granitic Seychelles on which both *Rattus* species currently coexist are Mahé and Praslin, the largest islands of the archipelago (Meyer, 1994, 1996), and the 21-ha Long Island, close to Port Victoria (Rocamora & Francois, 2000). This may be because of the rarity of colonization events, the relatively recent colonization of Seychelles by *R. norvegicus,* or as a result of competitive exclusion by the first-established species.

Rattus rattus is undoubtedly an early introduction to the Seychelles, but *R. norvegicus* was introduced more recently, probably in the late twentieth century. It was not recorded in the 1980s (Racey & Nicoll, 1984). However, in 1994, *R. norvegicus* was well established on Mahé. In a trapping survey, in over 300 buildings, it was the most commonly recorded rodent (Meyer, 1994). It was also present on Praslin by 1994, becoming widespread by 1996 (Meyer, 1994, 1996). In 1995, *R. norvegicus* colonized Frégate Island (210 ha), the largest rat-free island in the archipelago at that time (Thorsen *et al.*, 2000). It is possible that first invasion of Seychelles by *R. norvegicus* occurred between 1980 and 1994. However, as *R. norvegicus* is not arboreal and does not cause damage to coconut crops to the same extent as the ship rat, its presence at an earlier date may have been overlooked. Colonization of the three

Table 5 Mean biometric data on rats in Seychelles, Thailand and the U.K.

	Seychelles	Thailand	U.K.
R. rattus			
HB	162.9 ($n = 370$*)	182 ($n = 44$)	192 ± 25
T	202.0 ($n = 330$†)	188 ($n = 44$)	213 ± 21
Tail/total length percentage	55.3	50.8	52.2 ± 3.6
R. norvegicus			
HB	182.7 ($n = 111$)	233 ($n = 15$)	
T	171.9 ($n = 107$)	201 ($n = 15$)	
Tail/total length percentage	48.5	46.3	

*Includes individuals for which no pelage details were recorded.
†Differs from *n*(HB) as rats with damaged tails excluded.

major populated islands (Mahé, Praslin and La Digue) seems inevitable, since cargo-carrying schooners travel between harbours on these islands every day. However, transfer of rats to smaller islands is a less frequent event. Many of the smaller islands have no harbour, and have infrequent boat traffic.

While competitive exclusion cannot be demonstrated, in experimental communities of many species, including anurans (Alford & Wilbur, 1985) and *Drosophila* (Gilpin, 1987), the order in which species are added to a community greatly influences the outcome of interspecific competition and the subsequent composition of the community.

Index of abundance

It is difficult to test whether the values derived for index of abundance reflect differing abundance on the islands visited, and to what extent local variations (such as time of fruiting of fruit trees, which could offer an alternative food supply) might be responsible. Given that the two sampling periods are only about 6 months apart, it might be expected that populations in sampling period two should correlate with those in the first period. In fact, the level of correlation between index values for each season is low ($r^2 = 0.123$).

For a more accurate reflection of rodent population on an island, a larger number of trap-nights should be carried out in all habitats. Future studies involving quantitative survey techniques should be aware of the great seasonal variations in capture rates. However, for most of the endangered endemic species, presence/absence of rodent predators is, probably of greater importance than population density.

Seasonality

Juveniles were recorded throughout the trapping period, suggesting that breeding can occur year-round. However, a peak of lactating females in October and November, and of juveniles in November, suggest that there is at least one seasonal peak in breeding activity at the end of the dry season and beginning of the North–West monsoon.

Colour forms

The species *R. rattus* has been divided into a number of different subspecies, including the white-bellied subspecies *frugivorous* and the grey-bellied *alexandrinus* (Schwarz & Schwarz, 1965). Some subspecies of ship rat are polychromatic, including the nominate *R. r. rattus* in Europe, which can show a variety of different pelage colours (Lekagul & McNeely, 1971).

It is unclear whether the colour forms collected in the granitic Seychelles match previously described subspecies, although other authors have identified both *frugivorous* and *alexandrinus* from Aldabra (collections by Whitelaw, in Racey & Nicoll, 1984). White and grey-bellied forms can obviously coexist on the same island, perhaps with some stability (where all three forms occur, they do so at a similar ratio of the total population). Biometric data suggest that the white + grey-bellied form (usually, predominantly white with a grey pectoral streak) could be a hybrid between the two plain-coloured types, as it is intermediate in size but with a broad variance.

In Pacific Island populations, examples of the grey- and white-bellied forms have been shown to interbreed (Johnson, 1962), suggesting that subspecific divisions are invalid (Atkinson, 1985).

Conservation implications

Patterns of colour morphs and biometric data for *R. rattus* suggest that for some of the islands at least, colonization by rats is a rare event. For example, all the islands with three colour morphs show approximately the same proportion of each form, implying that there is a genetic basis to this trait and that the populations are at equilibrium. The inter-island difference in size of rats, not explained by the distribution of colour morphs, suggests that at least some of the island populations developed from small founding populations and that little re-invasion occurred. This could be for one of two reasons: (i) because few adult rats are transferred between islands, especially on small islands and since the abandonment of coconut plantations (and the regular interchange of large cargoes in which rats could be transferred); or (ii) established rat populations are resistant to new invaders. In this case, the islands where rats have been eradicated, invasion may become easier, and establishment a more frequent event.

Spennemann (1997), working on Pacific islands, also suggested that colonization by rats was a rare event and could only occur under very specific conditions, particularly, where boats were moored at piers. Other modes of

colonization, from small canoes, swimming and rafting between islands, and even shipwrecks, were rarely responsible for the introduction of rats. The construction of moorings and harbours on islands greatly increases the threat of rat invasion (or re-invasion). Two recent recorded invasions of previously rat-free islands in the granitic Seychelles were both associated with hotel construction work. In 1967, *R. rattus* colonized Bird Island in a consignment of roofing thatch: this population was eradicated in 1995 (Feare, 1999). *Rattus norvegicus* invaded Frégate Island during resort construction in 1995 (Lucking, 1997) before eradication in 2000 (Millet, Parr & Shah, 2000).

Rats have long been an important pest of coconut plantations, and have more recently been regarded as an important threat to the conservation value of island biota (Merton, 1975, 1978; Bell, 1978; Atkinson, 1985). Various efforts have been made to control their numbers. In the earlier part of the twentieth century, the agricultural department of the colonial government of Seychelles distributed poison baits (including phosphorous paste, zinc phosphide, arsenious oxide and barium carbonate) to land owners. In 1947, a rat extermination campaign initiated by the colony's department of agriculture resulted in the killing of 120,000 rats (Department of Agriculture, 1947), but no local eradications were reported. More recently, with the advent of anticoagulant baits, it has proved possible to completely eradicate rats on individual islands (first on Bird Island in 1995, Feare, 1999). On islands which have supported rats for many years and have reduced conservation value, few susceptible endemic species usually occur, but eradications on islands with high-biodiversity value are more problematic, requiring great effort to protect endemic vertebrates (Millet *et al.*, 2000; Thorsen *et al.*, 2000:). In mid-2000, eradication attempts were carried out on Denis, Curieuse and Frégate islands (Millet *et al.*, 2000); only one of these attempted eradications was actually confirmed as successful 12 months after the last bait drop. While *R. norvegicus* was eliminated on Frégate Island, *R. rattus* was present on the other two islands in mid-2001 (Hill, 2002). Whether rats had survived the attempted eradication or re-invasions had occurred is unknown as regular monitoring was not carried out on these islands, so the frequency of invasion events remains unknown. While it seems likely that invasions have historically been a rather rare event, data on the current rate of invasions would be useful in planning measures to maintain islands in a post-eradication rat-free state.

Acknowledgements

This work was carried out as part of the BirdLife Seychelles Avian Ecosystems project, funded by the GEF/World Bank. The authors would like to thank Don Merton of New Zealand Department of Conservation for advice on rat-trapping methods and comments on an early draft of this paper. Thanks are due to all island owners and managers who allowed work on their islands and provided practical support, and members of staff of Ministry of Environment, Government of Seychelles, for assistance in the field. Kerstin Henri and Steve Parr of BirdLife Seychelles provided essential backup for the project. Clive Hambler (Oxford University) and David Hall (Mauritian Wildlife Foundation) provided constructive advice on first drafts of this paper.

References

Alford, R.A. & Wilbur, H.M. (1985) Priority effects in experimental pond communities: competition between *Bufo* and *Rana*. *Ecology* **66**, 1097–1105.

Atkinson, I.A.E. (1985) The spread of commensal species of *Rattus* to oceanic islands and their effects on island avifaunas. In: *Conservation of Island Birds* (P. J. Moors, Ed.). International Council for Bird Preservation, Cambridge, UK.

Bell, B.D. (1978) The Big South Cape Islands rat irruption. In: *The Ecology and Control of Rodents in New Zealand Nature Reserves* (P. R. Dingwell, I. A. E. Atkinson and C. Hay, Eds). New Zealand Department of Lands and Survey Information Series no. 4.

Blackman, R. (1965) Bristol University Seychelles Expedition. Part 7. Biological control. *Animals* **8** (3).

Cunningham, D.A. & Moors, P.J. (1996) *A Guide to the Identification and Collection of New Zealand Rodents*, 3rd edn. Department of Conservation, Wellington, New Zealand.

Department of Agriculture (1947) *Colony of Seychelles*. Annual Report of the Department of Agriculture for the Year 1947. Government Printers, Victoria, Mahé, Seychelles.

Diamond, A.W. (1984) Biogeography of Seychelles land birds. In: *Biogeography and Ecology of the Seychelles Islands* (D. R. Stoddart, Ed.). Dr W. Junk Publishers, The Hague, pp. 487–504.

Feare, C. (1999) Ants take over from rats on Bird Island, Seychelles. *Bird Conservation Int.* **9**, 95–96.

Gilpin, M.E. (1987) Experimental community assembly: competition, community structure and the order of species introductions. In: *Restoration Ecology: a Synthetic Approach to Ecological Research* (W. R. Jordan, M. E. Gilpin and J. D. Aber, Eds). Cambridge University Press, Cambridge, UK.

Hill, M.J. (1999) *Island Assessment Methodology.* BirdLife Seychelles GEF Project Island Assessment Report no. 1 (Unpublished Report), BirdLife Seychelles, Mahé.

Hill, M.J., ed. (2002) Biodiversity surveys and conservation potential of inner Seychelles Islands. *Atoll Res. Bull.* (in press).

Johnson, D.H. (1962) Rodents and other Micronesian mammals collected. In: *Pacific Island Rat Ecology* (T. I. Storer, Ed.). *Bernice P. Bishop Mus. Bull.* 225, 21–38.

Lekagul, B. & McNeely, J.A. (1971) *Mammals of Thailand.* Saha Karn Bhaet Co., Bangkok.

Lucking, R. (1997) *Seychelles Magpie-Robin Recovery Programme.* Analysis Report January, 1996-September, 1997 (Unpublished Report), BirdLife Seychelles, Mahé.

Merton, D.V. (1975) The saddleback: its status and conservation. In: *Breeding Endangered Species in Captivity* (R. D. Martin, Ed.). Academic Press, London.

Merton, D.V. (1978) Controlling introduced predators and competitors on islands. In: *Endangered Birds: Management Techniques for Preserving Threatened Species* (S. A. Temple, Ed.). The University of Wisconsin press, Madison, Wisconsin, USA

Meyer, A.N. (1994) *Control of rats, rodent-borne disease and rat damage in Seychelles.* Unpublished Report. World Health Organisation–UNDP.

Meyer, A.N. (1996) *Control of rats, rodent-borne disease and rat damage in Seychelles.* Unpublished Report. World Health Organisation–UNDP.

Millet, J., Parr, S.J. & Shah, N.J. (2000) *Seychelles Magpie-Robin Recovery Plan.* Quarterly Report no. 39 & 40 (Unpublished Report), BirdLife Seychelles, Mahé.

Newton, E. (1867) The land-birds of the Seychelles archipelago. *Ibis* **3**, 335–360.

Racey, P.A. & Nicoll, M.E. (1984) Mammals of Seychelles. In: *Biogeography and Ecology of the Seychelles Islands* (D. R. Stoddart, Ed.). Dr W. Junk Publishers, The Hague.

Rocamora, G. & Francois, J. (2000) *Seychelles White-Eye Recovery Programme. Results from Phase 1.* Report to Ministry of Environment and Transport/IUCN/Dutch Trust Fund. Seychelles.

Schwarz, E. & Schwarz, H.K. (1965) A monograph on the *Rattus rattus* group. *Ann. la Escuela Nacional Ciencias Biol. Mexico* **14**, 79–178.

Spennemann, D.H.R. (1997) Distribution of rat species (*Rattus*. spp.) on the atolls of the Marshall Islands: past and present dispersal. *Atoll Res. Bull.* p. 446.

Thorsen, M., Shorten, R., Lucking, R. & Lucking, V. (2000) Norway rats (*Rattus norvegicus*) on Frégate Island, Seychelles: the invasion, subsequent eradication attempts and implications for the island's fauna. *Biol. Conservation* **96**, 133–138.

Walsh, R.P.D. (1984) Climate of the Seychelles. In: *Biogeography and Ecology of the Seychelles Islands* (D. R. Stoddart, Ed.). Dr W. Junk Publishers, The Hague.

(Manuscript accepted 14 August 2002)