ELSEVIER

PII: S0006-3207(97)00086-4

Biological Conservation 84 (1998) 83–88

0006-3207/98 $19.00+0.00

DEMOGRAPHY OF TWO LANDSNAIL POPULATIONS (*Placostylus ambagiosus*, PULMONATA: BULIMULIDAE) IN RELATION TO PREDATOR CONTROL IN THE FAR NORTH OF NEW ZEALAND

G. H. Sherley,[a]* I. A. N. Stringer,[b] G. R. Parrish[c] & I. Flux[d]

[a]*Science and Research Division, Department of Conservation, PO Box 10420, Wellington, New Zealand*
[b]*Department of Ecology, Massey University, Private Bag 11222, Palmerston North, New Zealand*
[c]*Whangarei Conservancy Office, Department of Conservation, PO Box 842, Whangarei, New Zealand*
[d]*Science and Research Division, Department of Conservation, PO Box 10420, Wellington, New Zealand*

(Received 15 November 1996; accepted 5 March 1997)

Abstract

Two Placostylus ambagiosus *populations were studied in New Zealand for 8 years to determine if poisoning rodent predators in the habitat of one population resulted in increased adult snail recruitment. 'Pulse' poisoning four times a year commenced a year after the study started in a population of* Placostylus ambagiosus paraspiritus. *A significant increase in the proportions of all juvenile snails with shells larger than 10 mm long was observed. The only other comparable population of this highly endangered snail species,* P. a. michiei, *was 33·7 km to the east. Here, predation mostly by birds had a similar effect on reducing adult snail recruitment as rodents did on* P. a. paraspiritus. *No predator control was done at the site occupied by* P. a. michiei, *and adult snail recruitment remained low throughout the study. This suggests that long-term pulse poisoning of rodents in remnant 'islands' of native habitat on the New Zealand mainland can be beneficial to the recovery of a landsnail population.*

Keywords: Placostylus ambagiosus, Gastropoda, Pulmonata, adult recruitment, rodent control.

INTRODUCTION

Placostylus ambagiosus Suter (Pulmonata: Bulimulidae) is endemic to the northernmost tip of New Zealand (Fig. 1). The shells of adult snails reach lengths of 60–95 mm (Powell, 1979). *P. ambagiosus* lives in litter under mainly coastal shrubs and forest, although the smallest juveniles are sometimes arboreal (Sherley and Parrish, 1989). Larger juveniles and adults feed exclusively on fallen leaves and gain some protection from desiccation by pushing the front of their shell shallowly into soil to cover the aperture (Powell, 1979; Penniket, 1981; Parrish *et al.*, 1995).

Shells vary in shape, size and colour between sites, and these differences have led to 17 subspecies being described by Powell (1938, 1947, 1951, 1979). The distributions and some genetic differences were described for eight of the 10 extant subspecies by Triggs and Sherley (1993) and the shell morphology of 7 of these were compared by Sherley (1996). Eight subspecies are acutely endangered and are listed as category A (highest priority for conservation action) by Molloy *et al.* (1994). Of the other two subspecies, we estimate that there are perhaps 2000 adult *P. a . paraspiritus* Powell and *P. a. michiei* Powell, but each of these is restricted to an area of < 10 ha. Both are listed as category B (second priority for conservation action) by Molloy *et al.* (1994).

P. ambagiosus has become threatened through habitat destruction and modification by farming and burning; and by predation by introduced pigs, rodents (*Rattus* sp., *Mus musculus* L.) and birds. Apart from fire control, *P. ambagiosus* is protected by fencing out feral pigs and domestic stock from four sites, by concentrating pig control in high-risk areas, by poisoning rodents using bait stations at nine sites, and by translocating three subspecies. In addition, *Rattus exulans* Peale was eradicated from Motuopao Island to protect *P. a. ambagiosus* there (Parrish *et al.*, 1995). Prior to our study, rodents were 'pulse' poisoned (Moors *et al.*, 1992) sporadically since the early 1980s at the site at which *P. a. paraspiritus* occurs (Parrish *et al.*, 1995).

It is not practicable to eradicate rodents or exclude them from mainland sites, so in the future, habitat for the mainland populations of *P. ambagiosus* will probably receive 'pulse' poisoning (Moors *et al.*, 1992) as suggested in the recovery plan (Parrish *et al.*, 1995). However, there are at least two questions which arise from 'pulse' poisoning: (1) Will rodents develop resistance to prolonged use of an anticoagulant poison? (2)

*To whom correspondence should be addressed.

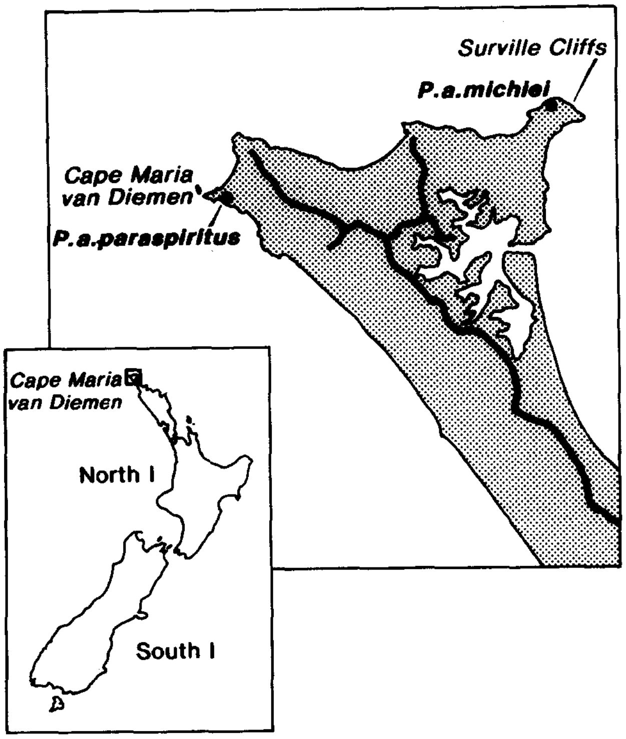

Fig. 1. Location of *Placostylus ambagiosus* in New Zealand and study sites.

How effective is the particular poisoning regime in reversing the effects of rodent predation on snails? Implicit in the latter are further questions such as what are the effects of rodent predation on *P. ambagiosus* and what is the minimum amount of poisoning that will allow adequate recruitment of adult snails. Given the high conservation status of *P. ambagiosus* (Molloy *et al.*, 1994), the most robust method of determining whether rodent poisoning improves adult recruitment is to compare populations where rodents are poisoned with ones that are not poisoned, but which suffer similar predation pressure. The results of such studies are important when considering whether endangered species can be managed by reducing the impacts of predators, or whether they should be translocated to predator-free islands where they probably never occurred previously.

In this paper we compare the demography of the two largest populations of *P. ambagiosus* over 8 years. These are the only populations known that are large enough to risk intensively studying a part of each without compromising their well being. We also attempt to measure what effect 'pulse' poisoning of rodents has on the population of *P. a. paraspiritus* at Cape Maria van Diemen (Fig. 1). However, the area of that site was so small that bait stations could affect rodents over the entire area (*c.* 2 ha). The site was, therefore, too small to be divided into adequate treatment and control plots. Fencing out rodents from a treatment plot was also impracticable because this was a sand dune site and fencing would have caused too much habitat destruction. We therefore compared this population with the population of *P. a. michiei* at Surville Cliffs (Fig. 1, *c.* 7 ha) where no predator control was carried out. These populations are widely separated but occupy comparable coastal locations that are prone to drought. *P. a. paraspiritus* depends on small clumps of *Macropiper excelsum* (Forst. F. Miq.), *Coprosma repens* (Hook. f.), *Geniostoma rupestre* (A. Rich.) and *Melicope ternata* (J. R. et G. Forst.) for food, while *P. a. michiei* is associated almost exclusively with small isolated bushes of *G. rupestre*.

Rodents are apparently rare at the *P. a. michiei* site, where the snails are predominantly eaten by birds, although we are uncertain which passerine is responsible. Their effects on that snail population are apparently similar to those of rodent predation on *P. a. paraspiritus* (see below), justifying use of the *P. a. michiei* population as a crude control for monitoring the effects of 'pulse' poisoning of rodents on the population of *P. a. paraspiritus*. The introduced landsnail *Helix aspersa* (Müller) occurs with *P. a. paraspiritus* but not with *P. a. michiei*. *H. aspersa* is also preyed upon by rodents (see below) so changes in their population were also noted as a further check on the effects of rodent control measures.

METHODS

Twelve 2 m×2 m permanent quadrats were established at both Cape Maria van Diemen and Surville Cliffs. Initially, plants eaten by *Placostylus* were located, then 12 were chosen for the quadrats so that these were spread throughout the accessible area. Quadrats were searched during October in most years from 1988 to 1995. We tried to minimize damage to the habitat within quadrats by reaching in from outside while searching them. However, we did effect some changes, such as when we untangled thickets of grasses or other plants, and when we searched through the leaf-litter. The following data were recorded from every snail found in a quadrat: maximum length of shell, age (juvenile, subadult or adult), live or dead (whole undamaged empty and predator-damaged shells), and the predator concerned where appropriate. Adult *P. ambagiosus* were recognised by their thickened varix (Penniket, 1981) which was apparently hard enough to prevent rodent predation. In a subadult, the lip of the shell splays outward before the varix develops. We assumed that most whole empty shells resulted from natural causes such as disease or desiccation, or from the actions of invertebrate predators such as *Rhytida duplicata* (Powell) (Gastropoda: Paryphantidae) which is present at the Cape Maria van Diemen site. Damaged empty shells were scored as preyed upon by rodents or birds as defined below. All live *Placostylus* were returned to their quadrats. Empty shells were discarded well outside the quadrats so they were not included in subsequent samples. Data recorded for *H. aspersa* collected from the same quadrats were the numbers of live snails, whole empty shells and damaged empty shells. All *H. aspersa* shells were also discarded well away from the quadrats.

Most *P. a. michiei* shells preyed upon by birds were found next to prominent rocks outside the quadrats. These shells typically lacked the tops of their spires. Their maximum lengths were estimated by comparing them with outlines of similarly sized intact shells.

'Pulse' poisoning (Moors *et al.*, 1992) was carried out at Cape Maria van Diemen, starting in 1989. This involved restocking bait stations four times a year in late winter, spring, summer and autumn. Initially we used 20 bait stations and then reduced the number to 10 in October 1990. These bait stations were spaced approximately evenly along a track through the middle of the site and at least 10 m from the nearest quadrat. Each bait station consisted of a length of plastic drainage tubing (50 cm long × 11 cm in diameter) (Moors *et al.*, 1989) secured to the ground with wire pegs. Each was stocked with six 'Ridrat Supa' Rentokil baits (bromodiolone 5 ppm) made from green dyed wheat kernels in a matrix of wax.

RESULTS

Mortality of *Placostylus*

Damaged empty shells clearly resulted from rodent or bird predation. Rodents typically removed a broad spiral band of shell from one or more whorls starting from the aperture lip (Fig. 2). The edges of this damage were irregular, suggesting that the shell is broken or bitten off piece by piece. Tooth marks were often evident on these damaged edges. In contrast, the apex of most bird-damaged shells was broken off (Fig. 2), and the remains were scattered about those rocks that served as anvils. No damaged adult shells were found.

Empty shells were first collected from the *P. a. paraspiritus* site at Cape Maria van Diemen and from the *P. a. michiei* site at Surville Cliffs in 1988. They represent the accumulated mortality over an unknown number of years. The high proportions of mid-sized predator damaged and low proportions of undamaged juvenile shells of both *P. a. paraspiritus* and *P. a. michiei* indicated that rodents and birds similarly preyed on these size categories of snails (Figs 3 and 4).

In 1988 73% of the empty *P. a. paraspiritus* shells collected from the quadrats were damaged by rodents, whereas no bird-damaged shells were found in the quadrats with *P. a. michiei*. Seven anvil rocks near the latter quadrats had the remains of 72 bird-damaged shells around them (range 4–14 shells per anvil rock).

More predator-damaged shells of *P. a. paraspiritus* and *H. aspersa* were found in 1988 than whole empty shells, but this reversed between 1990 and 1995 (Fig. 5) following the commencement of rodent poisoning at the *P. a. paraspiritus* population. No comparison was made

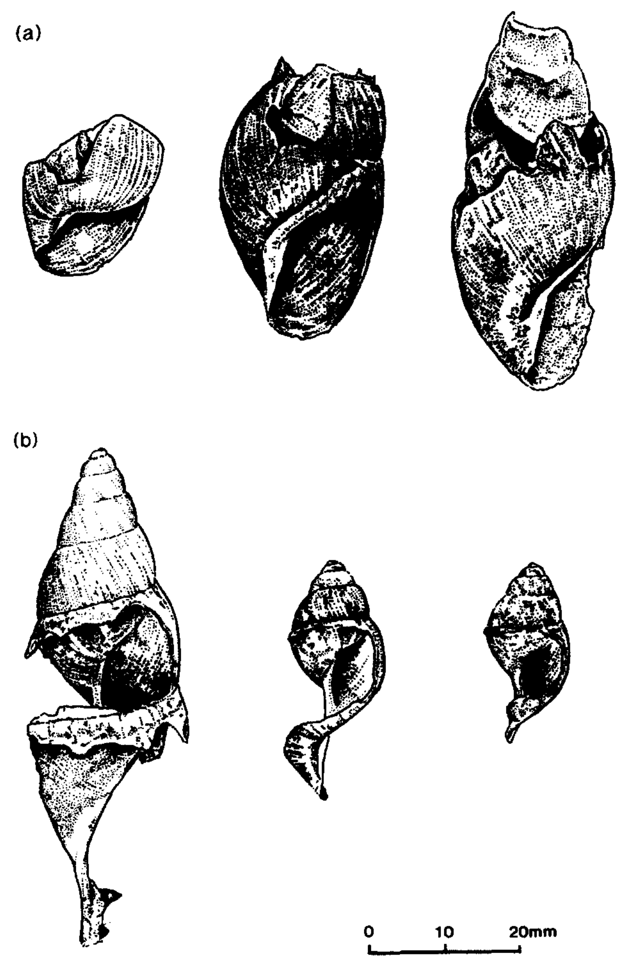

Fig. 2. Examples of rodent- and bird-damaged *Placostylus* shells. (a) Bird-damaged *P. a. michiei*; (b) rodent-damaged *P. a. paraspiritus*.

with *P. a. michiei* because the snails were taken from the quadrats and left empty and damaged beside prominent rocks. The origin of these shells was impossible to determine.

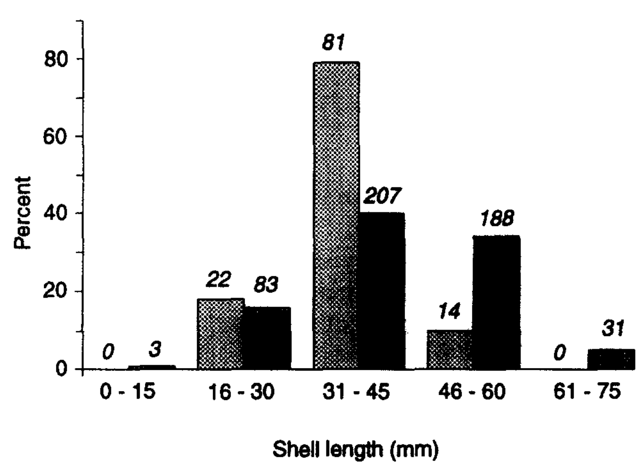

Fig. 3. Lengths of predator damaged shells of *P. a. michiei* (▒) and *P. a. paraspiritus* (■) collected in 1988. Lengths of *P. a. michiei* shells were estimated by comparing them with an intact shell. Numbers of shells are shown for each size interval.

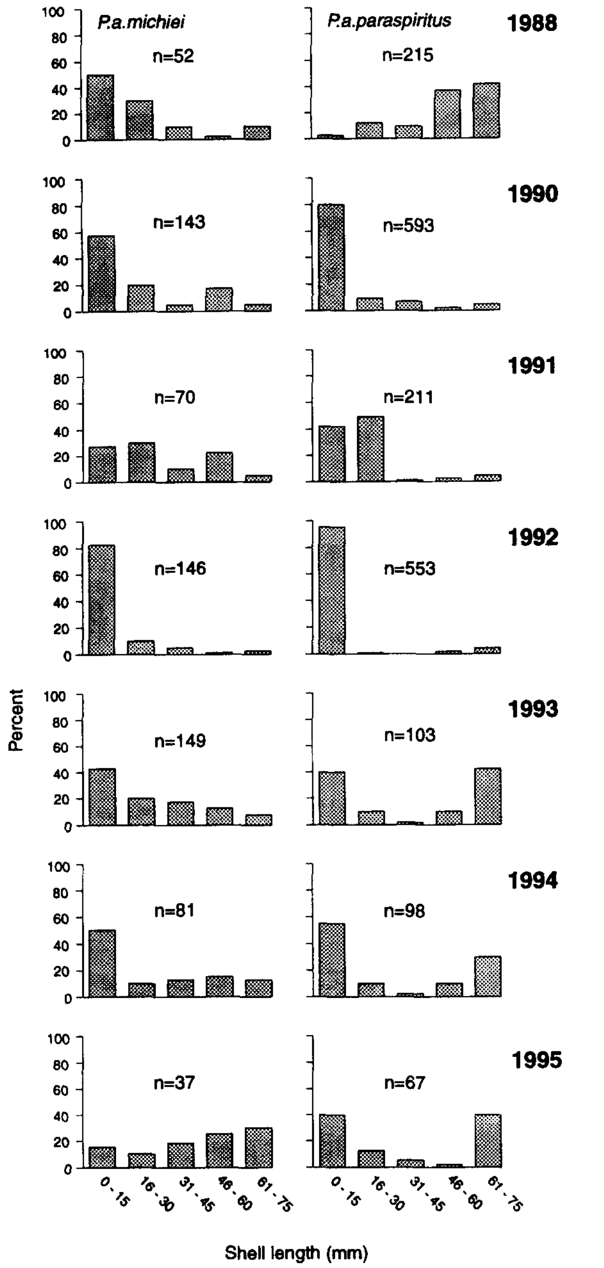

Fig. 4. Changes in the size distribution of whole empty *P. a. michiei* and *P. a. paraspiritus* between 1988 and 1995. All shells were collected from permanent quadrats at Surville Cliffs and Cape Maria van Diemen, respectively.

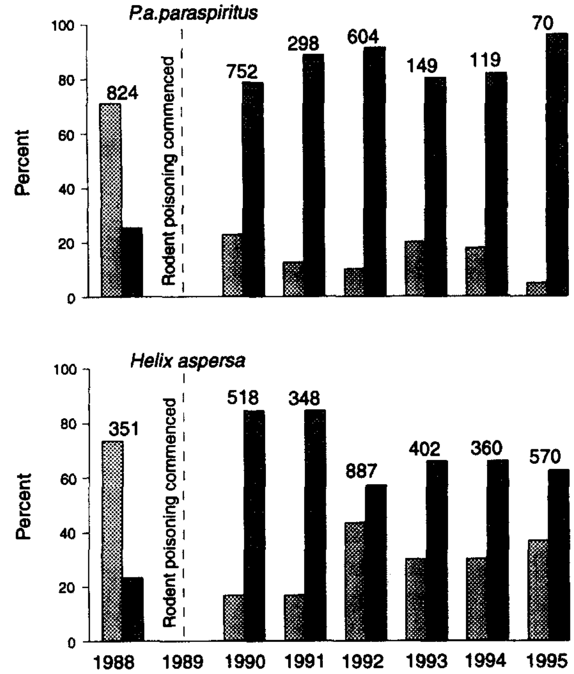

Fig. 5. Changes in the proportions of empty rodent-damaged (▒) and empty whole (■) shells of *P. a. paraspiritus* and *Helix aspersa* between 1988 and 1995. All shells were collected from permanent quadrats at Cape Maria van Diemen. Total numbers of empty shells are given for each year.

Changes in the populations of live *P. ambagiosus* between 1988 and 1995

The proportions of live juvenile, subadult and adult *P. a. paraspiritus* changed markedly after 1988 following the poisoning of rodents at the population. This change resulted mostly from a relative increase in the numbers of juveniles. In contrast, there was no apparent change in the proportions of these age classes at the *P. a. michiei* population, where no attempt was made to discourage predation by birds (Fig. 6).

Not enough time was available in 1988 to collect data on the shell length of live snails. From 1990 to 1995 the size distribution of live *P. a. paraspiritus* changed progressively from a high proportion of small snails in 1990 to a high proportion of larger snails in 1995 (Fig. 7). The proportions of subadult and adult *P. a. paraspiritus* in the two largest size categories dropped from an initially high level of 80% in 1990 to around 25% in 1992 and then rose again to 54% in 1995 as juveniles matured (Table 1). Thus, juvenile recruitment into the subadult and adult classes occurred by 1995. The size distribution of live *P. a. michiei*, on the other hand, remained approximately the same over this period and showed no significant change ($\chi^2=4{\cdot}9$, d.f.$=4$, $p>0{\cdot}05$, comparing 1990 with 1995; Table 1).

Mortality and population changes in *Helix aspersa*

The proportions of undamaged empty and rodent damaged shells of *H. aspersa* found in the quadrats at Cape Maria van Diemen showed similar changes to those of *P. a. paraspiritus* from 1988 to 1995 (Fig. 5). In both cases, there were more rodent-damaged shells than whole empty shells in 1988, but more whole empty shells were found than rodent-damaged shells between 1990 and 1995 after rodent poisoning commenced. The proportions of whole empty and rodent-damaged *H. aspersa* shells (Fig. 5), however, varied more from year to year than did those of *P. a. paraspiritus* (Fig. 5).

DISCUSSION

Placostylus shells (at least those over 10 mm) may last for many years in the dry environment so characteristic

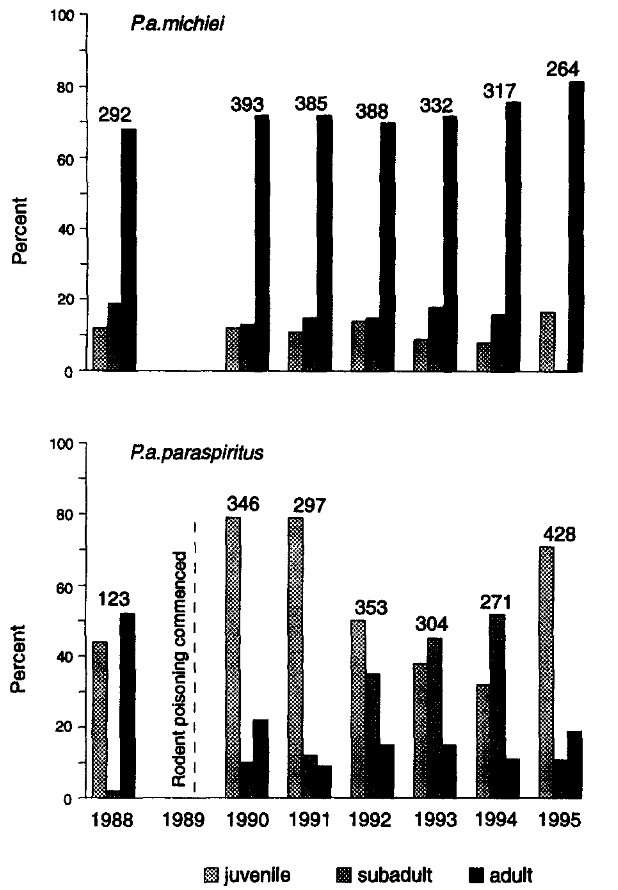

Fig. 6. Changes in the proportions of live juvenile, subadult and adult *P. a. michiei* and *P. a. paraspiritus* between 1988 and 1995. Total numbers of live snails are given for each year.

of these coastal sites. Hence the data from the 1988 survey represent an accumulated record of mortality, including predation over an unknown number of years. These data clearly showed that rodent and bird predation similarly restricted the recruitment of adult snails by removing medium to large-sized juveniles. Hence, our results suggest that, if left unchecked, rodent and bird predation would probably result in progressively ageing *Placostylus* populations which could ultimately die out.

We were not able to assess the effects of rodent and bird predation on eggs or snails < 10 mm long, because we believe these were so fragile that predators would have destroyed them completely. For the same reason we were unable to compare the relative effects of bird and rodent predation. Further, we may have overscored 'natural deaths' because some intact shells may have resulted from rodents attacking moving snails. *P. ambagiosus* is slow to retract and several live snails were seen with a damaged foot. We have also probably underestimated the effects of predation by rodents and birds because both may remove smaller snails from the quadrats. Thus, our assessment of the total impact of these predators is probably conservative. It is also possible that some of the benefits of reducing rodent predation on juvenile and subadult snails was underestimated because

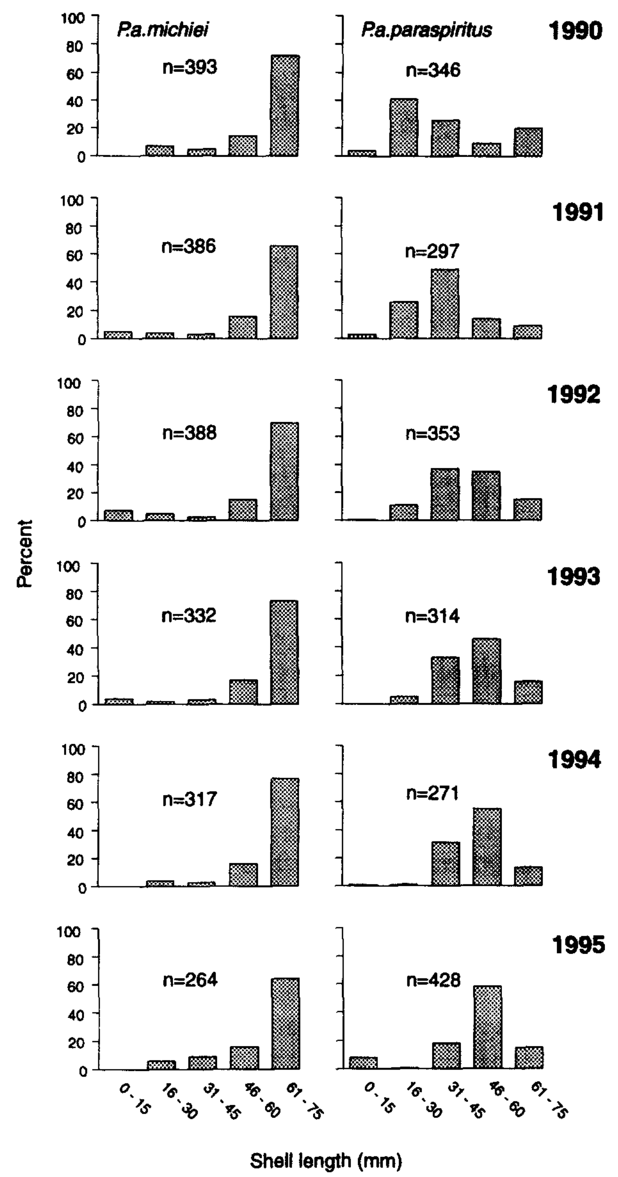

Fig. 7. Proportional changes in the lengths of live *P. a. michiei* and *P. a. paraspiritus* between 1990 and 1995. All shells were collected from permanent quadrats at Surville Cliffs and Cape Maria van Diemen, respectively. Total numbers of live snails are given for each year.

hedgehogs *Erinaceus europaeus occidentalis* Barrett-Hamilton have been seen near the population and they may also prey on *Placostylus*. Hedgehogs may also occur at Surville Cliffs but they have not been seen there.

Our size distribution data suggest that *P. a. paraspiritus* takes 7 or more years to become adult. These data also showed that there was an increase in the proportion of large juvenile *P. a. paraspiritus* during the first 6 years of rodent poisoning at Cape Maria van Diemen. The conclusion that this increase was caused by poisoning may be questioned because we were unable to provide a scientific control. However, cause and effect is suggested because, in the absence of poisoning for predators, the *P. a. michiei* population showed a stable structure with low proportions of juveniles over the same period.

Table 1. Age composition of *P. ambagiosus* snails >45 mm in length

Year	1990	1991	1992	1993	1994	1995
% subadult						
P. a. michiei	8·7	5·3	2·8	4·9	1·7	2·2
P. a. paraspiritus	5·0	17·6	4·9	7·7	10·9	20·4
% Adult						
P. a. michiei	90·4	95·6	94·6	95·1	92·4	90·1
P. a. paraspiritus	75·0	41·2	19·8	24·0	22·3	33·8
Total number						
P. a. michiei	343	432	316	286	302	91
P. a. paraspiritus	101	68	182	183	175	225

Parallel results were observed for *H. aspersa*, which also showed a rise in the proportion of live snails that survived following a decrease in rodent predation. *H. aspersa* is herbivorous and has a calcified shell so it could be a competitor for food and calcium with *Placostylus*. It may also destroy *Placostylus* habitat by defoliating food plants. Some qualitative evidence was observed for the latter in the last 2 years of the study. Thus, improving the conditions of *H. aspersa* through reducing rodent predation may be an unwelcome result of protecting *Placostylus* in this manner. However, the observed improvement in recruitment into older age groups of *Placostylus* more than offsets any disadvantages due to increased numbers of *H. aspersa*.

Another potential problem is the possibility that rodents could acquire resistance to anticoagulant poisons (Moors *et al.*, 1992). However, this might be minimised by changing poisons, stopping poisoning for 1 or more years, or changing the periods between laying poisons.

The number of whole empty *Placostylus* shells varied considerably from year to year (Fig. 4). While we did not gather any direct evidence to explain these variations, we believe that differences in rainfall from year to year and the incumbent risks of desiccation would explain most of the changes in mortality. Snails were frequently found 'caught out' in the sun in the process of overheating and dying. Also the availability of damp shaded areas in these isolated 'islands' of vegetation becomes progressively restricted during drought. Options for improving habitat for *Placostylus* by planting food species are considered in the recovery plan (Parrish *et al.*, 1995).

This study indicates that it is possible to manage highly endangered populations of invertebrates *in situ*—even if the predators are not eradicated. The costs of the poison and the task of restocking the stations were minimal. Management was facilitated by the fact that, as with many invertebrate populations, the area of habitat required for *P.a. paraspiritus* protection was small and it was isolated by surrounding sand dune. Thus, we consider that transfers to predator-free islands may not necessarily be required to protect some of New Zealand's large-bodied invertebrates. Instead, *in situ* management on the mainland may well be a viable alternative.

We know of no other comparable research that evaluates the benefits of controlling introduced predators of endangered macro-invertebrates in a mainland situation. While our study strongly indicates that rodent control can be beneficial, more research is required to determine the minimum level of poisoning effort that will allow adequate recruitment of adult snails, while preventing the rodents from acquiring resistance to the toxins. In addition, the seasonal changes in the density of rodent populations needs study in order to determine the optimum times for 'pulse' poisoning.

ACKNOWLEDGEMENTS

We are grateful to Bill McCleod, Mike Aviss, Trev Bullock, Nigel Miller, Richard Montifiore, Carrie Jane, Liz Grant, Peter McGregor and Stephanie Prince for field assistance. Thanks to Chris Edkins, Sean Hutton and Liz Grant for the figures and to Lisa Sinclair, Winston Ponder and an unknown referee for critical review of the manuscript.

REFERENCES

Molloy, J., Davis, A. M. and Tisdall, C. (1994) *Setting Priorities for the Conservation of New Zealand's Threatened Plants and Animals*, 2nd edn. Department of Conservation, Wellington.

Moors, P. J., Atkinson, I. A. E. and Sherley, G. H. (1989) *Prohibited Immigrants: the Rat Threat to Oceanic Islands.* World Wild Fund for Nature, Wellington.

Moors, P. J., Atkinson, I. A. E. and Sherley, G. H. (1992) Reducing the rat threat to island birds. *Bird Conserv. Int.* **2**, 93–114.

Parrish, G. R., Sherley, G. H. and Aviss, M. (1995) *Northern giant landsnail recovery plan* Placostylus *spp.*, Paryphanta *sp.* Threatened Species Recovery Plan Series 13. Department of Conservation, Wellington.

Penniket, A. S. W. (1981) Population studies of land snails of the genus *Placostylus* in the North of New Zealand. MSc thesis, University of Auckland.

Powell, A. W. B. (1938) The Paryphantidae of New Zealand No. IV and the genus *Placostylus* in New Zealand. *Records of the Auckland Institute and Museum* **2**, 139–151.

Powell, A. W. B. (1947) Distribution of *Placostylus* landsnails in northernmost New Zealand. *Records of the Auckland Institute and Museum* **3**, 173–189.

Powell, A. W. B. (1951) On further colonies of *Placostylus* landsnails from northernmost New Zealand. *Records of the Auckland Institute and Museum* **4**, 134–142.

Powell, A. W. B. (1979) *New Zealand Mollusca Marine, Land and Freshwater Shells.* Collins, Auckland.

Sherley, G. H. (1996) Morphological variation in the shells of *Placostylus* species (Gastropoda: Bulimulidae) in New Zealand and implications for their conservation. *N. Z. J. Zool* **23**, 73–82.

Sherley, G. H. and Parrish, G. R. (1989) *Placostylus* survey, management and research in Te Paki, Northland. *Science and Research Internal Report*, No. 61, Department of Conservation, Wellington.

Triggs, S. J. and Sherley, G. H. (1993) Allozyme genetic diversity in *Placostylus* land snails and implications for conservation. *N. Z. J. Zool* **20**, 19–33.