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SHORT COMMUNICATION

CHANGE IN DIET OF STOATS FOLLOWING POISONING OF RATS IN A NEW ZEALAND FOREST

Summary: The abundance and diet of stoats *(Mustela erminea)* were compared before and after an aerial 1080-poison operation *for* possums *(Trichosurus vulpecula)* in a New Zealand podocarp-hardwood forest. Poisoning dramatically reduced ship rat *(Rattus rattus)* abundance. Although rats were the main prey item of stoats before the poisoning, stoat abundance was unaffected by the operation and there was a change in stoats' diet from rats to birds. The conservation benefits and risks of undertaking such operations are not clear. It is not known whether the predation risk *for* any particular species of bird *(or* other animal) will be higher or lower with fewer rats but the same density of stoats; As large-scale poison operations are now common in New Zealand forests, a better understanding of predator-prey relationships in these areas is required as soon as possible.

Keywords: stoat; *Mustela erminea;* 1080 poison; ship rat; *Rattus rattus;* diet; predator-prey.

Introduction

Large-scale aerial poisoning with compound 1080 (sodium monofluoroacetate) is used to control Australian brushtail possums *(Trichosurus vulpecula* Kerr) in New Zealand forests (Cowan, 1990). Some of the direct effects of this poisoning on other animals have been studied. Ship rat *(Rattus rattus* L.) numbers can be reduced by over 90% but this effect is short-lived (Warburton, 1989; Innes and Williams, 1991). Some birds are killed but Spurr (1991) concluded that the potential benefit of poisoning possums to bird populations outweighs the detrimental effect of the loss of a few individuals. It is not known yet whether there are significant detrimental effects on bat, lizard or invertebrate populations.

The indirect effects of this poisoning, particularly on other predators, are not well understood. Stoats *(Mustela erminea* L.) are one of the commonest carnivores in New Zealand forests (Gibb and Flux, 1973) and could be secondarily poisoned by their scavenging on possum and rat carcases. If secondary poisoning is sufficiently common, a reduction in stoat densities should be detectable. Stoats may also be affected by poison operations in other ways. Where they occur, ship rats are a major component of the diet of forest-dwelling stoats (King and Moody, 1982). If there is a sufficiently large reduction in rat density, and stoats are not reduced by secondary poisoning, stoat numbers could fall, either through starvation or emigration to an area of higher rat density. If stoat numbers remain unchanged, it suggests that stoats (whether resident or immigrant) have switched to eating other food sources.

This study measured the abundance of stoats before and after an aerial 1080 poison operation in Mapara Reserve, a central North Island forest, to determine whether stoat density was reduced. We also examined the diet of stoats before and after the operation to test their response to a large decrease in abundance of their main prey.

Methods

Study area

Mapara Reserve (38°33'S, 175°17'E) is 1432 ha of steep hill country, 27 km southeast of Te Kuiti. The reserve contains a diverse range of mature and regenerating native forest and is administered by the Department of Conservation as an area *for* wildlife management. The composition and structure of the forest has been described by Coker (1978). The reserve has been logged in the past and very few mature podocarps remain; there is a mosaic of logging tracks and cleared areas, shrub hardwood and an essentially undisturbed tawa *(Beilschmiedia tawa* A. Cunn.) canopy. Its principal value is as a habitat *for* about 50 North Island kokako *(Callaeas cinerea wilsoni* Bonaparte). Rat and stoat numbers are being reduced in the reserve to see if kokako breeding success can be improved (Saunders, 1990).

Predator control

Although there was some localised rat control during the 1989-90 kokako breeding season (October - April), the overall density of rats in the reserve was largely unaffected (Innes and Williams, 1990). Immediately before the 1990-91 season, widespread rat control was achieved by an aerial broadcast of 1080 poison for possums on 10 September 1990. The 1080 poison was in cereal-based pollard baits at a concentration of 0.08% w/w (Wanganui No.7, Wanganui Poisons Factory, New Zealand). Baits were broadcast at 8 kg ha^{-1} over the entire reserve. In the following January, rat abundance (based on tracking-tunnel indices) was still only 11 % of the pre-poison average, but by April there was no significant difference between pre- and post-poison rat indices (Innes and Williams, 1991).

Kill-trapping was undertaken to try and reduce stoat numbers during kokako breeding seasons (October - April). A trap line of about 24 km in length was situated on the main ridge-lines throughout the reserve. Mark 4 Fenn traps (FHT Works, Worcester, England), 150 to 300 m apart, were set for 182 days from 15 October to 15th April. There were 103 traps in the 1989-90 trapping period, and 142 in the 1990-91 trapping period. Traps were usually checked twice a week but occasionally it was weekly. Traps were unbaited except for the first month of trapping in 1989, when they were baited with catfood. Ferrets *(M. furo* L.), weasels *(M. nivalis vulgaris* Erxleben) and ship rats were also caught in the Fenn traps. Stoats caught in Fenn traps were collected and frozen until autopsy.

Age and diet analysis

Stoats less than one year old are defined here as juveniles. Females were classed as juveniles or adults by measuring the post-orbital ratio (interorbital width divided by postorbital width) and by the presence of incremental lines in the canine cementum; the weight of the baculum was used to categorise males as juveniles or adults (Grue and King, 1984). In the 1989-90 kokako breeding season, 23 stoats were trapped of which 20 were autopsied. Of those, three had empty guts and were excluded from the diet analysis. In the 1990-91 season, 38 stoats were caught of which 28 were autopsied. Ten of these had empty guts and were excluded from the diet analysis.

For the diet analysis, the contents of the stomach and intestine were washed in a 0.5 mm sieve and stored in 70% ethanol. Gut contents were sorted under a low-power (x 10) microscope. Bird remains were assigned to orders by the structure of downy barbules (Day, 1966) and could sometimes be identified to species by claws or diagnostic feather patterns. Remains of egg shells and invertebrates were noted but not further identified. Where possible, remains of mammals were identified as either mice *(Mus musculus* L.), rats *(Rattus* spp.), or lagomorphs (rabbits or hares) from bones, teeth or hair scale patterns (Day, 1966).

Results of the diet analysis are presented as a frequency of occurrence, i.e., the percentage of guts with food that contained each prey item. The composition of the diet by weight was also estimated by expressing the numerical occurrence of each prey category as a proportion of the total diet, estimated from the sum of all occurrences. The counts of specimens in each category were weighted to correct for gross differences in the size of different prey species by the method of King and Moody (1982). Invertebrates, mostly wetas (Orthoptera), were weighted as 3 g, mice and birds as 109, and rats, lagomorphs and unidentified contents as 20 g.

Results

Abundance, age and sex ratio

The number of mustelids and rats trapped over two complete kokako breeding seasons are given in Table 1. There was an obvious decline in rat captures after the aerial poison operation, particularly during the first 3.5 months; from 15 Oct 1989 to 31 Jan 1990,220 rats were caught (1.98 captures per 100 trap nights) but during the same period in 1990-91, 14 rats were caught (0.09 captures per 100 trap nights). During the same period in 1989-90 and 1990-91, 17 stoats were caught in each season (0.15 and 0.11 captures per 100 trap nights respectively).

There was no significant change in the proportion of juvenile and adult stoats trapped between the two kokako breeding seasons for either sex (Table 2; females: $X^2 = 0.21$, d.f.=1, $P > 0.1$; males: $X^2 = 0.02$, d.f.= 1, $P > 0.1$).

Table 1: *Number of animals Fenn-trapped at Mapara from 15 October 1989 to 15 April 1990, and 15 October 1990 to 15 April 1991.*

Animal	Number caught		Captures per 100 trap nights	
	1989-90	1990-91	1989-90	1990-91
Stoats	23	38	0.12	0.15
Weasels	10	II	0.05	0.04
Ferrets	14	13	0.08	0.05
Rats	241	136	1.29	0.53

Table 2: *The number of juvenile and adult stoats Fenn-trapped at Mapara from 15 October 1989 to 15 April 1990. and 15 October 1990 to 15 April 1991. Annual catch of aged animals as a % in brackets.*

Age category	1989-90	1990-91
Juvenile females	6 (29%)	8 (25%)
Adult females	3 (14%)	6 (19%)
Juvenile males	7 (33%)	10(31%)
Adult males	5 (24%)	8 (25%)

There was no change in the sex ratio of stoats trapped over the two kokako breeding seasons. In 1989-90, nine of the 23 stoats caught (39%) were females and 14 (61 %) males. In 1990-91, 15 of the 37 stoats sexed (41%) were females and 22 (59%) were males (X^2= 0.01, d.f.= 1, $P > 0.1$).

Diet

During the 1989-90 kokako breeding season, rats were the commonest food of stoats, occurring in 12 (71 %) of the 17 guts that contained food (Table 3). Birds were a minor part of the diet, being found in only one (6%) of the guts (a tomtit - *Petroica macrocephala* Gmelin). In the 1990-91 season (after the poison operation), rats occurred in three of 18 guts; this was significantly less than in the season before X^2 = 8.3, d.f.= 1, $P < 0.01$). Birds occurred in 10 of 18 guts, which was significantly more often X^2 = 7.8, d.f.= 1, $P < 0.01$). Of the 10 birds, four were pigeons (almost certainly *Hemiphaga novaeseelandiae* Gmelin), four were Passeriformes (including one identified as a song thrush *Turdus philomelos* Brehm), one was not identifiable (but not Passeriformes) and one was not identifiable. The frequency of occurrence of lagomorphs and invertebrates in stoat diet (Table 3) was not significantly different between seasons (lagomorphs, X^2 = 0.01, d.f.= 1, $P > 0.1$, invertebrates, X^2 = 0.2, d.f.= 1, $P > 0.1$).

Table 4 gives an estimate of the composition by weight of the diet for the two study periods. The results are in agreement with the frequency of occurrence data. In spite of the fact that rats were weighted as 20 g compared to 10 g for birds, birds still constitute a much higher proportion of the diet by weight in the season following the aerial poison operation and rats a much lower proportion. If the four pigeons identified in the diet in 1990-91 season are weighted as 20 g (but the other birds left at 10 g), birds are found to constitute 47.3% of the diet by weight and rats 20.3%.

Table 3: *Percentage frequency of occurrence of prey identified in stoat guts collected from 15 October 1989 to 15 April 1990 (n=l7) and from 15 October 1990 to 15 April 1991 (n=18).*

Prey	% frequency of occurrence 1989-90	1990-91
Rat	71	17
Mouse	6	0
Lagomorph	12	17
Bird	6	56
Bird's egg	0	6
Invertebrate	6	17
Unidentified	6	6

Table 4: *Percentage composition by weight of the diet of stoats collected from* 15 *October* 1989 *to* 15 *April 1990 (n=l7) and from* 15 *October 1990 to* 15 *April 1991 (n=18).*

Prey	% Diet by weight 1989-90	1990-91
Rat	74.3	23.4
Mouse	3.1	0
Lagomorph	12.4	23.4
Bird	3.1	39.1
Bird's egg	0	2.7
Invertebrate	0.9	3.5
Unidentified	6.2	7.8

Discussion

Predators can respond to changes in the density of a given prey in two ways. There can be a functional response causing a change in the predator's diet, and/or a numerical response, involving a change in the number of predators (Krebs, 1972). At Mapara, it appeared that stoats only responded functionally to a decrease in ship rats (their main prey item), and switched to another prey type, birds. (The situation is complicated however, because stoat trapability may have changed at lower rat densities.) This is analogous to the situation in northern Europe, where natural cycles of rodent abundance occur. In years of low rodent numbers, stoats (and other predators) switch to birds and their eggs (Myrberget, 1972; Järvinen, 1985).

The only common pigeon at Mapara is the New Zealand pigeon. The fact that at least four of 11 birds eaten by stoats were identified to this order suggests that stoats may have a substantial (and little-recognised) impact on this species. It also indicates that in this case the contribution of birds to the diet by weight can be under-estimated. Although the method of King and Moody (1982) allows 10 g per bird, meal size from a N.Z. pigeon (which weighs about 650 g - Clout, Gaze and Hay, 1988) is potentially higher and should probably be at least 20 g, the same as for a rat.

In this study, we could not detect whether resident stoats died from secondary poisoning by eating poisoned rats or possums. In South Island *Nothofagus* forest, stoats dispersed over large distances within one month, in one case over 65 km (Murphy and Dowding, 1991). Trapping at Mapara was not undertaken until one month after the aerial poison operation, suggesting that even if resident stoats were killed, a change in stoat abundance might not have been detected because of rapid re-invasion. Whether the increased consumption of birds is due to surviving resident or immigrant stoats is immaterial from a conservation management perspective.

Although our study was only a preliminary one (and replication was not possible), our findings are of considerable importance to conservation management, showing as they do the importance of understanding the relative susceptibility of individual threatened species to various potential predators. It is not clear for example, whether kokako are more or less vulnerable in a regime of low rat numbers where stoats are consuming more birds. The answer for kokako may be different to that for hole-nesting birds such as kaka *(Nestor meridionalis* Gmelin), which may be more susceptible to predation by stoats than rats. Feral cats *(Felis catus* L.) are the other common carnivore in New Zealand forests (Gibb and Flux, 1973); as rats are also a major component of their diet (Fitzgerald and Karl, 1979), they could be similarly affected by aerial 1080 poison operations. Clearly the ideal would be to control or eradicate all potential predators at once, but this is rarely achievable.

Large-scale poison operations to control possums are undertaken regularly in New Zealand forests. It is therefore important to gain a detailed understanding of predator-prey relationships in these systems, and to study their responses to poisoning and other perturbations, such as the use of biological control agents. This will enable a more accurate assessment of the benefits or dangers, particularly to threatened species, of undertaking such operations.

Acknowledgements

We thank Landcare Research New Zealand Ltd., Ilam and the Zoology Department of Otago University for use of their laboratory facilities; Malcolm Thomas for histological work; Department of Conservation staff from Te Kuiti for helping to check traps; Bridget Farrell for finding references; John Dowding, Chris Frampton, Henrik Moller, Theo Stephens and Dave Towns for comments on drafts of this paper.

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