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NESTING SUCCESS OF NEW ZEALAND PIGEONS (*HEMIPHAGA NOVAESEELANDIAE*) IN RESPONSE TO A RAT (*RATTUS RATTUS*) POISONING PROGRAMME AT WENDERHOLM REGIONAL PARK

Summary: Anticoagulant poisons were laid within native forest at Wenderholm Regional Park (near Auckland) to reduce rat numbers during the summer months. Snap trapping indices and an artificial nest experiment confirmed the high potential for rat interference in unpoisoned forest patches outside Wenderholm, compared with the near-zero potential at Wenderholm. Over two breeding seasons, 70 New Zealand pigeon (*Hemiphaga novaeseelandiae*) nests were located and monitored. Nest predation was significantly lower at Wenderholm than in non-treatment areas, but hatching and fledging success were not significantly different, due to a high level of nest desertion at Wenderholm. Possums (*Trichosurus vulpecula*) were found to be nest predators, and their low numbers at Wenderholm confounded the results of the rat poisoning experiment.

Keywords: New Zealand pigeon; nest predation; mammal control; possum; ship rat.

Introduction

Ship rats (*Rattus rattus* L.) have been established throughout New Zealand for over a century. They are considered to be major nest predators of native birds, although most of the evidence is circumstantial and based on the interpretation of fragments of egg-shell and rat faeces found around failed nests (Clout *et al.*, 1995a; Brown, 1994; Moors, 1978, 1983; Kikkawa, 1966). A pertinent question for conservation managers is whether or not rats are threatening the survival of modern-day native bird populations.

Ship rats are clearly implicated in the extinction and decline of many island bird populations (Atkinson, 1985), although the evidence is largely correlational and must be interpreted with caution (Innes and Hay 1991; Moors, 1983). In French Polynesia, New Zealand and Hawaii there are many negative associations between the presence of ship rats and the numbers of native bird species (Seitre and Seitre 1992; Atkinson, 1977, 1978). Bell (1978) attributed the extinction of three species of landbird on the Big South Cape Islands to an irruption of ship rats. In contrast, the Galapagos and Christmas Islands, both of which had endemic rat species, lost no native land birds following the arrival of ship rats (Innes, 1990; Atkinson, 1985).

The New Zealand pigeon (*Hemiphaga novaeseelandiae* Gmelin) belongs to a monotypic genus now restricted to the New Zealand archipelago (Clout *et al.*, 1995a). It is a large, frugivorous pigeon which has probably had a long evolutionary history in New Zealand (Fleming, 1979). As with most pigeons, its defensive

behaviour when threatened is to take flight or hit out strongly with its wings (R.E. James *pers. obs.*). Its nest is a rather spartan arrangement of twigs approximately 30 cm in diameter. The single egg is incubated for 28-30 days (Clout *et al.*, 1995a), and the chick takes 30-55 days to fledge (James, 1995).

Research on the productivity of the New Zealand pigeon has indicated a high incidence of nest predation (Clout *et al.*, 1995a). Overall productivity can be very low: at two North Island sites birds failed to fledge a single chick in two consecutive breeding seasons (Clout *et al.*, 1995a). One of these sites, Wenderholm Regional Park, subsequently became the focus of an intensive rat poisoning programme in 1992. During this first summer of rat poisoning, five out of 11 New Zealand pigeon nests monitored within the park fledged chicks, producing a significant difference from the total of no chicks fledged from 27 nests prior to poisoning (Clout *et al.*, 1995b). However, since nests were only monitored within Wenderholm Regional Park and no measure of nesting success was taken from outside the park, it was impossible to preclude the possibility of a year effect.

This paper presents the results of a field experiment which tested the hypothesis that rodent poisoning leads to an increase in productivity of New Zealand pigeons by reducing the levels of nest predation. This was done by monitoring the survival and outcomes of New Zealand pigeon nests found within the poisoned area and comparing them with those found in adjacent non-poisoned areas. Artificial nests were also used to supplement the results from natural nests.

Methods

Study areas and experimental design

Rodent poisoning took place within the boundaries of Wenderholm Regional Park (Fig. 1), so adjacent forest patches were chosen as experimental control sites. These forest patches ranged from Waiwera north through Schischka's farm to Mahurangi West Regional Park, which incorporated both Cudlip and Te Muri points (Fig. 1). The general forest type within Wenderholm Regional Park and these adjacent forest patches was coastal broadleaved forest, in which pohutukawa (*Metrosideros excelsa*[1]), kanuka (*Kunzea ericoides*), kowhai (*Sophora microphylla*), puriri (*Vitex lucens*), taraire (*Beilschmiedia tarairi*), karaka (*Corynocarpus laevigatus*) and nikau (*Rhopalostylis sapida*) were common trees.

Introduced mammals occurring around Wenderholm which were suspected predators of New Zealand pigeon nests included ship rats, stoats (*Mustela erminea* L.), and feral cats (*Felis catus* L.). It was assumed that nests in both Wenderholm and the control sites were equally exposed to predation by these species.

Rat control

Storm Rodenticide (Shell Agriculture) baits (active ingredient 0.05g kg^{-1} Flocoumafen) were used at Wenderholm during the summer of 1993-94. The following summer, Talon (ICI Chemicals) baits (active ingredient Brodifacoum) were used. The baits were placed in 217 50cm-long Novacoil-tube stations, to reduce the risk of non-target poisoning and to protect the baits from rain. Stations were set out on a 100m x 50m grid. Poisoning in the 1993-94 season commenced at the beginning of October 1993 and continued until the beginning of March 1994 (T.C. Greene *pers. comm.*), whilst in the 1994-95 season it commenced in September 1994 and continued until December 1994 (B. Green, *pers. comm.*).

A snap-trap transect, established at Wenderholm in 1990 before rat control began, was used to give an index of rat abundance. The transect included 36 stations spaced 50 m apart, each of which consisted of two Ezeset™ rat traps baited with peanut butter and cheese. The transect was monitored over four successive nights in July 1993, November 1993 and March 1994, August 1994 and November 1994.
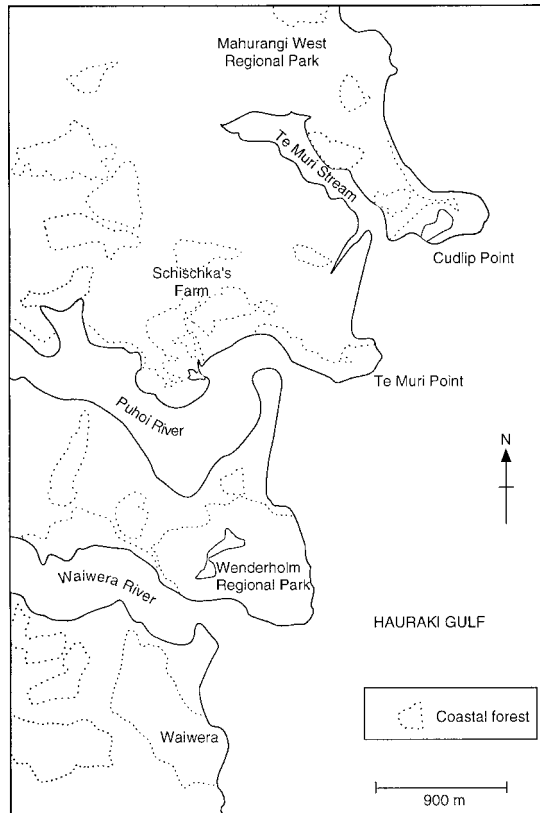

Figure 1: *Study area, centred on Wenderholm Regional Park, 50km north of Auckland City.*

Snap-trap transects were also established in the non-treatment area, but contained fewer stations (<15) because of a concern that trapping could reduce the rat numbers in the smaller forest patches. These transects were monitored over four consecutive nights in August 1993 and April 1994.

Artificial nests

To test the impact of rodent poisoning on the fate of pigeon eggs a total of 48 artificial nests were set up in March 1994, 12 at Wenderholm and 12 at each of three forest patches within the non-treatment area. These "nests" were 25 cm-diameter wicker baskets baited with a single rock pigeon (*Columba livia* Gmelin) egg. The baskets were left outside for a week before use, to cleanse them of any odours. Their final position in the field was standardised in order to minimise within-site variation.

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[1] Botanical nomenclature follows Allan (1961).

All artificial nests were placed in clumps of epiphytic kahakaha (*Collospermum hastatum*) in puriri trees, 4-6 m above the ground. This position had been recorded for natural nests. The nests were left for 8 days before being checked for results, to avoid the risk of leaving scent trails which might attract predators.

Pigeon breeding

Three methods were used to find nests:
i   following birds fitted with radio transmitters;
ii following birds seen gathering twigs;
iii searching for nests within the forest and in isolated trees near the forest margin, or by finding fresh egg shell fragments (membrane still adhereing to shell) or piles of defaecated seeds on the ground beneath the nests.

In the 1993-94 season, nests were monitored at least once per week to determine whether they had failed or were still active. This provided data which were used to estimate survival rates using the method of Mayfield (1975), as modified by Johnson (1979). Survival rates were compared between sites and nest stages using the ratio of the difference in daily mortality rates to their standard errors against a normal distribution. In the 1994-95 season, however, nest monitoring was less regular and therefore did not yield data suitable for the estimation of survival rates.

The separation of nests through space or time was assumed to be sufficient to treat their outcomes as independent for analysis by chi-square test.

Predator sign

Fates of eggs were assessed on the basis of shell fragments and faeces found in nests. Following Moors (1978), shells that had been opened in half, usually longitudinally, with uncrushed jagged edges and small uncrushed fragments were considered evidence of rat predation (Fig. 2). Such sign was almost always found in association with rat faeces. Crushed eggs were recorded separately.

Chick predation was classified on the basis of the position and condition of the remains.
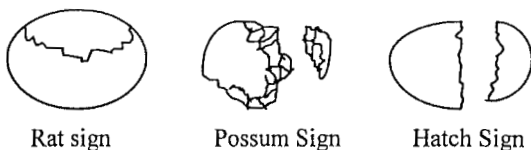

Figure 2: *Shell remains used to assign fate of egg. If remains did not match any of these categories, they were classified as "unknown predator".*

Results

Rat numbers

Snap-trapping indices indicate there were low numbers of rats (0.7 captures per 100 trap-nights) at Wenderholm even before poisoning began in October 1993. In contrast, the early indices for the non-treatment areas (pooled data 6.8 C/100TN) showed rat numbers to be approximately an order of magnitude higher than at Wenderholm. The later indices for the non-treatment areas (pooled data 9.7 C/100TN) also indicated higher rat numbers (Table 1).

Rats were caught in all forest patches outside Wenderholm. Snap-trapping along the Wenderholm transect caught no rats before or after poisoning began in September 1994.

Artificial Nests

At Wenderholm, 10 out of 12 eggs remained intact, while in each of the non-treatment areas only 0 to 1 out of 12 remained intact. The difference between sites was highly significant (Fisher's exact test, $P<0.0001$) as a result of the high number of eggs remaining intact at Wenderholm. No egg shell or faecal remains indicative of rat predation were found at Wenderholm, but at the non-treatment sites such evidence was found in up to 10 out of 12 nests.

Pigeon Nests

A total of 70 New Zealand pigeon nests was found between August 1993 and March 1995. Of these, 38 were found at Wenderholm and 32 at non-treatment sites, 21 of which were on Schischka's farm. All nests found at non-treatment sites were pooled for analysis on the basis that the forest patches were of similar canopy composition and that snap-trapping indicated that rats were present at each site (Table 1).

Table 1: *Rat snap-trapping indices (nC/100 trap nights, corrected for sprung traps and on-target captures) at Wenderholm and control sites. Transect lengths varied between sites, so the number of trap stations per transect is given in brackets.*

	Wend. (36)	Control Areas			
		Waiw. (14)	TeM/Sc (12)	Cudlip (9)	Pooled (35)
Jul/Aug 1993	0.7	7.8	3.5	10.3	6.8
Nov 1993	0	-	-	-	
Mar/Apr 1994	0	15.3	9.0	2.2	9.7
Aug 1994	0	-	-	-	
Nov 1994	0	-	-	-	

Fourteen nests were found using radio transmitters, 17 by following twig-carrying birds and 39 by searching. The nests were found at varying stages, from pre-laying to near-fledging.

Relatively few nests were successful either within Wenderholm or in non-treatment areas (Table 2). Only 10 chicks fledged at Wenderholm, and four in the non-treatment areas, producing an insignificant difference between sites (χ^2=2.07, d.f.=1, P>0.1). When hatching percentages are compared, the chi-square value is very close to the critical value (3.841) for the 95% level of significance (χ^2=3.55, d.f.=1, P>0.05). A highly significant difference was, however, detected between sites in the percentage of eggs which appeared to have been preyed upon (χ^2=16.48, d.f.=1, P<0.001).

There was no difference between years in the percentage of fledged chicks at Wenderholm (26% vs. 26%) or in the non-treatment areas (11% vs. 14%), nor in the percentage of nests which were possibly preyed upon at Wenderholm (26% vs. 26%) or in the non-treatment areas (72% vs. 79%).

Egg predation was qualified as "possible" because of the uncertainty involved in assigning this as a cause of nest failure. It is impossible to know whether the shell fragments found are a result of the actual nest failure, or of subsequent scavenging (Brown *et al*., 1993). In four cases, near complete sets of large egg-shell fragments were found below nests after episodes of strong easterly winds. However they showed signs of some disturbance (such as the dispersion of fragments or unusually

fractured margins), which could have resulted from either scavenging or nest predation, so they were conservatively classified as possible predation.

The survival rates of nests found during the 1993-94 season showed no significant differences between the poisoned and non-poisoned areas in either the incubation or nestling stages (incubation ratio=1.60, P>0.10; nestling ratio=0.44, P>0.65). There was a significant difference in survival rate between the incubation and nestling stages at both areas (Wenderholm ratio=2.00, P<0.05; non-treatment ratio=2.25, P<0.03). When the incubation and nestling stages were combined for each area to give the respective probabilities of nest success, the figure for Wenderholm was 0.40 and that for the non-treatment area was 0.12.

Discussion

Rats

The pre-poisoning indices of rodent abundance suggest that little ship rat reinvasion or population recovery had taken place at Wenderholm since the previous summers' poisoning operations. This contrasts with the rapid re-establishment of these rats in other North Island forests following the cessation of poisoning programmes (Brown 1994; J. Innes and D. Williams, *unpubl. data*). The most likely explanation for the slow recovery of ship rats at Wenderholm is its location on a peninsula, which limits reinvasion to its western boundaries.

Table 2: *Summary of nest outcomes within Wenderholm and control areas, sub-divided by years.*

Stage	Outcome		Wenderholm 93-94	Wenderholm 94-95	Control 93-94	Control 94-95
Egg	?Preyed on	- rat		1	3	
		- possum	1	2	1	5
		- unknown		2	8	6
		- broken in nest	1			
		- fell?	3			
		Total	**5**	**5**	**13**	**11**
	Deserted	- early	4	2		
		- full term	3	4		
	Unknown	(early failure)			2	
	Hatched		7	8	3	3
	TOTAL		**19**	**19**	**18**	**14**
Chick	Preyed on	- stoat	1			
		- unknown			1	
	Entire corpse			1		1
	Unknown		1	2		
	Fledged		5	5	2	2

Because of the small number of trap stations outside Wenderholm and the possibility that capture rates on the ground are influenced by changes in ship rat behaviour through time, these non-treatment indices are simply interpreted as confirming the presence of rats in the respective areas throughout the pigeon breeding season. This conservative interpretation is justified using the comparison of snap-trapping indices for April 1994 (Cudlip Point=2.2 C/100TN, Te Muri Point=9.0 C/100TN) with rat predation rates for artificial nests around the same time (Cudlip Point=9/12, Te Muri Point=10/12).

The artificial nest experiment confirmed the suitability of the chosen non-treatment forest patches as experimental "controls", by showing a high potential for rat disturbance of unattended nests.

New Zealand pigeon nesting success

The lower incidence of suspected egg predation in both natural and artificial nests initially suggests that rat poisoning may have positive benefits for New Zealand pigeon nests, particularly at the egg stage. The impact of ship rats as egg predators has been implied by circumstantial evidence in other studies (Clout *et al*., 1995a; Major, 1991; Conry, 1988; Moors, 1983; Kikkawa, 1966; Bull, 1946). It appears from this study, however, that the impact of rats is greater on unattended artificial nests than on natural nests which are attended by an adult pigeon.

Because the calculations for nest survival do not discriminate between predation and abandonment, the 34% incidence of egg desertion at Wenderholm underlies the insignificant difference in nest survival between areas during the incubation stage. This desertion of nests in the poisoned area is also an obvious reason for the insignificant difference in nesting success as indicated by the proportion of nests hatching or fledging young. Low nesting success resulting from natural accidents and abandonment seems to be a feature of *Hemiphaga* nests (Clout *et al*., 1995a; Powlesland *et al*., 1994).

Given the high level of egg desertion at Wenderholm, and the high levels of rat disturbance of artificial nests in the non-treatment areas (compared with those observed in natural nests), it may be that ship rats are often scavengers rather than predators of New Zealand pigeon eggs. Powlesland *et al*. (1994) found no significant difference in fledging success between Chatham Island pigeon nests around which rats were trapped, and those where no trapping took place.

Studies of smaller passerine birds have shown that the protection of nests from rat predation through poisoning and tree-banding (McCormack

and Kynzle, 1990) or trapping (Bull, 1946) can produce substantial increases in nesting success. It is possible that control of ship rats (*c*. 150g) is more likely to produce statistically significant increases in the productivity of smaller-sized (<100g), more fecund bird species than it is for the large-sized (650g), slow-reproducing New Zealand pigeon.

Although the figures for hatching success and incubation survival at Wenderholm are not significantly different at the 95% probability level, they are very close to their respective critical values. Therefore it is simplistic to say that there is an insignificant difference which is merely due to the scavenging of eggs by rats. If this was the case, the hatching proportions and incubation survival values would be much closer to each other than they are. This implies that there may have been some difference between sites due to predation.

The initiation of rodent poisoning at Wenderholm in October 1992 was followed by a statistically significant increase in New Zealand pigeon fledging success, from 0% pre-poisoning to 45% in the first season of poisoning (Clout *et al*., 1995b). This was interpreted as meaning that ship rats were nest predators, whose impacts could be reduced through poisoning.

It therefore appears that the poisoning of ship rats has produced mixed results for New Zealand pigeon breeding success. Some results imply that rats merely scavenge eggs, while others suggest that rat-poisoning has led to a reduction in nest predation.

A confounding variable

In July 1994, infra-red video monitoring of a New Zealand pigeon nest recorded a brushtail possum (*Trichosurus vulpecula* Kerr) preying on a nest at the incubation stage (James, 1995). The size of the possum (2-3kg) may have been an important factor in shifting the adult bird, as this same nest had previously been visited twice by ship rats (*c*. 150g), which failed to move the incubating pigeon off its egg. The resulting post-predation eggshell fragments were of the "crushed" type, consistent with the observations by Brown *et al*. (1993) of possum predation on kokako (*Callaeas cinerea* Gmelin) eggs.

Results from the yearly cyanide poisoning of possums at Wenderholm were subsequently obtained from the Auckland Regional Council Parks service. Possum control had been conducted every winter since the mid 1980s. However, by 1992 (when rat poisoning started at Wenderholm) the annual number of possums killed (66) was only 35% of the number killed in 1990 (189) when most of the pre-

poisoning nest monitoring took place (M.N. Clout *unpubl. data*). Since 1992, the number of possums killed at Wenderholm has continued to decline, with only 9 taken in 1995 (Auckland Regional Parks, *unpubl. data*). This trend presumably reflects a real local decline in possum abundance, resulting from the annual control efforts.

Although some possum control also took place in the non-treatment areas, this was not as intensive or successful as at Wenderholm and there is evidence of a difference in possum abundance between sites as a result. Wotherspoon (1993) found that cyanide poisoning in July 1993 reduced the number of possums at Wenderholm but not at Mahurangi West Regional Park, with post-poisoning trap indices being 0.67 and 3.00, respectively. No possum-poisoning operation was undertaken on Schischka's farm (the non-treatment site at which most New Zealand pigeon nests were found), although night shooting of possums was frequently undertaken (J.B. Schischka *pers. comm.*). No trap index figure was available for this site.

The increase in pigeon fledging success at Wenderholm following the initiation of rodent poisoning in late 1992 therefore appears to have coincided with a reduction in possum numbers as well as a reduction in ship-rats. It is therefore impossible to distinguish between the two as factors in the results of Clout *et al.* (1995b). Similarly, the results of this experiment using non-treatment sites may also confounded by differences in possum abundance between sites. Furthermore, it is known that possums consumed poisoned baits during the rat poisoning operations at Wenderholm (M.N. Clout *pers. obs.*, B. Green, *pers. comm.*), so even without the cyanide poisoning it is likely that the experiments would have been confounded.

Conclusions

The effect of summer rat-poisoning operations on the nesting success of New Zealand pigeons is complicated by the confounding effect of possum control in the experimental design, which prevents conclusions on the impacts of rat poisoning on pigeon breeding success and nest predation from being made with any confidence. The impression gained, which will require further testing, is that rats are most likely scavengers of New Zealand pigeon eggs whilst possums are predators.

It is difficult to avoid confounding biotic variables in spatially controlled field experiments on this scale, since patches of habitat are rarely identical. Replication of experimental controls and treatments through space and time is the ideal, but this not always possible in large scale projects when resources and time are restricted. This study found possums to be a predator of New Zealand pigeon eggs not through inference from the experimental design, but through direct observation by video monitoring of individual nests. This illustrates the benefits of detailed observation to supplement post hoc inference from general experimental outcomes. Future research into the benefits of mammal control for the breeding success of native bird species in New Zealand should incorporate possum monitoring into the experimental design and, where possible, seek to record predation events by using remote sensing technology. Further research of this nature is clearly needed to determine whether or not ship rats are significant predators at the nests of large bird species.

Acknowledgements

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