

Kiore (*Rattus exulans*) predation on the eggs of the Little Shearwater (*Puffinus assimilis baurakiensis*)

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ABSTRACT

Evidence of predation by kiore (*Rattus exulans*) on Little Shearwater (*Puffinus assimilis baurakiensis*) eggs was obtained on Lady Alice Island, Hen and Chickens Group, during the 1994 breeding season. A time-lapse video camera filmed a kiore removing a Little Shearwater egg from a nesting chamber. This egg was later recovered, showing signs of damage typical of rat predation. A kiore was also filmed breaking open and eating a punctured hen egg that had been placed in a shearwater burrow. Sixteen (55%) of the 29 nests monitored failed during incubation, and predation by kiore was the probable cause of failure for up to 75% of these nests.

KEY WORDS: *Rattus exulans*, *Puffinus assimilis*, shearwater, egg predation.

INTRODUCTION

The kiore, or Polynesian rat (*Rattus exulans*) is the smallest of three rat species present in New Zealand, and is now confined to offshore islands and parts of South Westland and Fiordland (Atkinson & Moller 1990). Most of the offshore islands in New Zealand with kiore are also breeding sites for burrow-nesting seabirds, and the impact that kiore have on these species is uncertain. The diet of kiore consists mainly of grass seeds and shoots, leaves, fruits, and invertebrates (Campbell *et al.* 1984, Newman & McFadden 1990, Roberts & Craig 1990) although they can have a large impact on seabird populations. On Kure Atoll, Hawaii, kiore prey on the eggs, chicks, or adults of at least five seabird species (Kepler 1967, Fleet 1972, Wirtz 1972). In New Zealand, there is strong circumstantial evidence that kiore prey on the eggs of the Diving Petrel (*Pelecanoides urinatrix*) (Thoresen 1967), and the eggs and chicks of Cook's Petrels (*Pterodroma cookii*) (Imber 1978, 1984).

Interactions between kiore and the North Island Little Shearwater (*Puffinus assimilis baurakiensis*), a small seabird endemic to islands off the north-east coast of the North Island, were observed during a study of the breeding biology of the Little Shearwater on Lady Alice island. As all other Procellariidae, the Little Shearwater lays a one-egg clutch with no re-laying. Both members of the pair alternate incubation shifts, and incubation lasts approximately 54 days (Warham 1955, 1958). The Little Shearwater is non-migratory and breeds in the winter (Glauert 1946).

At the time of our study, kiore were the only introduced predator present on the island. In this paper we present evidence that kiore preyed on the eggs of the Little Shearwater. We also describe the signs left by kiore after preying on eggs, and discuss the impact of kiore predation on the Little Shearwater.

STUDY SITE AND METHODS

Lady Alice Island (35°54'S, 174°44'E; 138 ha) is the largest of the Chickens Islands in the Hen and Chickens Group. Four procellariid species breed on Lady Alice Island - Little Shearwaters and Grey-faced Petrels (*Pterodroma macroptera*) in winter; and Pycroft's Petrels (*P. pycrofti*) and Flesh-footed Shearwaters (*Puffinus carneipes*) in summer. Tuatara (*Sphenodon punctatus*) are also present on Lady Alice Island.

Twenty-nine burrows containing breeding Little Shearwaters were monitored continuously during six trips to the study site in 1994: 14 - 22 June, 19 - 29 July, 16 - 30 August, 12 - 26 September, 12 - 21 October, and 18 November - 4 December. Adult attendance during incubation was recorded by using a 'fence' of twigs set up over the burrow entrance. Whenever a fence was displaced, the nesting chamber was checked to see if an incubating bird was present. When nests failed during the incubation stage, egg shell remains were collected and photographed, and nest material in the burrow was examined for evidence of the cause of failure. In order to determine the effect of investigator disturbance, ten control burrows were used. These burrows were visited once at the start of the incubation period, to determine that an incubating Little Shearwater was present. The control burrows were not visited again until the end of the breeding season, when they were checked for the presence of Little Shearwater chicks.

A time-lapse video camera with an infra-red light source was used at a nesting chamber which contained an incubating Little Shearwater. The roof of the nesting chamber was removed, and the camera was erected on top of a light-proof box, pointing directly down into the chamber. The camera was run for a total of 157 hours over 11 nights, between 13 September and 18 October 1994. After a kiore was filmed removing a Little Shearwater egg, a hen egg was placed in the same nest. The nest material was depressed so that an egg could not easily be rolled out of the nesting chamber. The hen egg was larger than the Little Shearwater egg, so it was punctured to make it more accessible for kiore.

To obtain comparative material for identifying predator species from feeding signs, a punctured hen egg was offered to three caged kiore. Damage to the egg shell was photographed, and used to verify predator identity.

RESULTS

Unattended eggs

During the periods of monitoring, Little Shearwater eggs were left unattended for one or more days in at least 77% of the burrows (N = 29), for an average of 1.9 days (S.D. = 1.5 days, range = 1 - 4; N = 26). In burrows where eggs were left unattended, the incubating adult was absent for an average of 1.5 times (S.D. = 0.6, range = 1 - 3).

Evidence of kiore predation of Little Shearwater eggs

The video camera filmed a kiore removing an uncracked Little Shearwater egg from the nesting chamber at 02:50 h on 14 October 1994. This egg had been left unattended since 20:25 h on the previous night. The kiore tucked the egg under its



FIGURE 1 - Kiore removing a Little Shearwater egg from the nesting chamber (video still on top, interpretation aided by a drawing).

chin (Figure 1), and removed it from the camera's field of view in 9 seconds. No kiore visited this burrow again on the same night. The following morning, the egg was recovered from the burrow where its contents had been eaten just out of view of the camera. A kiore was filmed breaking open and eating a punctured hen egg in the same burrow in full view of the camera at 20:35 h on 14 October 1994. After this predation event, the nesting chamber was visited four times during the same night by a kiore for periods lasting between 7 seconds and *c.* 5 minutes. During these visits, the kiore searched through nest material in the nesting chamber.

Signs left by kiore on Little Shearwater and hen eggs

The Little Shearwater egg which was filmed being removed from the nesting chamber by a kiore is shown on Figure 2a. Damage to this egg was similar to signs left by other rat species, and included a large hole at the narrow end with a jagged edge where small pieces of egg shell (mean width = 0.5cm) had been broken off, and one set of incisor marks on the edge of the hole. The hen egg which was filmed being eaten by a kiore was broken into two large pieces, both of which had jagged edges. The hen egg eaten by captive kiore (Figure 2b) showed similar damage to marks on both the Little Shearwater egg and the hen egg which were filmed. Neither of the hen eggs had incisor marks on them. Numerous pieces of egg shell from both the Little Shearwater and the hen egg were found spread throughout the nesting material, indicating that kiore "snuffle" or spread pieces of egg shell around inside the nest lining after preying on eggs. Kiore droppings were also found in the nest.

At the other Little Shearwater nests containing eggs whose predation was attributed to kiore, the signs left were similar to that described above. Complete removal of the egg was also attributed to predation; at one burrow the egg disappeared overnight and no egg shell remains were found in or around the burrow.

Timing of egg predation

The date of egg failure was recorded for seven nests where we suspected predation by kiore. The mean length of time to failure after laying was 43 days (S.D. = 9.2 days). The mean incubation period of the Little Shearwater on Lady Alice Island was 57 days (S.D. = 1.1 days, N = 4), approximately eight weeks. All predation for which the date was recorded occurred in the second half of the incubation period, mostly during the sixth or seventh week.

Impact of kiore on Little Shearwater breeding success

At the start of the breeding season, the 29 burrows monitored contained Little Shearwater adults incubating eggs. Of these nests, 16 (55%) failed during incubation. Thirteen chicks hatched, of which 11 survived to fledging. The overall breeding success of Little Shearwaters during the 1994 breeding season was 38%. Of the ten control burrows, three (33%) were successful to the fledging stage. There was no significant difference in breeding success between the control burrows and those burrows monitored throughout the breeding season ($\chi^2 = 0.68$, N.S.).

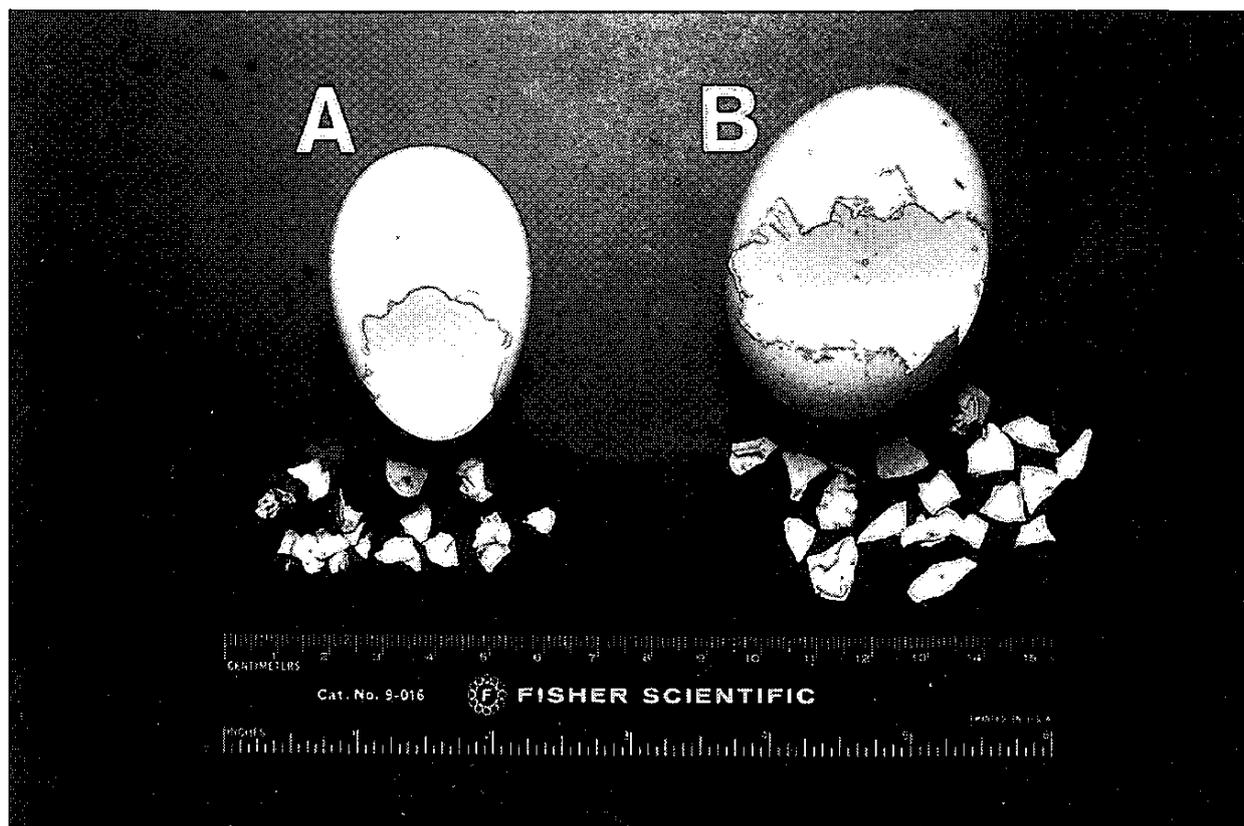


FIGURE 2 - Remains of a Little Shearwater egg which was filmed being removed from the nesting chamber by a kiore (a). Remains of a domestic hen egg placed in a cage with captive kiore (b). Note the large holes in both eggs, with jagged edges, and the numerous small egg shell pieces.

Predation by kiore was the probable cause of failure for at least 12 (75%) of the 16 nests which failed during incubation. All of these nests contained egg shells bearing signs of kiore damage, similar to those described above. Moreover, kiore droppings were found in seven of the 12 burrows. At the other four burrows which failed during incubation, two were suspected to have failed due to Little Shearwater adults breaking the eggs, and two failed for unknown reasons.

Overall, kiore predation probably occurred in 13 (45%) of the 29 nests with Little Shearwater eggs.

DISCUSSION

The video footage of a kiore removing a Little Shearwater egg from the burrow provides the first evidence of kiore preying on seabird eggs in New Zealand. Recovery next morning of this egg showing signs of rat damage left no doubt that kiore prey on the eggs of the Little Shearwater.

It is very important to identify the sign left by different mammalian predators, because this is usually the only way that a predator can be identified after a predation event (Moors 1978). The signs left by kiore on Little Shearwater eggs were similar to signs left by other rat species (Moors 1978, Major 1991). We cannot exclude the possibility that some of these nests failed due to reasons not related to kiore predation, such as breakage by tuatara or Little Shearwater adults. Therefore, some of the eggs found with kiore sign may have been scavenged rather than preyed on by kiore.

Predation occurred late in the incubation period, and may indicate that rats learned to exploit a new food source as the season progressed. Grant *et al.* (1981) suggested that the removal and eating of petrel eggs is a learned behaviour by black rats (*R. rattus*). Imber (1984) found an increasing rate of rat (*Rattus* spp.) predation of gadfly petrel (*Pterodroma* spp.) eggs through the incubation period, which also suggested that rats learned to prey on eggs. Other explanations for the increase in the rate of predation include alternative kiore food sources declining through the winter, or an increase in predation opportunities due to changes in behaviour of Little Shearwater adults.

Several aspects of the behaviour of Little Shearwaters during the breeding season may increase their vulnerability to predation by kiore. Chicks start pipping up to eight days before hatching (*pers. obs.*), and adults often leave eggs unattended for a night at this stage, presumably to feed before the chick hatches. A combination of the egg shell being cracked by the emerging chick and a high rate of non-attendance makes the eggs especially vulnerable just before hatching. Little Shearwater eggs are frequently left unattended during the incubation period. Temporary absence during incubation is common in many procellariiform birds (Boersma & Wheelwright 1979, Chaurand & Weimerskirch 1994), in which the embryos can survive intermittent chilling. Such behaviour may increase the vulnerability of eggs to rat predation (Imber 1984).

After establishing that an introduced mammal is preying on a bird species, it is important to determine whether this induces population decline (Moors 1983, Moors *et al.* 1992), so that appropriate management decisions can be made. The long-term impact of kiore predation on seabirds and other native species is a contentious issue. Atkinson and Moller (1990) implicated kiore in the extinction of mainland petrel species such as Cook's Petrels. Craig (1986), however, suggested that the evidence of the effects of kiore on endemic biota was equivocal and circumstantial, with no direct evidence that kiore reduced seabird numbers. The impact of kiore on Little Shearwater breeding on Lady Alice Island was high during 1994, with 62% of all nests failing, and predation by kiore responsible for up to 75% of these. This rate of predation causes a decline in the population, if losses due to kiore predation exceed annual recruitment (Moors 1983). Although our results from this short study may not be representative, breeding success was not higher in 1993 (50%, $N = 20$; R. J. Pierce, unpubl). It would be prudent to minimise the impact of a predator responsible for a such a high rate of nest failure as even small rates of loss by predation may be enough to cause insufficient recruitment in a population (Moors 1983).

Kiore were eradicated from Lady Alice Island in October 1994, providing an opportunity to monitor the breeding success of the Little Shearwater in the absence of kiore. Continued monitoring of the population will determine whether annual productivity is higher after kiore have been eradicated. The best indication of the impact of kiore predation on the Little Shearwater will be whether recruitment rate, and therefore population density, increases after the eradication. The age at which Little Shearwaters first breed is unknown. The closely related Manx Shearwater *P. puffinus* first breeds at about five years old (Harris 1966) and thus it may be necessary to continue studies beyond five years to measure recruitment and thus assess the impact of kiore on the Little Shearwater population. An immediate increase in annual productivity would signal a beneficial effect of kiore eradication.

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LITERATURE CITED

- ATKINSON, I.A.E.; MOLLER, H. 1990. Kiore, *Rattus exulans* (Peale, 1848). Pp. 175-192 in King, C.M. (ed.) The Handbook of New Zealand Mammals. Oxford University Press, Auckland.
- BOERSMA, P.D.; WHEELWRIGHT, N.T. 1979. Egg neglect in the Procellariiformes: reproductive adaptations in the Fork-Tailed Storm-Petrel. *Condor* 81: 157-165.
- CAMPBELL, D.J.; MOLLER, H.; RAMSAY, G.W.; WATT, J.C. 1984. Observations on foods of kiore (*Rattus exulans*) found in husking stations on northern offshore islands of New Zealand. *N.Z. J. Ecol.* 7: 131-138.
- CHAURAND, T.; WEIMERSKIRCH, H. 1994. Incubation routine, body mass regulation and egg neglect in the Blue Petrel *Halobaena caerulea*. *Ibis* 136: 285-290.
- CRAIG, J.L. 1986. The effects of kiore on other fauna. Pages 75-83 in The offshore islands of northern New Zealand. New Zealand Department of Lands and Survey Information Series.
- FLEET, R.R. 1972. Nesting success of the Red-tailed Tropicbird on Kure Atoll. *Auk* 89: 651-659.
- GLAUERT, L. 1946. The Little Shearwater's Year. *Emu* 46: 187-192.
- GRANT, G.S.; PETTIT, T.W.; WHITTOW, E.C. 1981. Rat predation on Bonin Petrel eggs on Midway Atoll. *J. Field Ornithol.* 52: 336-338.
- HARRIS, M.P. 1966. Age of return to the colony, age of breeding and adult survival of Manx Shearwaters. *Bird Study* 13: 84-95.
- IMBER, M.J. 1978. The effects of rats on the breeding success of petrels. Pp. 67-72 in Dingwall, P.R.; Atkinson, I.A.E.; Hay, C. (eds.) The ecology and control of rodents in New Zealand nature reserves. Department of Lands and Survey Information Series, Wellington.
- IMBER, M.J. 1984. Exploitation by rats of eggs neglected by Gadfly Petrels. *Cormorant* 12: 82-93.
- KEPLER, C.B. 1967. Polynesian rat predation on nesting Laysan Albatrosses and other Pacific seabirds. *Auk* 84: 426-430.
- MAJOR, R.E. 1991. Identification of nest predators by photography, dummy eggs, and adhesive tape. *Auk* 108: 190-195.
- MOORS, P.J. 1978. Methods for studying predators and their effects on forest birds. Pp. 47-56 in Dingwall, P.R.; Atkinson, I.A.E.; Hay, C. (eds.) The ecology and control of rodents in New Zealand nature reserves. Department of Lands and Survey Information Series 4.
- MOORS, P.J. 1983. Predation by mustelids and rodents on the eggs and chicks of native and introduced birds in Kowhai Bush, New Zealand. *Ibis* 125: 137-154.
- MOORS, P.J.; ATKINSON, I.A.E.; SHERLEY, G.H. 1992. Reducing the rat threat to island birds. *Bird Cons. Int.* 2: 93-114.
- NEWMAN, D.G.; MCFADDEN, I. 1990. Seasonal fluctuations of numbers, breeding and food of kiore (*Rattus exulans*) on Lady Alice Island (Hen and Chickens Group), with a consideration of kiore: tuatara relationships in New Zealand. *N.Z. J. Zool.* 17: 55-63.
- ROBERTS, M.; CRAIG, J.L. 1990. The demography of kiore, *Rattus exulans*, in three habitats. *N.Z. J. Zool.* 17: 43-53.
- THORESEN, A.C. 1967. Ecological observations on Stanley and Green Islands, Mercury Group. *Notornis* 14: 182-200.
- WARHAM, J. 1955. Observations on the Little Shearwater on the nest. *West. Aust. Nat.* 5: 31-39.
- WARHAM, J. 1958. Photographic studies of some less familiar birds. XCII. Little shearwater. *Brit. Birds* 51: 393-397.
- WIRTZ, W.O. 1972. Population ecology of the Polynesian Rat, *Rattus exulans*, on Kure Atoll, Hawaii. *Pacific Sci.* 26: 433-464.

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