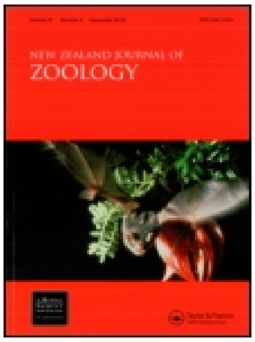

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Rodents and their predators in the eastern Bay of Islands

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Abstract Traps were set for rodents and mustelids on five islands (Motukiekie, Moturua, Okahu, Urupukapuka, and Waewaetorea) in the eastern Bay of Islands in March 1984. Kiore (*Rattus exulans*) were caught on Moturua Island and Norway rats (*R. norvegicus*) on all five islands, but no mustelids were caught or seen. Kiore on Moturua Island were very scarce compared with other northern offshore islands, perhaps because of competition from Norway rats and the presence of stoats and cats. Kiore were breeding and young matured in the season of their birth. Norway rats were scarce and found mainly near the shoreline on four of the islands. On Waewaetorea Island they were plentiful and widespread despite the possible presence of stoats. About a third of the mature females were visibly pregnant. Average litter size was 6.9 embryos, and 44% of the parous females had borne two or three litters. Females first ovulated at 180 ± 5 g weight and 356 ± 5 mm total length on average. Males first produced sperm at 189 ± 7 g weight and 364 ± 4 mm total length. Most rats matured before reaching a tooth-wear age index of 5.

Keywords *Rattus exulans; Rattus norvegicus; Mustela erminea;* islands; population; reproduction

INTRODUCTION

Our knowledge of the distribution of rodents on the northern offshore islands is still incomplete. The trapping reported here was for rodents and mustelids on five islands (Motukiekie, Moturua, Okahu, Urupukapuka, and Waewaetorea) in the eastern Bay of Islands in March 1984.

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Kiore (*Rattus exulans*) population density, reproduction, and sexual development have not been extensively studied on islands with either stoats (*Mustela erminea*) or cats (*Felis catus*) which had been reported on three of the islands where we trapped (McFadden, pers. comm.; Hitchmough & McCallum 1980). Moller & Craig (unpublished data) predict kiore will have lower density, prolonged breeding, earlier sexual maturation, and lower litter size on islands where predators are present.

Information on Norway rat (*Rattus norvegicus*) population ecology in New Zealand is limited to a few studies (Beveridge & Daniel 1965; Daniel 1969; Bettesworth 1972; Moors 1985); only the latter two authors give detailed analyses of reproduction and sexual development of the type presented here.

STUDY AREA AND METHODS

The five islands studied in March 1984 are in the eastern part of the Bay of Islands Historic and Maritime Park, 7–12 km northeast of Russell (Fig. 1). Urupukapuka (208 ha) is permanently inhabited; Moturua (162 ha) and Motukieke (33 ha) have a few holiday homes which are occupied intermittently. Waewaetorea (47 ha) and Okahu (21 ha) have no dwellings but are often visited by holidaymakers making day trips. All islands have been farmed at some time but stock are now kept only on Urupukapuka and Waewaetorea.

Trap-lines were operated in three habitat types (scrubland/bush, grassland, and shoreline). The following description of the vegetation in these habitats is based mainly on Esler (1973).

Scrubland/bush on all islands is predominantly tea tree (*Leptospermum scoparium* and *L. ericoides*) but on Moturua there are also small areas containing kawakawa (*Macropiper excelsum*), whau (*Entelea aborescens*), mahoe (*Melicytus ramiflorus*), cabbage trees (*Cordyline australis*), *Coprosma* species, tree ferns (*Cyathea dealbata* and *C. medullaris*), and brush wattles (*Albizia lophanta*).

Grassland on all islands is mainly danthonia (*Notodanthonia penicillata* and *N. racemosa*), ratstail (*Sporobolus africanus*), sweet vernal (*Anthoxanthum odoratum*), ricegrass (*Microlaena stipoides*), and paspalum (*Paspalum dilatatum*) with kikuyu

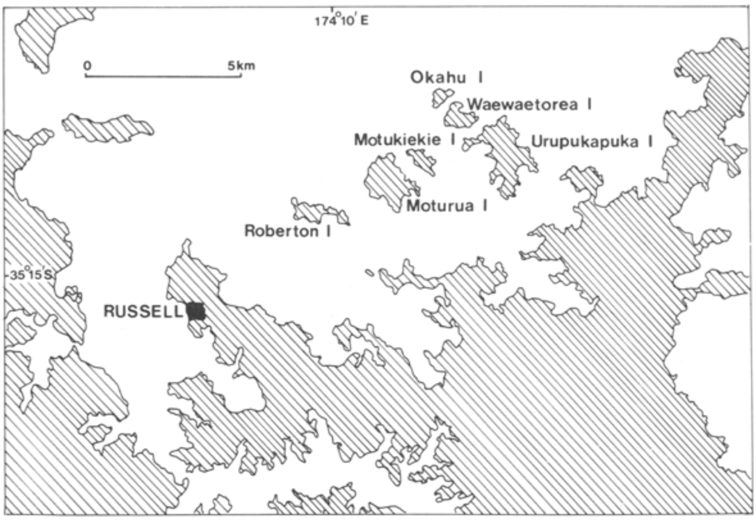

Fig. 1 The eastern Bay of Islands showing the five islands where rats were trapped.

grass (*Pennisetum clandestinum*) prominent above the shoreline in some bays. One trap-line on Moturua was set through an area previously covered in manuka which had burned the year before this study. Burnt manuka stumps and branches remained standing amongst grasses which were rank but did not yet completely cover the earth. The grasses on Okahu were also rank (thigh-high in places), but here they formed a dense sward in which scattered flax (*Phormium tenax*) and pohutukawa (*Metrosideros excelsa*) grew. Grasses on Urupukapuka and Waewaetorea were cropped shorter by sheep and cattle than grasses on Moturua, Motukiekie, and Okahu, where there were no stock. Part of the grassland trap-line on Waewaetorea followed the fence excluding stock from reserve areas, so here rats were sampled on the boundary between rank grasses and shrubs, and cropped pastureland. Inkweed (*Phytolacca octandra*) was abundant on Waewaetorea, but not seen elsewhere.

"Shoreline" traps were set in grassland along the edge of the beach, or on sand or rocks above the high-tide mark.

Rat traps (Ezeset Supreme brand) were baited with a mixture of peanut butter and rolled oats and set 10–15 m apart along transects (shown by dashed lines in Fig. 2). A mouse trap was placed alongside each rat trap for the last 4 trapping nights on Motukiekie after pellets were found there which may have been mouse faeces. Traps on Motukiekie were visited each day except 18 and 19 March (see Table 1).

Fenn traps were set on Moturua and Motukiekie in pairs between the rat traps and along stream banks (Fig. 2). They were set in wooden boxes or under PVC tunnels which were covered with branches, litter, stones, or driftwood and baited with commercial fish-based cat food. Fenn traps were set between 13 and 22 March but were not checked on 18, 19, and 21 March.

Rats were weighed and their total length (excluding terminal hair filaments) measured. Pregnant females were reweighed after the uterus was removed; the weights presented in the results exclude the weight of the uterus of pregnant females.

For females the vagina was scored as perforate or imperforate and lactation judged by whether or not milk could be expressed. The uterus condition (thread, string, cord, or pregnant) was noted, corpora lutea were judged as present or absent from macroscopic inspection of the ovaries, and the number and length (crown-rump) of any embryos determined. Uterine scars were judged new or old (from their size) and were counted in all but three parous females.

For males the length of one testis was measured and sexual maturity was judged from the presence or absence of enlarged tubules within the cauda epididymis (Jameson 1950).

The skulls of all rats were cleaned by dermestid beetles. Norway rats were aged from tooth-wear indices on upper molars devised by Karnoukhova (1972), but only after incorporating the following modifications or standardisations: (i) longitudinal fusions of tubercles in the third molar occurred very early and were therefore ignored when determining wear class; (ii) tubercle 7 in M^2 was separated by a distinct trough from neighbouring tubercles until teeth were very worn; (iii) wear sometimes varied from one side of the jaw to the other. These standardisations were with the provisos that we ignored

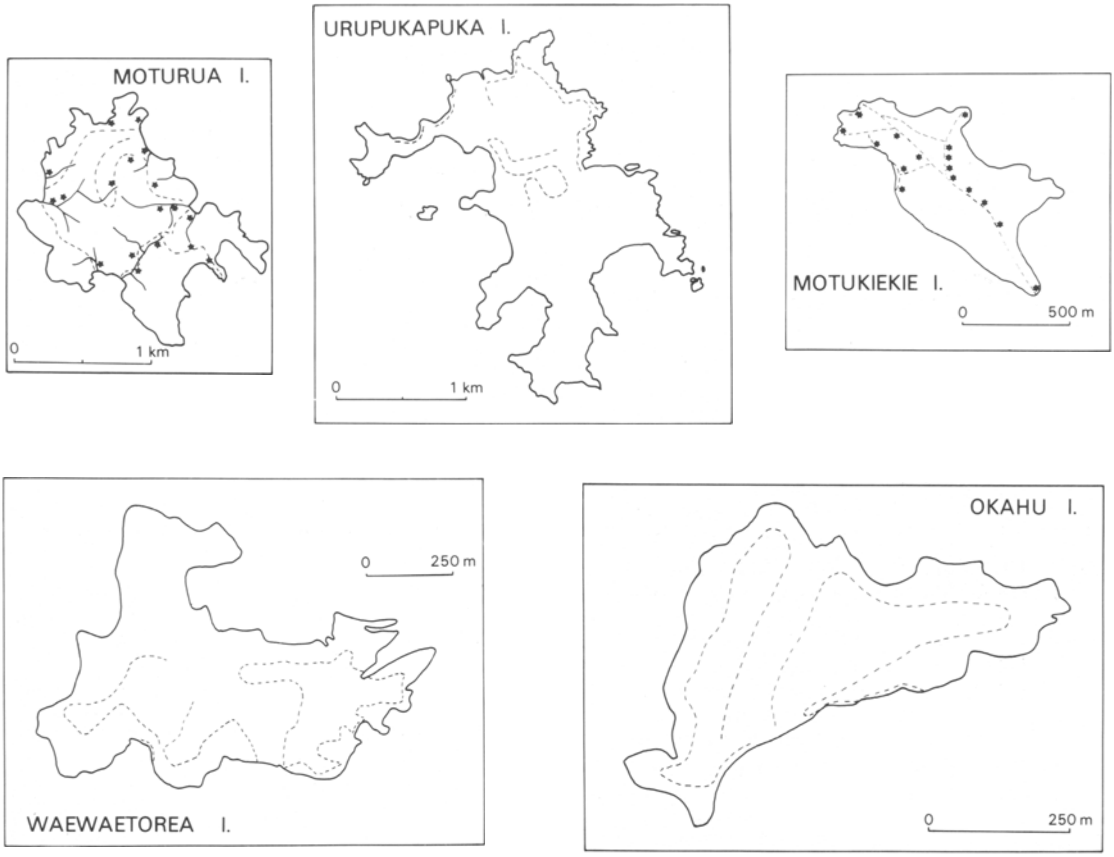

Fig. 2 Maps of islands trapped. Dashed lines show trap transects. Stars show location of Fenn traps. Solid lines on Moturua show creeks.

the criterion of "pressing against" neighbouring tubercles, and that we always chose the most worn category when assigning an age class (e.g., if longitudinal fusions in dentine had occurred on the lingual margin of M^1 on one side of the jaw, but not the other, we assigned a tooth-wear class of 6 rather than 5). All skulls were aged independently by each of us and any differences resolved by re-inspection.

Samples were too small for statistically robust comparisons of all tooth-wear classes between islands, habitats, and sexes. Accordingly, χ^2 tests of independence were performed on pooled samples of the number of younger rats (tooth-wear class 3–4) compared with older rats (tooth-wear class 5–7). Whenever expected frequencies were too small for comparisons of trap success (and the proportion of rats with shortened tails) Fisher's exact test was used.

The mean weight and length at onset of sexual maturity was determined by plotting percentage mature (on a probability scale) against the midpoint of successive partitions of body measurements (on an arithmetic scale). A line was fitted by eye from which the normal equivalent deviate (used to calculate the 95% confidence interval) was read.

RESULTS

Trap success and population density

Norway rats were trapped on all islands and kiore were also caught on Moturua. Neither mice (*Mus musculus*) nor ship rats (*Rattus rattus*) were caught.

A total of 153 Fenn trap days on Moturua caught four Norway rats (all from the shoreline), one kiore (in grassland) and no mustelids. Nothing was caught in 121 Fenn trap days on Motukiekie.

Trap effort and trap success figures for rat traps are presented in Table 1 for each habitat and island. The "effective trap nights" calculation incorporates a correction by subtracting half a trap night for each trap found sprung by any cause (Nelson & Clark

Table 1 Rat trap nights set and trap success in the eastern Bay of Islands.

Island (and nights trapped)	Datum	Habitat: Bush	Grass-land	Shore-line	Burnt manuka/ grass-land	All habitats
Moturua (13–16 March)	Effective trap nights	548.5	83.5	43.5	332.0	1007.5
	Corrective % trap success for *R. exulans*	0.5	1.2	0	2.4	1.2
	(95% confidence interval)	(0–2)	(0–7)	(0–8)	(1–5)	(1–2)
	Corrective % trap success for *R. norvegicus*	0.4	0	0	0	0.2
	(95% confidence interval)	(0–1)	(0–4)	(0–8)	(0–1)	(0–1)
Motukiekie (14–19 March)	Effective trap nights	357	454.5	65.5	—	877
	Corrected % trap success for *R. norvegicus*	0	0	1.5	—	0.1
	(95% confidence interval)	(0–1)	(0–1)	(0–8)	—	(0–1)
Urupukapuka (18–20 March)	Effective trap·nights	436	315	64	—	815
	Corrected % trap success for *R. norvegicus*	0	0	1.6	—	0.1
	(95% confidence interval)	(0–1)	(0–1)	(0–9)	—	(0–1)
Okahu (19–21 March)	Effective trap nights	—	408	36	—	444
	Corrected % trap success for *R. norvegicus*	—	0.2	5.6	—	0.7
	(95% confidence interval)	—	(0–1)	(1–20)	—	(0–2)
Waewaetorea (21–22 March)	Effective trap nights	18	352	73.5	—	443.5
	Corrected % trap success for *R. norvegicus**	55.6	25.6	29.9	—	27.5
	(95% confidence interval)	(31–78)	(21–31)	(20–42)	—	(23–32)

* includes one trap containing paw only.

1973). Approximate 95% confidence intervals for corrected percentage trap success were calculated from tables of Mainland et al. (1956). Nothing was caught in 502 effective mouse trap nights on Motukiekie.

Trap success for kiore on Moturua averaged 1.2% (95% CI = 1–2%) (Table 1). Significantly more traps (snap-traps and Fenn traps combined) caught kiore in grassland than in bush (Fisher's exact test: $P=0.0142$), but there was no difference between shoreline and the other habitats (grassland $P=0.232$; bush $P=0.714$). The "burnt manuka" line was considered as grassland habitat in these comparisons.

Trap success for *R. norvegicus* was considerably higher on Waewaetorea (27.5%; 95% CI=23–32%) than on all other islands (combined data, corrected % trap success = 0.2%; 95% CI=0–0.4%). Some of the 22 traps missing on Waewaetorea (Table 1) may have caught rats (traps were often dragged by captured rats 5–10 m away form where set). If traps missing are counted as rats caught, overall trap success on Waewaetorea would have been 30.9% (95% CI=27–35%). Of the 587 trap nights set on Waewaetorea, 68% caught rats, were missing, had bait taken, or were sprung.

Signs other than trap success suggested high density of rats on Waewaetorea. Rat faeces were abundant even in closely cropped pasture over 100 m from cover. Two live rats were seen while clearing the trap-line in mid morning. Seven percent of 121 rats caught were eaten in the trap by other rats.

A significantly higher proportion of effective trap nights (Fenn and snap-traps combined) caught Norway rats along the shoreline than in bush ($P= 1.63 \times 10^{-5}$) and grassland ($P= 1.46 \times 10^{-6}$) on all islands other than Waewaetorea. There was no significant difference in catch between bush and grassland on these islands ($P=0.3454$). On Waewaetorea trap success was significantly higher in bush than in grassland ($\chi^2=7.81$, d.f. = 1, $P < 0.01$) and than along the shoreline ($\chi^2=4.09$, d.f. = 1, $P < 0.05$). There was no difference in catch between grassland and shoreline ($\chi^2=0.65$, d.f. = 1, $P > 0.05$).

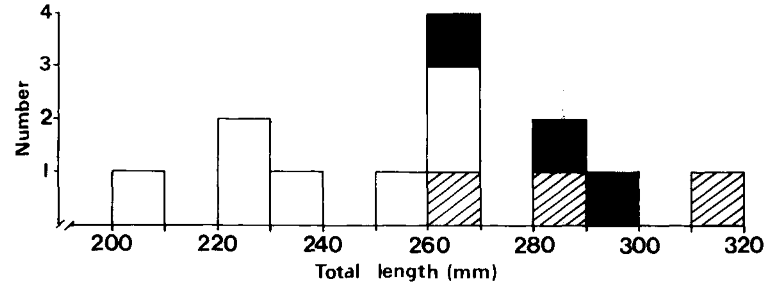

Fig. 3 Total lengths of *Rattus exulans* caught on Moturua Island. Females are shown by hatched bars. Males with testes > 12 mm long are shown by black bars. Males with testes < 12 mm long are shown by open bars.

Table 2 Tooth-wear class of male and female Norway rats on Waewaetorea and other islands.

Wear class	Waewaetorea		All other islands	
	Females	Males	Females	Males
3	3	3	1	0
4	34	49	5	2
5	2	4	0	2
6	4	1	0	0
7	10	5	0	1
all	59*	62	6	5

* includes six females of unknown tooth-wear class.

Table 3 Number of Norway rats of each sex and age group caught in each habitat on Waewaetorea Island.

Sex	Age classes	Habitat		
		Bush	Grassland	Shoreline
females	3 & 4	5	24	8
	5–7	1	13	2
	unknown	0	4	2
males	3 & 4	4	40	8
	5–7	0	8	2

Kiore autopsies

Two of three female kiore collected were lactating. The third showed signs of recent ovulation and development of the uterus, but was not visibly pregnant nor carrying uterine scars. This female weighed 46 g and was 263 mm long.

None of 10 male kiore had visibly enlarged tubules in their cauda epididymis. However, three had testes 12–16 mm long, the size range in which spermatogenesis begins in kiore on Tiritiri Island (Moller 1977). This suggests the males caught on Moturua were nearing sexual maturity.

Three of the kiore collected were less than 230 mm long (Fig. 3) and weighed less than 35 g.

Norway rat sutopsies

Pregnant Norway rats were trapped on Moturua, Urupukapuka, and Waewaetorea, but no sexually mature females were trapped on Okahu or Motukiekie. There were no significant differences in the age structure or sex ratio of Norway rats from Waewaetorea and that on all other islands trapped (Table 2; age, $\chi^2=0.12$, d.f. $=1$, $P > 0.05$; sex ratio, $\chi^2=0.003$, d.f. $=1$, $P=0.96$). All subsequent analyses are for Norway rats on Waewaetorea Island only unless otherwise stated.

Sex and age ratios for rats from the three habitats did not differ (Table 3; sex, $\chi^2=1.059$, d.f. $=2$, $P=0.59$; age, $\chi^2=1.00$, d.f. $=2$, $P > 0.05$).

There were significant differences in the mean weight and mean total length of male and female rats of a given tooth-wear class (Table 4). Males were heavier and longer than females of class 4 where sample sizes were largest (Table 5). Growth was rapid between tooth-wear classes 3 and 4 but nearly ceased between 6 and 7. These mean weights include the stomach which averaged 8.0 g (SE=0.49, $n=76$, range 1–20 g). Rats with shortened tails (from old injuries not associated with the snap-trap) were not considered in the analyses of total length in Tables 4 and 5. All five of the rats (65 females and 67 males) with shortened tails were males. This difference between the sexes is statistically significant (Fisher's exact test: $P=0.031$).

Only 54% ($n=59$) of females were mature (i.e., had ovulated as judged by the presence of corpora lutea or follicles, and visible pregnancy or uterine scars). Ten (31%) of these mature females were visibly pregnant and a further five (16%) were lactating. No females were lactating as well as being visibly pregnant.

There was a mean of 6.7 (SE=0.29) visible embryos in nine females from Waewaetorea (the other pregnant female had been partly eaten and her litter size is unknown). The mean litter size was 6.9 (SE=0.31) when two pregnant females from other islands are included. When four counts of new scars are also included the overall number of implantation sites per pregnancy is 6.9 (SE=0.26, $n=15$). One of the 11 pregnant females was resorbing a single embryo. The distribution of embryo

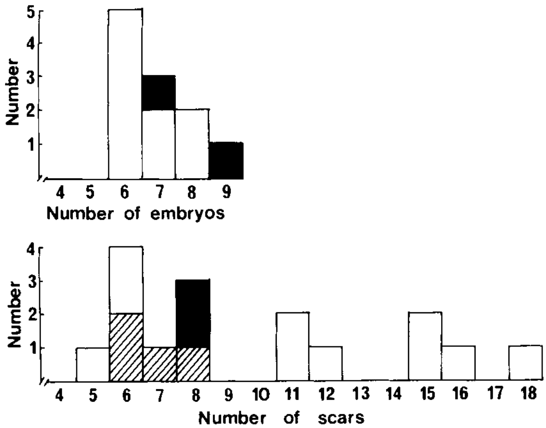

Fig. 4 Numbers of implantation sites in *Rattus norvegicus;* (upper) embryos per pregnancy; (lower) uterine scars. Black bars show embryo counts and old scar counts on islands other than Waewaetorea. Open bars show embryos and old scars on Waewaetorea. Hatched bars show recent scars on Waewaetorea.

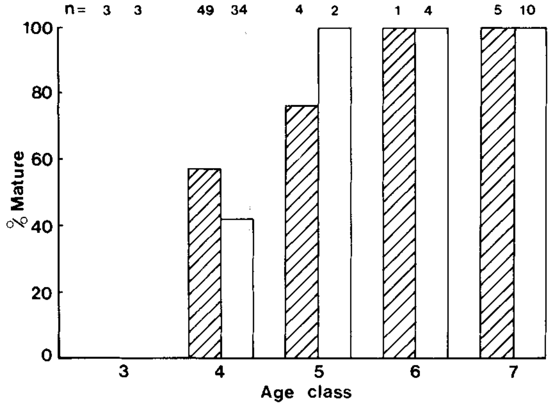

Fig. 5 Percentage of male (hatched bars) and female (open bars) *Rattus norvegicus* which were mature in relation to tooth-wear class on Waewaetorea Island. Sample sizes are given at the top of each bar.

and uterine scar counts (Fig. 4) suggests 7 (44%) of 16 parous females had carried two or three litters.

Females first ovulated at an average weight of 180 g (95% CI = 5.0 g) and a length of 356 mm (95% CI = 5.2 mm). The heaviest immature female weighed 195 g and the longest immature female was 379 mm long. The smallest mature female weighed 159 g and was 337 mm long. All females had ovulated by the time they reached tooth-wear class 5, but sample sizes were small (Fig. 5).

Sixty percent ($n = 60$) of males caught on Waewaetorea were mature as judged by the presence of visibly enlarged tubules in their cauda epididymis. The mean weight and total length at onset of maturity was 189 g (95% CI = 7.4 g) and 364 mm (95% CI = 4.2 mm). The largest immature male weighed 214 g and was 380 mm long. The smallest mature male weighed 173 g and was 352 mm long. Most males matured at tooth-wear class 4 but one immature male of class 5 was trapped (Fig. 5). The shortest mature testis was 19 mm long and the longest immature testis measured 21 mm.

DISCUSSION

Species present

Our trapping showed that Norway rats are present on Moturua, Motukiekie, and Okahu and confirmed earlier findings that kiore are present on Moturua, and Norway rats on Urupukapuka and Waewaetorea (Appendix 1).

McFadden (1982b) saw stoat prints at Army Bay on Moturua in mid 1982. The Bay of Islands Maritime and Historic Park Board staff caught two stoats in 148 gin trap-nights during 29 July–2 August 1985 on Moturua (S. Anderson, pers. comm.). A further 135 gin trap nights during 10–14 September 1985 caught two stoats. The lack of captures during our study suggests stoats were at low numbers, as often found on the mainland, where catch success is often below one stoat per 100 trap nights (King 1983). Stoats were probably

Table 4 Two way analysis of variance of weight and total length of Norway rats (the independent variables) on tooth-wear class and sex (the dependent variables).

Weight	Interaction effect:	$F = 2.115$, d.f. = 4, 94, $P = 0.085$
	Tooth-wear class:	$F = 29.310$, d.f. = 4, 94, $P < 0.001$
	Sex:	$F = 11.763$, d.f. = 1, 94, $P < 0.001$
Total length	Interaction effect:	$F = 2.965$, d.f. = 4, 94, $P = 0.024$
	Tooth-wear class:	$F = 27.500$, d.f. = 4, 94, $P < 0.001$
	Sex:	$F = 4.435$, d.f. = 1, 94, $P = 0.038$

Table 5 Weight and total length of female and male Norway rats of each tooth-wear age class on Wawaetorea Island.

Age class	Sex	Weight (g) Mean	*n*	SE	Range	Total length (mm) Mean	*n*	SE	Range
3	female	145	3	25	96–176	328	3	26	276–354
	male	92	3	22	53–130	278	3	33	217–332
4	female	173	29	6	109–253	354	32	4	309–397
	male	206	47	6	133–287	371	45	3	318–418
5	female	214	2	55	159–269	370	2	33	337–404
	male	246	3	31	192–301	390	3	16	358–406
6	female	269	4	13	240–302	403	4	5	394–419
	male	251	1	—	—	404	1	—	—
7	female	271	9	11	222–332	409	10	6	383–434
	male	314	4	16	268–343	414	5	8	394–436
All	female	200	47	8	96–332	368	51	5	276–434
ages	male	210	58	7	53–343	371	57	4	217–436

Table 6 Occurrence of rodents and small carnivore species on islands in the eastern Bay of Islands (√ : present, × : absent, √? : presence not confirmed but island within swimming range of stoats).

	Rattus norvegicus	*Rattus rattus*	*Rattus exulans*	*Mus musculus*	*Mustela erminea*	*Felis catus*
Moturua	√	×	√	×	√	√
Motukiekie	√	×	×	×	√?	?
Urupukapuka	√	×	×	×	√	?
Okahu	√	×	×	×	√?	?
Waewaetorea	√	×	×	×	√?	?

also present on Motukiekie because they could easily swim the 350 m of calm water that separates it from Moturua (Taylor & Tilley 1984).

The presence of rats, stoats and cats on the five islands studied is summarised in Table 6.

The absence of kiore on all but Moturua Island is interesting in view of the previous intensive use of these islands by Maoris, who are likely to have introduced this rat for food. Competitive interactions with other rats, as stressed by Taylor (1984), may lessen the chance of persistence of kiore on some islands.

Kiore

Kiore trap success on Moturua in this study (Table 1) was similar to that obtained there by Page (1981) and McFadden (1982a) (Appendix 1). McFadden (1982b) obtained a higher trap sucess in June/July 1982 (18%) but with only 24 trap nights the 95% confidence intervals were wide (5–40%). Kiore trap success on Moturua (present study and Appendix 1) was very low compared to that on other northern offshore islands in late summer and autumn (Moller 1977). Competition or interference by Norway rats may have reduced kiore density (Taylor 1975, 1978, 1984) on Moturua. Trap success for kiore was lower on Kapiti Island (where Norway rats also live) and on southern South Island and Stewart Island (all rats present) than on northern offshore islands where kiore occur alone (Moller 1977). However, the effects of differences in presence of predators, habitat, and size of island will need to be considered before the relative importance of competition will be known.

Daniel (1978) stressed that cats and stoats significantly reduce the numbers of rats in New Zealand. Two cats were abandoned by a resident on Moturua in July 1983 (S. Anderson, pers. comm.). One was killed in September 1983, one in August 1984, and a third in December 1985 (S. Anderson, pers. comm.). Since three cats were caught and only two were known to have been abandoned, a feral population may persist there. Predation by cats and stoats may in part cause low kiore density.

Moller & Craig (unpublished data) suggested that when predators lower kiore density, kiore breed longer, mature earlier, and have smaller litters. The capture of lactating females and very small rats (Fig. 3) confirms recent recruitment to this population in mid March, 6–8 weeks after it ceased on Tiritiri (Moller 1977). A young female trapped on Moturua had reached sexual maturity at a much smaller size than occurs on Tiritiri (Moller 1977), but at a similar size to kiore maturing on Little Barrier (J. S. Watson unpublished data). Three young males caught on Moturua were judged near to sexual maturity, since they had 12–16 mm long testes, the sizes at which spermatogenesis began on Tiritiri (Moller 1977). Thus, young were reaching sexual maturity within their season of birth, and at a much smaller size, on Moturua and Little Barrier than is common on Tiritiri. Differences between these islands and Tiritiri may result from different seasonal distributions of food availability, but the present study does support a link between low kiore density, late summer breeding, and early sexual maturation.

A higher catch in grassland than elsewhere is consistent with Taylor's (1975) suggestion that kiore prefer grassland habitats. Kiore are less trappable in grassland than bush (Moller 1977); thus, the true difference in density between habitats is likely to be relatively greater than indicated by differential trap success. Competitive interactions with Norway rats may accentuate differences between habitats by partly excluding kiore from areas without dense ground cover (Moller 1977).

Norway rats

Norway rats were more abundant and more widely distributed on Waewaetorea than on all other islands studied. The catch was highest in bush but rats were ubiquitous. Rats on the other islands existed mainly along the shoreline, and then in much lower numbers. Taylor (1978) suggested Norway rats are ubiquitous in the absence of stoats but patchily distributed along waterways in their presence. If the high density and widespread population on Waewaetorea results simply from an absence of stoats there, why were densities not similarly high on Okahu, where stoats were also probably absent? The apparent stoat absence on Waewaetorea would then be an enigma because only 300 m of comparatively calm water separates Waewaetorea and Urupukapuka, and Taylor & Tilley (1984) showed that stoats regularly emigrate to islands up to 800 m offshore. It is certain that stoats occur on Urupukapuka because they have been regularly seen there (Hitchmough & McCallum 1980). A sprung rat trap on Urupukapuka smelt strongly of mustelid during the present study. Hitchmough & McCallum (1980) heard a report of a stoat being caught by a camper's cat on Waewaetorea, but the reliability of this record is unknown. If stoats are present then they are not influencing Norway rats as strongly on Waewaetorea as they are thought to elsewhere in New Zealand. The situation there deserves more study.

Waewaetorea had abundant inkweed patches but these were not seen on nearby Urupukapuka. Inkweed seeds were an important food of Norway rats from late summer to mid winter on Whale Island (Bettesworth 1972). No other obvious differences in vegetation were noticed between two islands which could have contributed to the large differences in density.

Trap success on Waewaetorea was less than on Mokoia Island (Beveridge & Daniel 1965) but was higher than on all other islands studied in New Zealand (Moors 1985). Trap success on the other islands of the eastern Bay of Islands was similar to that on Stewart Island but otherwise considerably lower than encountered elsewhere (Moors 1985).

The very similar sex and age ratios between islands and habitats suggest that seasonal reproduction and subsequent survival are broadly similar throughout in this study.

Capture of pregnant and lactating females and small rats testifies to previous and continuing reproduction in March. Beveridge & Daniel (1965), Bettesworth (1972), and Moors (1985) found breeding in March during their studies. The mean litter size in the present study was very close to that found on Whale Island (6.5 live embryos, 0.5 resorbing embryos) by Bettesworth (1972). The prevalence of pregnancy and the weight at onset of sexual maturity on Waewaetorea is intermediate to that in March 1971 on Whale Island (150 g for males, 225 g for females). These parameters are likely to vary throughout the season and with rat density.

Too few studies have yet been done to delineate in detail the seasonal pattern of population dynamics, reproduction and sexual maturation, and growth of Norway rats in the New Zealand region. Moors (1985) suggested non-commensal populations in New Zealand tend to be sparser, be smaller in size and lower in condition, exhibit delayed maturation, and have lower litter size than Norway rats in urban and rural environments studied elsewhere. He suggested shortage of nutritionally adequate food and shortage of fresh water may limit the population in the Noises Islands. Taylor (1978, 1984) suggested that predation and competition are important in some places. Moller & Craig (unpublished data) suggest island confinement (restricting dispersal) and predation will interact with the seasonal distribution of food availability to influence rodent demography. Many of the results presented from this short study will be judged consistent or inconsistent with each of these different perspectives only when overdue, long-term, and detailed studies of Norway rats in New Zealand ecosystems have been completed.

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APPENDIX

Previous rodent trapping on large islands of the eastern Bay of Islands.

Island	Source	Date	Trap nights set	Catch	Effective trap nights	Corrected % trap success (± 95% CI)
Moturua	Page (1981)	Oct 1981?	40 rat	Nil	40	0 (0–9)
	McFadden (1982 a)	17–22 Jan 1982	36 rat } 32 mouse }	1 *exulans*	67.5	1.5 (0–8)
	McFadden (1982 b)	27 Jun–2 Jul 1982	24 rat	4 *exulans*	22.0	18 (5–40)
Motukiekie	Page (1981)	Oct 1981?	18 rat	Nil	18	0 (0–19)
	McFadden (1982 a)	17–22 Jun 1982	36 rat	Nil	36	0 (0–10)
			32 mouse	Nil	32	0 (0–12)
	McFadden (1982 b)	27 Jun–2 Jul 1982	60 rat	Nil	60	0 (0–6)
Okahu	Page (1981)	Oct 1981?	14 rat	Nil	12.5	0 (0–26)
	McFadden (1982 a)	17–22 Jan 1981	40 rat	Nil	40	0 (0–9)
			28 mouse	Nil	28	0 (0–12)
	Anderson (unpub. data)	5–7 Jul 1983	40 rat	Nil	39.5	0 (0–9)
Urupukapuka	Hitchmough & McCallum (1980)	4–13 Jan 1980	75 rat	Nil	75	0 (0–5)
	Page (1981)	Oct 1981?	18 rat	Nil	18	0 (0–19)
	McFadden (1982 b)	27 Jun–2 Jul 1982	?	2 *norvegicus**	?	?
Waewaetorea	Page (1981)	Oct 1981?	14	Nil	13	0 (0–25)
	McFadden (1982 a)	17–22 Jan 1981	40 rat } 24 mouse }	? *norvegicus*	?	?

* animal recorded as *R. rattus* subsequently reassigned as juvenile *R. norvegicus* (I. McFadden, pers. comm.).