Diet of moreporks (*Ninox novaeseelandiae*) in Pureora Forest determined from prey remains in regurgitated pellets

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Abstract: The diet of radio-tagged moreporks (*Ninox novaeseelandiae*) was studied at Pureora Forest from May to December 1997. An examination of 187 pellets yielded 1226 prey items. Approximately 99% of the diet was invertebrates; the commonest items being beetles (48.6%), stick insects (25.6%) and weta (11.8%). Vertebrate prey included silvereye (*Zosterops lateralis*) and rodents in small numbers. The diet varied significantly from month to month.

Keywords: morepork; monthly diet; pellet analysis; secondary poisoning.

Introduction

The morepork (*Ninox novaeseelandiae*[1]) or ruru, is widely distributed in New Zealand (Falla *et al*., 1986, Heather and Robertson, 1996), in forests and forest remnants, including those in farmland and urban areas (Moon, 1988). Moreporks are sedentary and territorial (Heather and Robertson, 1996). Some individuals use the same daytime roosts for several consecutive days, while others frequently choose new ones. Regurgitated pellets containing indigestible prey remains can be easily collected from beneath roosts and assigned to a particular individual.

The diet of the morepork consists mostly of insects (Haw and Clout, 1999), but they also take geckos (Ramsay and Watt, 1971), birds (Hogg and Skegg, 1961), mice (*Mus musculus*), and kiore (*Rattus exulans*) (Atkinson and Campbell, 1966). Of the insects eaten, moths, weta, and beetles appear to be the most common prey items (Cunningham, 1948; Lindsay and Ordish, 1964; Daniel, 1972; Imboden, 1975; Saint Girons *et al*., 1986; Clark, 1992; Haw and Clout, 1999).

These studies suggest that the morepork is primarily insectivorous but that it occasionally supplements its diet with vertebrate prey. Several authors report that moreporks feed on house mice and kiore when they are abundant (Atkinson and Campbell, 1966; Saint Girons *et al*., 1986). Because they feed on rodents, moreporks have been considered to be at risk of secondary poisoning in pest control or eradication programmes targeted at rodents. Ogilvie *et al*. (1997) found residues of brodifacoum in the liver tissue of a dead morepork after a poison operation on Lady Alice Island. Moreporks have also been found dead after 1080 poison operations using carrot or cereal-based baits to control possum (*Trichosurus vulpecula*) populations (Spurr and Powlesland, 1997). Presumably the birds died from secondary poisoning because they are not known to eat baits.

Because of concern about the possible effects of poisoning of moreporks and a lack of information on dietary changes throughout the year on the New Zealand mainland, the monthly diet of the morepork in Pureora Forest was investigated. Here we describe the diet of the species as a result of examining the prey remains in regurgitated pellets.

[1]Bird nomenclature follows Heather and Robertson (1996); mammal nomenclature follows King (1990); plant nomenclature follows Salmon (1997)

Methods

Study Area

Radio-tagged moreporks were present in two blocks of Pureora Forest: Tahae and Waimanoa (Fig. 1). Powlesland *et al*. (1999) describe the reserve in detail. The birds had been radio-tagged to monitor their mortality during 1080-carrot bait operations carried out by Environment Waikato to reduce possum densities and so reduce the incidence of bovine tuberculosis in cattle on neighbouring farms (Powlesland *et al*., 1998).

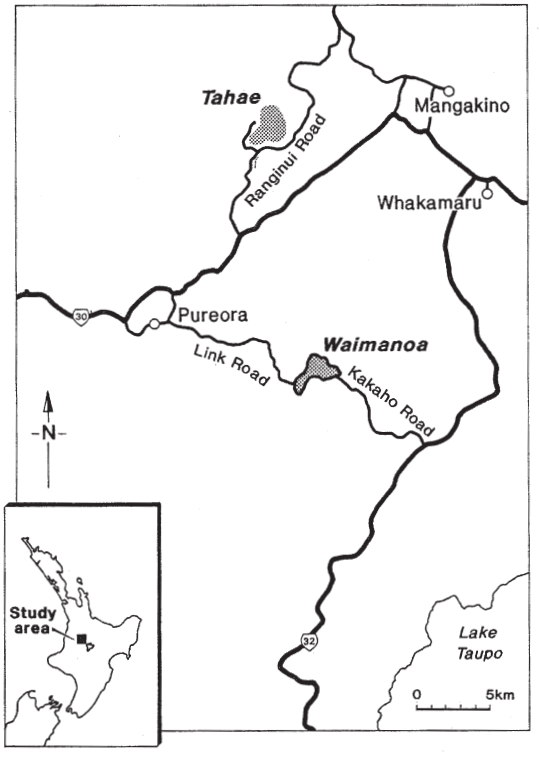

Figure 1. Location of study sites at Pureora Forest.

Radio-tags allowed ready location of birds at their roosts and therefore enabled a search for regurgitated pellets and partly eaten prey beneath the roosts.

The Tahae forest block is part of the Waipapa Ecological Area (38° 25¢ S, 175° 35¢ E), which covers an area of approximately 4000 ha, and is 45 km north-west of Taupo and 7 km north of Pureora village. It is situated on an extensive, flat plateau which forms a broad, low saddle between the Rangitoto Range to the north and the Hauhungaroa Range to the South. The topography over much of the reserve is gentle, with only shallowly incised streams. Forest covers about 70% of the Waipapa Ecological Area. It is largely unmodified, lowland rimu (*Dacrydium cupressinum*), miro (*Prumnopitys ferruginea*), totara (*Podocarpus totara*), kahikatea (*Dacrycarpus dacrydioides*) and tawa (*Beilschmiedia tawa*) forest with a mixed understorey (Leathwick, 1987). The reserve contains valuable habitats for many species, in particular for threatened birds such as the kokako (*Callaeas cinerea*), kaka (*Nestor meridionalis*), and New Zealand falcon (*Falco novaeseelandiae*). The long-tailed bat (*Chalinolobus tuberculatus*) and lesser short-tailed bat (*Mystacina tuberculata*) are also present, along with various introduced mammals. Possum control in the study area was carried out until March 1994 using 1080 (0.15% w/w) cereal baits in bait stations. Possum control by Environment Waikato was last carried out in the block in September 1996 by the aerial broadcasting of 1080 (0.08% w/w) -carrot baits.

The Waimanoa block is located to the south of Tahae (Fig. 1) and comprises about 3000 ha. The topography is of rolling country, with the altitude varying from 700 to 740 m a.s.l. During the 1970s, logging of mainly emergent podocarps occurred, therefore the density of emergents is less in parts of the block than at Tahae. On the former skid sites and logging tracks through the forest, wineberry (*Aristotelia serrata*) and toetoe (*Cortaderia fulvida*) are common. Possum control had not been carried out recently in this block; however the forest to the north of Waimanoa Road was aerially poisoned with 1080-carrot baits (1080 conc. unknown) in winter 1993, and that to the south of Link-Kakaho Road with 1080-carrot baits (0.08% w/w) in winter 1994.

Obtaining morepork pellets

The study was carried out between May 1997 and December 1997 at Tahae and Waimanoa. Radio-tagged birds were located at their roost sites, and the ground below each roost searched for pellets and partly eaten prey. When possible, roost sites were visited daily during monthly field trips. Collecting effort was the same for each month, but a lack of radio-tagged birds at Waimanoa after August 1997 meant pellets were collected from this site during only May to August. Each pellet was placed in an individual plastic bag, and the bag marked with location and date. Once back at the laboratory, each pellet was inspected under a dissecting microscope.

In addition to the pellets collected in 1997, a sample of 21 pellets was obtained from Pureora Forest between December 1995 and October 1996 by RGP, and J. Knegtmans and I. Marshall of the Department of Conservation (Pureora, N.Z.). These were not systematically collected.

Diet analysis

Prey items were identified by comparing the bones, feathers and fragments of insect exoskeleton present in the pellets with those of reference specimens. Vertebrates were identified at the Auckland Museum. Rodent remains were identified to species by dental and cranial features, whilst birds were identified by their skulls, bills, feet, pelvises and feathers. The number of individuals represented was determined by counts of skulls, jaws or pelvises for rodents, and skulls, mandibles

Table 1. Monthly number of regurgitated pellets found under the roosts of individual Morepork at Pureora Forest, May – December 1997.

	Monthly collection status[1]							
Bird	May	June	July	August	September	October	November	December
1	-	3	12	14	9	13	15	8
2	-	-	-	-	1	2	2	1
3	2	9	10	3	3	1	1	
4	1	+						
5	2							
6	-	-		4	13	7	6	2
7	-		2	#				
8	-	-	3	#				
9	-	4		+				
10	3	4	2	1	+			
11	1	+						
12	-	-	-	-	1	-	-	-
13				1		7	10	4
Total	9	20	29	23	27	30	34	15

[1]Symbols: - : bird unavailable; + : transmitter battery expired; # found dead

and long bones for birds, as demonstrated by investigations into the diets of tawny owls (*Strix aluco*) and other owl species (Short and Drew, 1962). Invertebrate material was identified to order, or further when possible. Invertebrates were counted when intact, and occasionally by compiling remains of partially digested individuals, as proposed by Calver and Wooller (1982). Data were analysed for individual pellets from both forest blocks together (Tahae and Waimanoa).

Statistical analysis

The importance of a particular prey item in the diet is expressed in terms of numerical occurrence and frequency of occurrence. For testing the significance of monthly variation in diet, ANOVA was used.

Results

A total of 187 pellets were collected during the eight month study, from 13 moreporks (Table 1). In most months pellets were collected from five different individuals. Fewer pellets were collected in summer and autumn (December – May).

In all, 1226 prey items were recorded from six taxonomic classes; Insecta, Diplopoda, Chilopoda, Arachnida, Aves and Mammalia. Overall, beetles (Coleoptera) were the most frequently occurring prey item (Table 2), consisting of at least six family groups; Scarabaeidae, Cerambycidae, Carabidae, Elateridae, Curculionidae and Brentidae. Scarabaeidae and Cerambycidae were the most common Coleoptera eaten, comprising 94.8% of the total beetle items. Another

Table 2. Frequency and percentage of occurrence of prey items found in 187 morepork pellets collected in Pureora Forest from May 1997 to December 1997.

Prey item	Frequency	%
Vertebrates		
Rodentia		
Muridae		
Rattus rattus	1	0.1
Unidentified	3	0.2
Aves		
Passeriformes		
silvereye *Zosterops lateralis*	2	0.2
Unidentified	1	0.1
Invertebrates		
Lepidoptera	4	0.3
Coleoptera		
Scarabaeidae	391	31.9
Cerambycidae	174	14.2
Carabidae	11	0.9
Elateridae	1	0.1
Curculionidae	4	0.3
Brentidae	5	0.4
Unidentified	10	0.8
Orthoptera		
Stenopelmatidae	144	11.7
Rhaphidophoridae	1	0.1
Hemiptera		
Cicadidae	3	0.2
Cicadidae larvae	10	0.8
Phasmida	314	25.6
Hymenoptera	4	0.3
Araneae	119	9.7
Phalangida	3	0.2
Diplopoda	5	0.4
Chilopoda	16	1.3
Total	1226	99.8

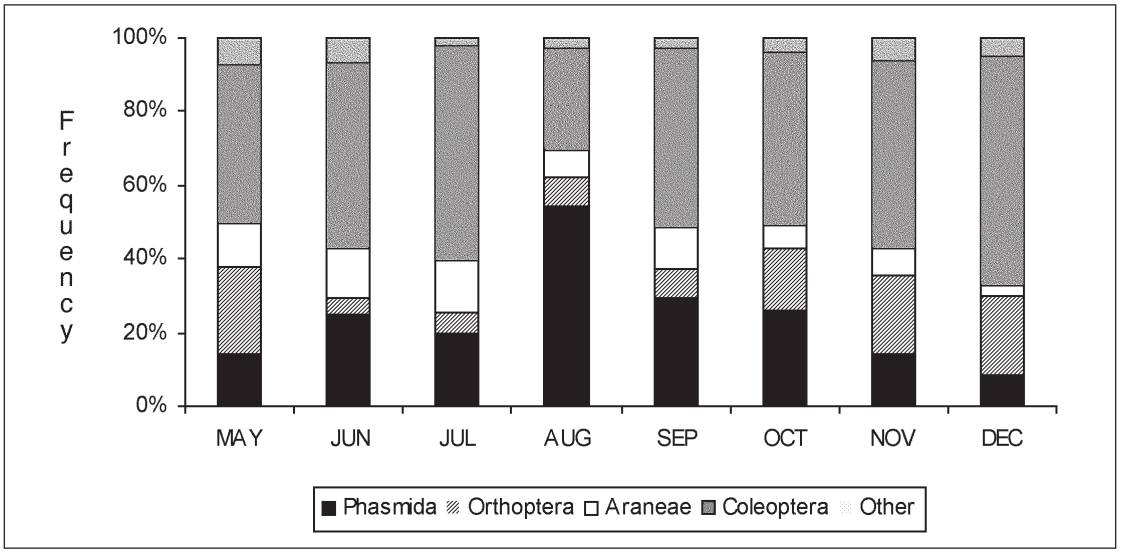

Figure 2. Percentages of five prey types each month in morepork pellets from Pureora Forest, from May 1997 to December 1997.

important component of the morepork's diet was stick insects (Phasmida), which accounted for 25.6% of the dietary items. Weta (Orthoptera) (11.8%) and spiders (Araneae) (9.7%) were also well represented. Other invertebrates recorded included cicadas (Hemiptera; suborder Homoptera), moths (Lepidoptera), bees (Hymenoptera), harvestmen (Phalangida), millipedes (class Diplopoda) and centipedes (class Chilopoda). The remains of just three birds were found in the pellets (0.3%). Of these, two were identified as silvereyes (*Zosterops lateralis*). Rodents also made up a very small portion of the diet (0.3%) numerically. Of four rodents found, just one could be identified to species from bones, and it was a young ship rat (*Rattus rattus*).

A fairly consistent monthly pattern of was exhibited from May to December 1997 (Fig. 2). Four main prey types (Coleoptera, Phasmida, Orthoptera, and Araneae) were consumed each month. The number of individuals taken varied significantly between months ($P = 0.031$) and there were also significant differences between months in the type of prey eaten ($P = 0.012$). The staple prey appeared to be beetles which was well represented each month and was the most commonly taken prey type each month except for August. A distinct change in diet involved the reduction in consumption of Scarabaeidae from October to December. Cerambycidae replaced Scarabaeidae as the most commonly eaten beetles throughout this period.

Stick insects were an important food source, particularly in winter; they were the most frequently occurring prey item in August (Fig. 2). Weta were present in the diet every month and were most frequent in November, December and May. Spiders were a constant food source and showed little monthly variation. Birds were present in autumn and spring samples only, whilst rodents were taken in winter, spring and summer but at extremely low frequencies.

A similar range of prey items was found in pellets collected from December 1995 to October 1996 (Table 3) compared to those present in May – December 1997. Again, beetles were the most frequently preyed upon item each month in 1995 – 96 (Fig. 3), as for the other sample period. Overall differences between the two collection periods include more Coleoptera and Hemiptera eaten and reduced Phasmida and Araneae from December 1995 to October 1996.

Discussion

The food items recorded at Pureora Forest are typical of those taken by moreporks in general (Cunningham, 1948; Lindsay and Ordish, 1964; Saint Girons *et al.*, 1986; Clark, 1992; Haw and Clout, 1999). However, differences in the preference for particular prey indicate feeding habits of the morepork are dependent on habitat (mainland forest, urban, island). In particular, the preponderance of beetles in the diet of forest–dwelling moreporks was evident at Pureora (Tables 2, 3) and at Lady Alice Island (e.g. Saint Girons *et al.*, 1986).

At Pureora, beetles were the most frequently consumed invertebrates during every season. Scarabaeid beetles are active, noisy and clumsy fliers

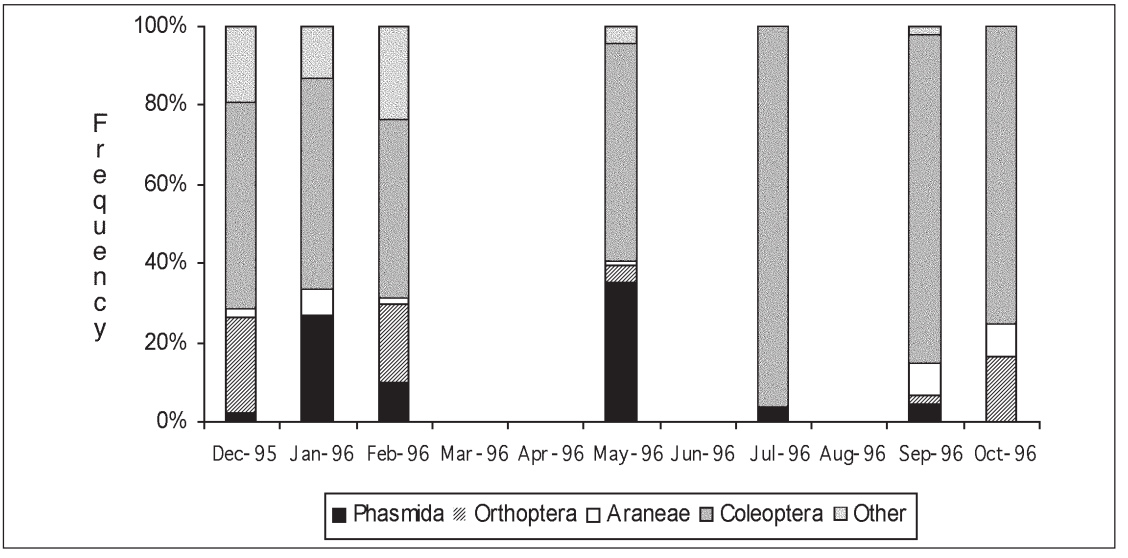

Figure 3. Percentages of five prey types each month in morepork pellets from Pureora Forest, December 1995 to October 1996.

(Gillott, 1995). It is interesting that Pureora moreporks consistently fed on this food item, but that these beetles were not evident in the diet of moreporks studied elsewhere. The shift from these to Cerambycidae in the morepork diet during October to December may reflect changes in the availability of prey. Scarabaeid beetles overwinter as active adults and are therefore more abundant from June to August (Gillott, 1995). In contrast, Cerambycid adults are most common in summer (Gillott, 1995). Other authors (Cunningham, 1948; Lindsay and Ordish, 1964) have suggested that the morepork's diet changes in response to the seasonal availability of its prey.

Predation of stick insects in large numbers by moreporks has not previously been recorded, but they were frequent prey in this study. According to Salmon (1991), most New Zealand stick insects hatch in early spring and reach maturity in autumn. Weta were the third largest group of invertebrates consumed by Pureora moreporks, the Orthoptera comprising 11.8% of the total diet. From their studies, Lindsay and Ordish (1964) also noted the importance of weta (which are available throughout the year) in the diet of moreporks. From the results of this study, weta emerge as an important food source in May 1997 and from October 1997 to December 1997.

Spiders were taken mostly in winter, particularly in June and July. Previous authors have reported the presence of spiders in morepork diets (Cunningham, 1948; Lindsay and Ordish, 1964; Clark, 1992), but not to the extent reported here (9.7% of the total prey items). Cicadids and their emerging pupae, Diplopods and Phalangids were minor prey items of moreporks in 1997. Chilopods and Hymenoptera, which were recorded in this study, have not previously been recorded as morepork prey.

Table 3. Frequency and percentage of occurrence of prey items found in 21 morepork pellets collected in Pureora Forest during December 1995 to October 1996.

Prey item	Frequency	%
Vertebrates		
Rodentia		
Muridae		
Mus musculus	1	0.4
Unidentified	1	0.4
Aves		
Passeriformes	1	0.4
Unidentified	4	1.5
Invertebrates		
Coleoptera		
Scarabaeidae	130	48.9
Cerambycidae	24	9.0
Carabidae	5	1.9
Brentidae	3	1.1
Unidentified	5	1.9
Orthoptera		
Stenopelmatidae	26	9.8
Hemiptera		
Cicadidae	11	4.1
Cicadidae larvae	8	3.0
Phasmida	38	14.3
Araneae	9	3.4
Total	266	100.1

In comparison with Cunningham's (1948) study conducted in urban Masterton and that of Clark's (1992), our study showed that forest-dwelling moreporks at Pureora consumed few moths. A possible explanation is that few pellets were collected at Pureora in summer. Also moths are attracted to street lights in the urban situation where perhaps they can be readily captured by moreporks while flying or settled near lights. When flying in the forest, moths may be more difficult for moreporks to capture on the wing.

Vertebrates comprised only 0.6% of total prey items at Pureora, including just four rodents in all of the 187 pellets examined. It must be noted that rat numbers at Tahae were low at the beginning of the sampling period in May 1997 due to a possum control operation in September 1996, but mice were abundant throughout the study. According to Powlesland *et al*., (1999), rodent populations were very high and remained so throughout the study as Waimanoa remained a non-treatment area for 1080 possum poison operations. However, Pureora moreporks largely ignored mice as a food source.

The relative insignificance of rodents in the diet of moreporks inhabiting mainland forest (Clark, 1992; Lindsay and Ordish, 1964; this study) is of particular interest in relation to the risk of secondary poisoning of moreporks during 1080 possum control operations. However, a note of caution is that no pellets were collected from January to April, when numbers of rodents, especially young ones, would have been expected to be more readily available (King, 1990). It seems that rodents are only an important prey of moreporks when they are very common (e.g., on some offshore islands), and that moreporks typically only take mice and small rats (kiore and juvenile ship rats), not adult ship rats. Overall, this study suggests that moreporks at Pureora Forest have a mainly insectivorous diet, which changes as the availability of prey species changes.

Conservation implications

Studies of morepork diet have not found them feeding on endangered native birds or reptiles. However, shore plover (*Thinornis novaeseelandiae*) released on Motuora Island, in Hauraki Gulf, in February 1997 were preyed upon by resident moreporks (S.A. Boyd, Department of Conservation, Auckland, N.Z., *pers. comm.*). This emphasises that all morepork populations cannot be considered similar in their feeding habits.

Aerial possum control operations are becoming increasingly common, and little is known about the effects that secondary poisoning has on predatory birds that prey on invertebrates or rodents. Included among the forest bird species that have been found dead and contained 1080 after aerial possum poisoning operations, (whether carrot or cereal baits were used) was the morepork (Spurr and Powlesland, 1997). At the population level, Spurr and Powlesland (1997) considered that there was a medium risk of moreporks going extinct as a result of the mortality brought about by poisoning during an aerial 1080 possum poisoning operation. However, too little information is available about the population dynamics and reproductive capacity of the morepork to be certain of the risks of extinction of morepork populations from 1080 operations. Limited observations indicated that moreporks were still common in areas where aerial 1080 operations had been carried out (Pierce and Montgomery, 1992; Walker, 1997; Powlesland *et al*., 1998).

This study suggests that moreporks are at minimal risk in mainland forests from secondary poisoning through consumption of poisoned rodents because moreporks eat few rodents. Our study indicates that the more likely source of secondary poisoning of moreporks in such habitats is by the eating of invertebrates that have fed on baits or on carcasses of animals poisoned by 1080 (Spurr, 1994). While little work has been carried out to determine the risk which morepork populations face when 1080 poison operations are carried out in mainland forests, the information available suggests that there is a minimal risk of population extinction (Spurr and Powlesland, 1997).

Brodifacoum, a second generation anticoagulant rodenticide, has been used successfully in rodent eradication operations on islands in New Zealand (Ogilvie *et al*., 1997). Eason and Spurr (1995) suggested that the morepork is at risk of secondary poisoning by eating rodents or invertebrates that have eaten brodifacoum baits. One study on Kapiti Island of moreporks exposed to two aerial applications of brodifacoum baits in September – October 1996 and monitored by calling rate, suggested that the rodent eradication programme had little impact on the morepork population (Empson and Miskelly, 1999).

Ogilvie *et al*. (1997) reported the presence of brodifacoum in the liver tissue of a morepork found dead after an aerial application of brodifacoum baits on Lady Alice Island. The authors noted that the bird may have consumed prey that had eaten brodifacoum, but the source was unknown. The presence of brodifacoum in the tissues of cave weta suggests that moreporks could accumulate brodifacoum in their liver through their invertebrate diet (Ogilvie *et al*., 1997; P. Craddock, University of Auckland, Auckland, N.Z., pers. comm.). However, no assessment of risks via this route has been attempted. Too little work has yet been carried out at mainland sites where brodifacoum baits have been placed in bait stations over several years to determine whether or not this toxin will accumulate in the livers of moreporks and affect reproduction or survival.

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