

Diet of Morepork (*Ninox novaeseelandiae*) throughout New Zealand by analysis of stomach contents

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ABSTRACT

The diet of the Morepork (*Ninox novaeseelandiae*) in New Zealand was investigated by analysing stomach contents. In the sample of 75 stomachs from throughout New Zealand, 1696 prey items were identified, 98% of them invertebrates. Major invertebrate prey taken included Lepidoptera, Coleoptera, and Orthoptera. Lepidoptera were consumed mostly in summer and Coleoptera in winter. Vertebrate prey were predominantly birds, but included one house mouse (*Mus musculus*). New dietary items included praying mantis (Dictyoptera), blowflies (Diptera), wasps (Hymenoptera), and slaters (Isopoda). Most prey was 20-50 mm in body length. Diets of male and female Moreporks were similar, as were those of North and South Island birds. As suggested from other studies, the diet of Moreporks is varied, but consists primarily of invertebrates. Food habits apparently reflect the seasonal abundance of prey.

Keywords: Owl, *Strigiformes*, diet, Insecta.

INTRODUCTION

The Morepork (*Ninox novaeseelandiae*) is now the only native owl in New Zealand, the Laughing Owl (*Sceloglaux albifacies*) being now extinct (Worthy & Holdaway 1996). The diet of the latter species is known from fossil deposits of pellets. It ate a range of invertebrates, as well as small and medium-sized vertebrates (Holdaway & Worthy 1996). It is unknown if Moreporks and Laughing Owls had complementary diets. The study reported here describes modern Morepork diet. Knowledge of this is of intrinsic interest, but is also needed to assess potential risks of secondary poisoning through consumption of rodents which have eaten toxic baits (Eason & Spurr 1995).

The Morepork is found throughout New Zealand in native and introduced forest and also close to settlement (Heather & Robertson 1996). They are widely distributed in the North, South and Stewart Islands, but they are scarce in Canterbury and Otago, perhaps because of competition from the more common Little Owl (*Athene noctua*) (Moon 1988).

The sexes are similar in appearance and size (about 30 cm long) (Imboden 1985). Moreporks typically hunt in forest, but many have adapted to life in farmland or suburban parks (Olsen & Moon 1990). Moreporks have been observed to feed on insects that have been attracted to street lights and also to take insects from trees (Lindsay & Ordish 1964, Ramsay 1988). Night-flying insects such as moths and huhu beetles (*Prionoplus reticularis*), including those attracted to lights, are caught by Moreporks with their talons or bill. Although insects are considered to be their most important food source, little is known about the diet in detail.

Cunningham (1948) and Lindsay & Ordish (1964) indicated that, as a rule, Morepork diet is varied and the birds eat what is most convenient to catch.

This study examines Morepork diet in detail. The objectives were: (1) to describe the diet; (2) to determine if there were seasonal changes in diet; (3) to determine the preferred size class or classes of Morepork invertebrate prey; (4) to determine if there are sexual differences in Morepork diet; and (5) to compare the diets of North Island and South Island birds.

METHODS

Diet analysis

Various organisations provided Morepork carcasses for diet analysis. These organisations included Auckland Institute and Museum, Department of Conservation, Ornithological Society of New Zealand, and Royal Forest and Bird Protection Society. Stomachs of dead birds were removed and preserved in 70% ethanol for later inspection and analysis. The taxonomic composition of the contents was analysed of all stomachs that contained food. Stomach contents were washed through a fine sieve, then dried on blotting paper, and examined using a dissecting microscope. Collections from Auckland Institute and Museum were used to identify mammalian and avian prey. Invertebrate material was identified to Order (or to lower taxonomic category when possible), the number of individuals present was counted and an estimation of their size was made. Invertebrates were grouped in four categories of body length, 0-0.9 mm, 10-19 mm, 20-50 mm, >50 mm in length. Percentages were derived from the total number of prey items found in stomachs.

Statistical analysis

Diet composition was expressed both as the numerical occurrence of prey species and the percentage of the diet, with respect to the total prey taken. Seasonal variation of prey items was analysed using ANOVA, which was used also for testing the numeric size distribution of prey. A chi-squared test was used to compare male and female diet. t-test was used to compare proportions. Variation in diet between North and South Island Moreporks was not analysed statistically because habitats of the individuals examined were unknown.

TABLE 1 – Location of Morepork stomachs.

Location	Frequency
NORTH ISLAND	
Auckland	10
Rotorua	12
Gisborne	3
Wanganui	5
Palmerston North	3
Wellington	2
Other	12
SOUTH ISLAND	
Nelson	1
West Coast	20
Fiordland	1
Other	6
Total	75

RESULTS

Diet - general

Seventy-five Morepork stomachs were collected from throughout New Zealand (Table 1). A total of 1696 prey items representing 14 Orders of invertebrates and two classes of terrestrial vertebrates was recorded in the stomachs (Table 2). In all, 1667 invertebrates and 29 vertebrates were identified. Overall, invertebrates made up 98% of the total dietary items.

The most common insects eaten were beetles (Coleoptera), which made up 34.6% of the 1696 prey items and occurred in 85.3% of stomachs (Fig. 1). Several families were represented but Scarabaeidae and Cerambycidae were the most frequent. Scarabaeidae beetles constituted 61.6% of the total beetles eaten. Lepidoptera (mainly adult moths, otherwise caterpillars) formed a major part of the diet. Nearly as many individual moths and caterpillars as beetles were found. Orthoptera also occurred frequently (60.0% of stomachs), of which the vast majority (94.0%) were weta. The weta consumed consisted of two families, tree weta (Stenopelmatidae) and cave weta (Rhaphidophoridae). These two families were present in fairly equal proportions.

Spiders (Araneae) were the fourth most important food item: 100 individuals were recorded, 5.9% of the total diet. Stick insects (Phasmida) and cockroaches (suborder Blattaria) were present in similar numbers.

TABLE 2 - Frequency and percent occurrence of prey items in 75 Morepork stomachs from throughout New Zealand.

Prey item	Frequency	%
Vertebrates		
RODENTIA		
Muridae		
<i>Mus musculus</i>	1	0.1
AVES		
Passeriformes	4	0.2
yellowhammer <i>Emberiza citrinella</i>	1	0.1
Unidentified	23	1.4
Invertebrates		
LEPIDOPTERA		
Moths	383	22.6
Caterpillars	162	9.6
COLEOPTERA		
Scarabaeidae	362	21.3
Scarabaeidae larvae	120	7.1
Cerambycidae	83	4.9
Carabidae	19	1.1
Elateridae	2	0.1
Unidentified	2	0.1
ORTHOPTERA		
Stenopelmatidae	157	9.3
Rhaphidophoridae	132	7.8
Gryllidae	4	0.2
Tettigoniidae	16	0.9
HEMIPTERA		
Cicadidae	11	0.6
Cicadidae larvae	3	0.2
PHASMIDA		
DICTYOPTERA		
Mantodea	4	0.2
Blattaria	36	2.1
HYMENOPTERA		
DIPTERA		
Calliphoridae	4	0.2
Tipulidae	8	0.5
DERMAPTERA		
ISOPODA		
ARANEAE		
PHALANGIDA		
DIPLOPODA		
OLIGOCHAETA		
Total	1696	100.0

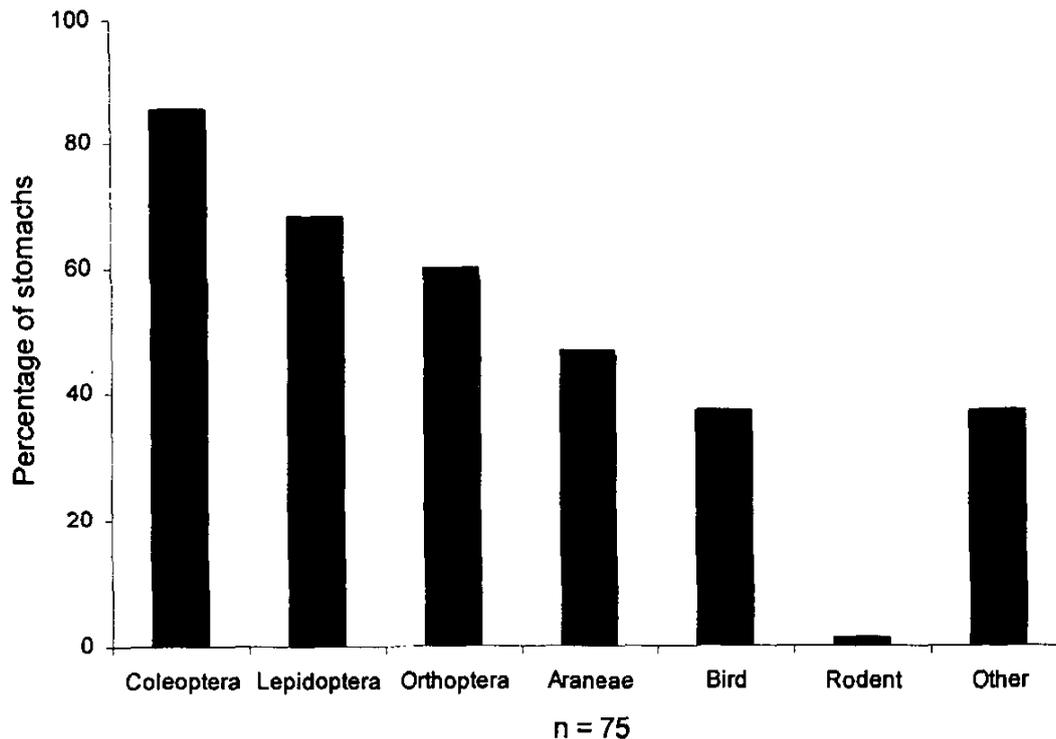


FIGURE 1 - Percentage of stomachs containing major prey items.

Most Diptera (66.7%) were crane flies (*Tipulidae*), with the rest being blowflies (*Calliphoridae*). Of particular interest were rare occurrences of praying mantids (suborder *Mantodea*), earthworms (Class *Oligochaeta*), and slaters (Class *Isopoda*). Cicadas (*Hemiptera*), earwigs (*Dermaptera*), and harvestmen (*Phalangida*) comprised less than 1% of the diet.

Representatives of two classes of terrestrial vertebrates were found in the stomachs. Rodent remains were found in only one stomach and were identified as a house mouse (*Mus musculus*). 28 birds were recorded in stomachs. Only one was identifiable to species level; a yellowhammer (*Emberiza citrinella*). Bone remains of four other birds were identified as belonging to the Order *Passeriformes*. Unidentifiable feathers or bones of 23 unknown birds were also recorded.

Seasonal differences in diet

The collection date was known for 53 of the 75 stomachs. A seasonal pattern in the food habits of the Morepork was apparent from the contents of the stomachs (Fig. 2). Prey composition varied significantly between seasons ($P = 0.017$).

The most important prey species in summer were Lepidoptera, comprising 41.2% of food items. These were mostly (95.1%) adult moths, with the rest being caterpillars. Orthoptera and Coleoptera were the second and third largest groups of remains found in Morepork stomachs in summer. Cicadas and their larvae were consumed in summer in their highest proportions. Lepidoptera and weta were also important food items in autumn. Spiders were most frequently consumed in autumn, comprising 8.2% of the diet.

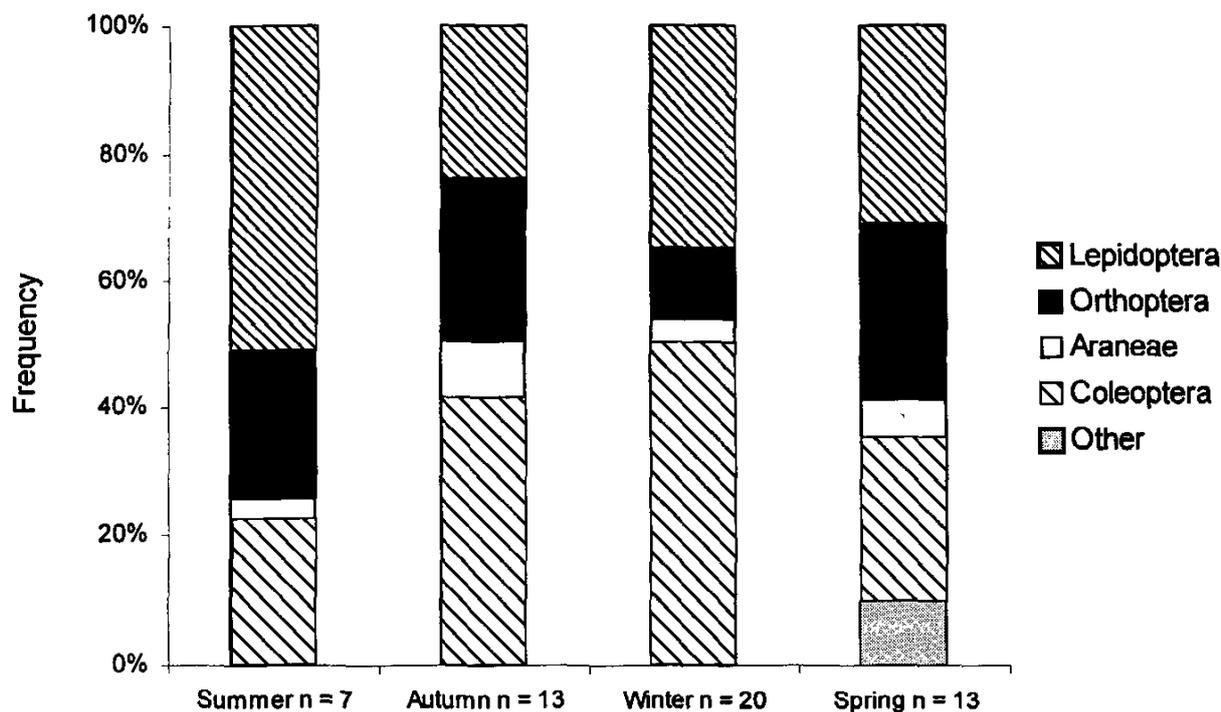


FIGURE 2 - Seasonal variation in Morepork diet by frequency of occurrence.

Coleoptera were frequent prey in all seasons but were consumed most often in autumn and winter. During winter, beetles formed the bulk of the diet (46.7%), with Scarabaeidae beetles being most the frequently consumed. A high proportion (42.8%) of Lepidoptera consumed during winter were taken as caterpillars. Weta were the third most important winter food source and two slaters were recorded.

In spring, diet was dominated by Lepidoptera (29.8%), weta (29.1%), and Coleoptera (25.5%). Together they made up 84.4% of the total diet in spring. Cockroaches and earthworms were taken most during spring and constituted 4.4% and 1.5% of total spring prey items, respectively.

Size of prey

Most (67%) invertebrates taken by Moreporks were large (i.e. body length 20-50 mm), whereas 30% of the total invertebrates consumed were in the medium size class (10-19 mm), and small (<10mm) and very large (>50mm) items together comprised of only 3% of the total invertebrate diet (Table 3). The very large size class contained only stick insects, all >50mm, and small spiders accounted for all items within the small size class (<10mm).

Influence of sex on diet

Of the 75 Morepork stomachs analysed, 45 were from females, 22 from males, and the remaining eight from unsexed birds (Table 4). Significantly more weta were taken by females (18.5%) than males (15.0%) (t-test for difference between

TABLE 3 - Number of invertebrates in different size classes taken by Moreporks.

Prey item	Size class			
	0-9 mm	10-19 mm	20-50 mm	>50 mm
Lepidoptera		3	542	
Coleoptera		374	214	
Orthoptera		40	269	
Phasmida				38
Araneae	12	31	57	
Other		52	35	
Total	12	500	1117	38

proportions, $P < 0.05$). Stomachs of females in particular contained large numbers of Coleoptera (41.3%), although no significant difference was found between males and females in overall diet ($X^2 = 2.70$, $df = 1$, $P = 0.101$) (Fig. 3). Likewise, no significant difference was found in the consumption of spiders ($X^2 = 2.82$, $df = 1$, $P = 0.093$). Lepidoptera formed the bulk of the diet in males (45.1%). Of the Lepidoptera consumed by females, 36.0% were caterpillars, while only 21.5% of Lepidoptera eaten by males were caterpillars. Other prey items which were taken in similar proportions by both sexes are stick insects and Diptera (Table 5).

Regional differences in diet

Of a total of 1034 prey items recovered from 47 stomachs of North Island birds, Lepidoptera (33.2%), Coleoptera (32.2%), and weta (20.3%) dominated numerically (Fig. 4). Hymenoptera, Diptera, millipedes (class Diplopoda), earthworms, and slaters occurred only in North Island birds (Table 6). A total of 661 prey items was identified from the 28 stomachs of South Island birds. Once again Coleoptera (38.6%), Lepidoptera (30.4%), and weta (12.0%) made up the bulk of the diet. For South Island birds caterpillars made up 70% of the total Lepidoptera eaten and spiders represented an important food source, comprising 9.4% of the total items.

DISCUSSION

This study confirms previous studies of Morepork diet (Cunningham 1948, Lindsay & Ordish 1964, Saint Girons *et al.* 1986, Clark 1992) in showing that this species feeds mainly on insects and to a lesser degree birds and rodents. The method used here has been applied in most dietary studies of owls: estimates of the relative importance of prey is assessed by the numerical occurrence of prey species and percentage of the diet, with respect to the total prey taken. However, it must be noted the method over-emphasizes the importance of small items, since no correction for biomass is applied.

TABLE 4 - Comparison of the relative number of male and female Morepork stomachs collected each season.

Season collected	Stomachs		Checked	
	Male	Female	Male	Female
Summer	5	2		
Autumn	9	3		
Winter	2	12		
Spring	5	7		
Unknown	1	21		
Total	22	45		

Moreporks were found to consume a greater number of Coleoptera than any other invertebrate group. Saint Girons *et al.* (1986) also noted that Coleoptera were common prey items. The abundance of Lepidoptera in Morepork diets revealed by the study was similar to that reported for Moreporks in New Zealand (Cunningham 1948, Clark 1992). These authors reported adult moths as being the most important food source, whereas caterpillars were rarely reported in the diets. In contrast, we recorded a large number of caterpillars in stomachs (30% of the total Lepidoptera, most taken in winter).

The importance of Orthoptera in the diet of Moreporks, has been noted by Lindsay & Ordish (1964), Imboden (1975), Saint Girons *et al.* (1986), and Clark (1992). According to Lindsay & Ordish (1964), weta are a staple item of diet because they are available throughout the year. In the present study, weta represented 17.1% of the total prey taken.

Lindsay & Ordish (1964) noted grass grub moth larvae (*Oxycaenus* spp.) in their samples, suggesting that Moreporks will feed from the ground. Stomachs containing Scarabaeidae larvae, earwigs, and Carabidae (Ground beetles) in the present study support this suggestion. Beetle larvae live primarily below the surface and earwigs are mainly nocturnal and prefer damp situations such as in soil, under bark, and under stones (Romoser & Stoffolano 1994). The presence of puriri moth larvae in stomachs indicates that Moreporks also forage on tree trunks, because larvae burrow deep into tree trunks and enclose themselves within a silk pad (D.R. Cowley pers. comm.). The high proportion of cave weta in the diet implies that Moreporks also spend some time foraging in or on leaf litter.

The consumption of spiders has previously been reported by several authors (Cunningham 1948, Lindsay & Ordish 1964, Clark 1992), but in low numbers. In our study, spiders comprised of nearly 6% of the total diet. Invertebrates which have also been recorded previously at extremely low frequencies, included stick insects, cockroaches, katydids (Tettigoniidae), earwigs, cicadas, harvestmen, millipedes, earthworms, and crickets (Gryllidae).

TABLE 5 - Comparison of frequency and percentage occurrence of prey items in stomachs of male and female Moreporks.

	Male (n = 22)		Female (n = 45)	
Prey item	Frequency	%	Frequency	%
Rodent			1	0.1
Bird	11	2.3	16	1.4
Lepidoptera: Moth	172	35.4	197	17.1
Lepidoptera: Caterpillar	47	9.7	111	9.6
Coleoptera	80	16.5	476	41.3
Orthoptera	80	16.5	226	19.6
Hemiptera	13	2.7		
Phasmida	12	2.5	26	2.3
Dictyoptera	24	4.9	20	1.7
Hymenoptera			1	0.1
Diptera	4	0.8	7	0.6
Dermaptera			8	0.7
Isopoda			2	0.2
Araneae	37	7.6	60	5.2
Phalangida	2	0.4	2	0.2
Oligochaeta	4	0.8		
Total	486	100.2	1153	100.1

Among the Diptera, craneflies have previously been reported as prey (Lindsay & Ordish 1964), but there are no previous records of blowflies. Similarly, praying mantids, Hymenoptera, and slaters have not previously been reported in the Morepork diet. These results serve to emphasize the varied diet of this versatile predator.

Only 29 (1 mouse, 28 birds) of the 1696 prey items were vertebrates. Saint Girons *et al.* (1986) showed rodents to be common in Morepork diet on Lady Alice Island. The authors considered the abundance of Moreporks on the island resulted from the presence of Pacific rats (*Rattus exulans*), which made up the bulk of the chick diet. Chambers *et al.* (1955) observed similar predation on Lady Alice Island and also noted the absence of bird remains in Morepork nests there. In the present study, the only rodent recorded was the smallest of the few introduced species, the house mouse which is, the only one comparative in size to the Pacific rats on the main islands. The almost complete absence of mice and rats from the stomachs analysed in this study suggests that Moreporks rarely feed on rodents (on the main islands, at least in areas where the 75 stomachs were collected), but will take them in some places (e.g. offshore islands), where they are particularly abundant.

TABLE 6 - Comparison of frequency and percent occurrence of prey items between North and South Island Morepork stomachs.

Prey item	North (n = 47)		South (n = 28)	
	Frequency	%	Frequency	%
Rodent			1	0.2
Bird	15	1.5	13	2.0
Lepidoptera: Moth	322	31.1	61	9.2
Lepidoptera: Caterpillar	22	2.1	140	21.2
Coleoptera	333	32.2	255	38.6
Orthoptera	221	21.4	88	13.3
Hemiptera	14	1.4		
Phasmida	26	2.5	12	1.8
Dictyoptera	16	1.5	24	3.6
Hymenoptera	1	0.1		
Diptera	12	1.2		
Dermaptera	5	0.5	3	0.5
Isopoda	2	0.2		
Araneae	37	3.6	62	9.4
Phalangida	2	0.2	2	0.3
Diplopoda	1	0.1		
Oligochaeta	5	0.5		
Total	1034	100.1	661	100.1

In general few birds are taken by Moreporks, except in urban environments (Cunningham 1948, Hogg & Skegg 1961, Daniel 1972, Imboden 1975). The small number of birds taken by Moreporks in this study is therefore not unusual (Lindsay & Ordish 1964, Saint Girons *et al.* 1986, Clark 1992). According to Imboden (1985), Morepork chicks are thought to be fed mainly on birds and, to a lesser extent, insects. In the present study, bird remains were found in the stomach of a Morepork chick.

Moreporks have been considered to be versatile predators, whose food habits reflect the relative abundance of prey (Cunningham 1948, Lindsay & Ordish 1964, Imboden 1975). The present study demonstrated seasonal trends in the diet. The trends may have reflected the seasonal abundance of certain prey species, which may temporarily have become the prevailing food source. For example, although Lepidoptera were consumed in all seasons, there was a peak in summer. Cicadas were also mainly taken in summer. Moths and cicadas reach peak abundance in summer and there are fewer adults at other seasons, especially winter (Gillott 1995).

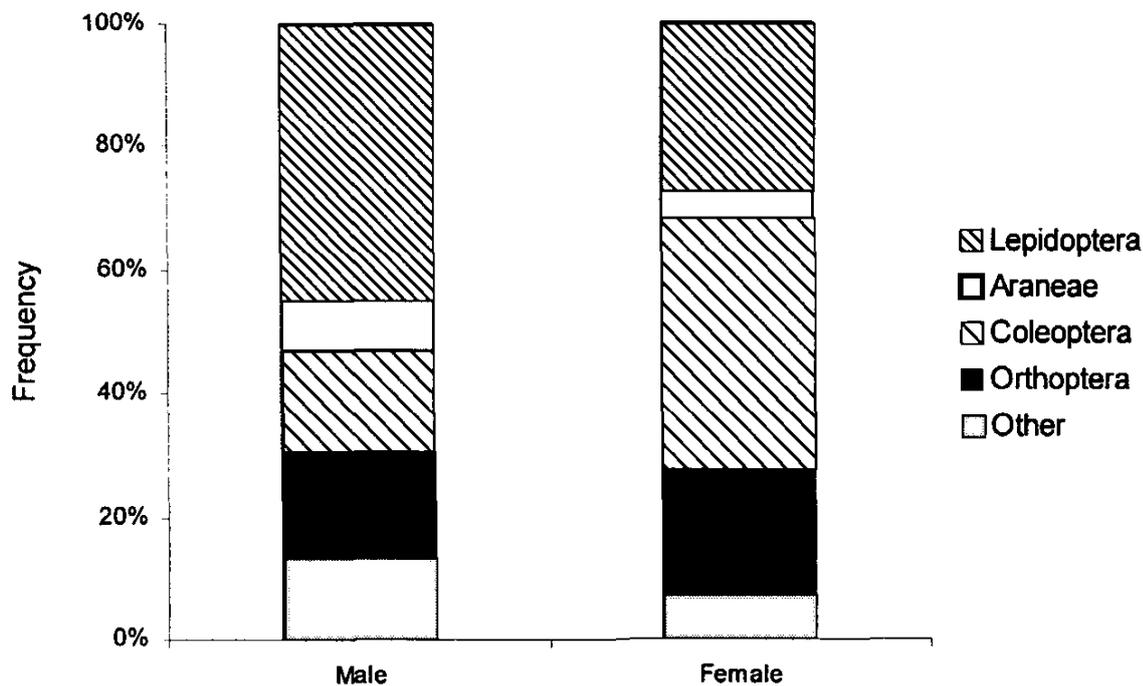


FIGURE 3 - Comparison of stomach contents of male ($n = 22$) and female ($n = 45$) Moreporks.

Conversely beetles and weta are abundant throughout the year. Beetles formed an important food supply throughout the year but were most frequently taken in autumn and winter. This is because a large proportion of the beetles taken were Scarabaeidae, which overwinter as adults (Gillott 1995). Also the decline in moths and cicadas, especially in winter, means that any of the other foods would likely to rise in proportion. Weta are important prey items as they are frequent throughout the year (Lindsay & Ordish 1964, Imboden 1975). The observations recorded in this study therefore confirm that Moreporks are generalists and eat whatever is available.

Moreporks consumed considerably more invertebrates measuring 20-50 mm in body length, than those of other sizes. Although the data suggest that Moreporks select large prey, this is because the birds are taking prey of the appropriate size that are most abundant in their particular habitat where the bird was collected. Scarabaeidae beetles are classed within the 10-19 mm size range and are primarily responsible for the reasonable number of medium sized invertebrates consumed.

Females apparently preyed upon beetles more often than males and male birds consumed a higher percentage of Lepidoptera. However, this apparent sexual difference in diet may have been confounded by seasonal differences (Table 4). Five of the seven stomachs collected in summer belonged to male birds and 12 out of 14 of female stomachs were collected in winter. The collection date of 21 of the female stomachs was unknown. Even though female stomachs contained significantly more weta than males, this result may have been biased by the fact that there was a larger sample size for females than males. However, both sexes preyed on the remaining species in similar proportions (e.g. stick insects, spiders, birds).

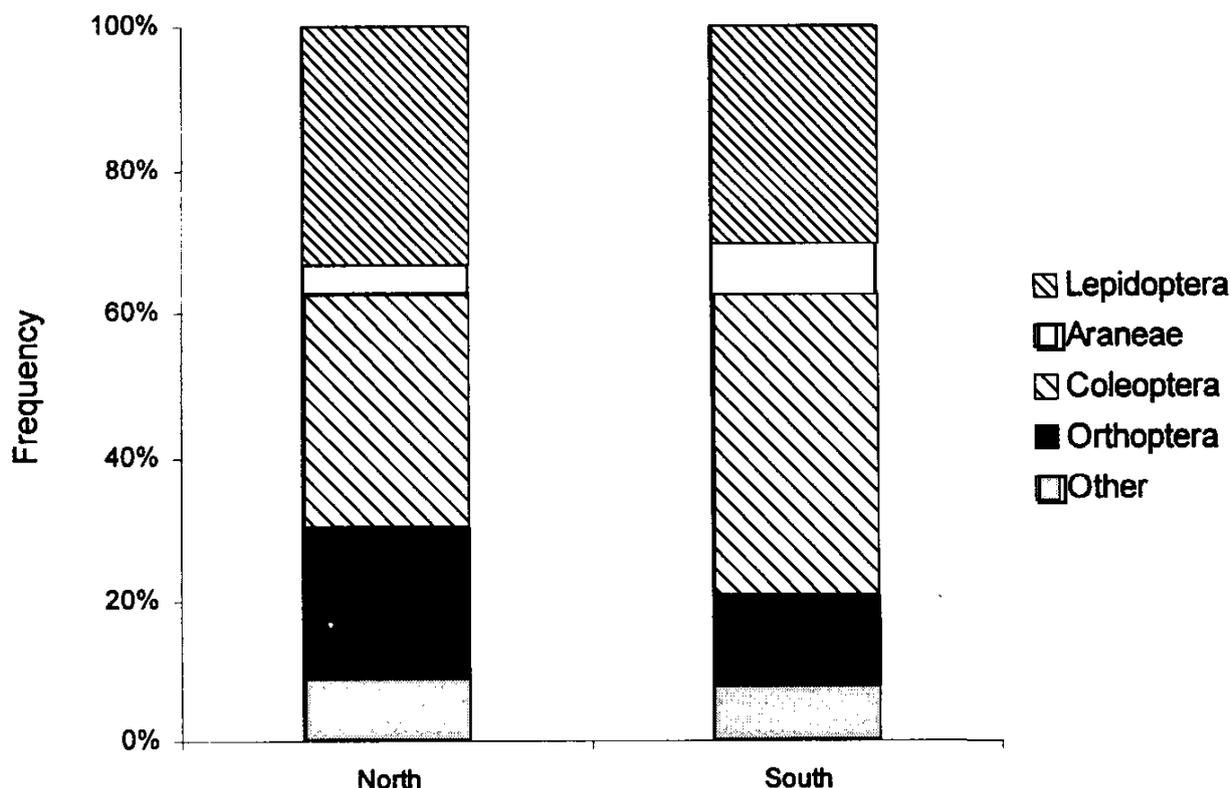


FIGURE 4 - Comparison of stomach contents of North ($n = 47$) and South ($n = 28$) Island Moreporks.

The diets of North and South Island Moreporks were similar but are evident. North Island birds consumed a greater variety of prey and South Island birds consumed a greater number of caterpillars and spiders but this could reflect small scale habitat differences rather than a difference in diet between islands. Birds were recorded in similar numbers in Morepork stomachs from both islands, and rodents were absent or rare in both cases (a single mouse in one South Island stomach).

The evident rarity of rodents in Morepork diet suggests that risks of secondary poisoning from this source are low. However, if large-bodied invertebrates (e.g. weta) regularly consume toxic baits this may be a potential threat to Moreporks, since such invertebrates consistently form a significant part of the diet, and occurred in 60.0% of stomachs.

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