

Diet provided for chicks by New Zealand Falcons (*Falco novaeseelandiae*) nesting in forested habitat

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ABSTRACT

This paper describes the diet fed to chicks of two pairs of New Zealand Falcons nesting in forested habitat. Both pairs fed their chicks almost exclusively on birds weighing less than 85 g. No mammals or reptiles were recorded in the diet; invertebrates represented an insignificant component. Both pairs caught more medium-sized birds (20-35 g) than large (70-646 g) or small birds (5-14 g). Falcons showed no size-based selection; rather, the size of prey that falcons selected to feed to chicks closely matched their abundance.

Sixteen species of birds were identified in the diet, and comprised 44% of the bird species present in the home ranges of both pairs. About half of the birds in the diet were introduced species.

KEYWORDS: *Falco novaeseelandiae*; diet; chick-rearing; forest.

INTRODUCTION

Fox (1977, 1988) described three forms of the New Zealand Falcon (*Falco novaeseelandiae*). He stated that the forms differed in their morphology, distribution and ecology. Large, pale, eastern falcons inhabit the South Island high country, while the smaller darker "bush" falcons dwell in the forests of the North Island (mainly south of 37°S), in the forests of the West Coast of the South Island and around the Nelson region. Intermediate in size and coloration are the southern falcons, which inhabit the forests of Fiordland and the Auckland Islands. New Zealand Falcons also inhabit Stewart Island, and have been reported on Codfish Island, off the coast of Stewart Island.

The New Zealand Falcon is categorized as a class B threatened species by the Department of Conservation (Tisdall, 1994) and as a near-threatened species under IUCN criteria (Collar *et al.* 1994). Fox (1977) cited the bush form as being most at risk due to habitat loss. Habitat disturbance and loss will result in alterations to the prey base as habitats become less suitable for some species and more favourable for others. In such circumstances, highly specialised predators are vulnerable to

extinction, while predators that are less specialised in terms of dietary requirements and foraging behaviour are more likely to persist. We examined the diet of New Zealand Falcons that were feeding young in order to develop an understanding of the bird's dietary requirements during this energetically demanding stage of the life cycle, and to ascertain whether falcons breeding in forest use an altered prey base.

Apart from observations made by Fitzgerald (1965), the diet of New Zealand bush falcons has not been studied. Fox (1977) quantified the diet of eastern falcons inhabiting open habitats in the South Island high country. He found that eastern falcons were generalist predators that fed mainly on birds, although they occasionally preyed on introduced mammals, skinks and invertebrates as well. Fox (1977) summarised the available literature on the falcons' diet; the review included records of falcons preying on birds ranging in size from the 7 g Grey Warbler (*Gerygone igata*) to the New Zealand Pigeon (*Hemiphaga novaeseelandiae*), averaging 590 g, and Kaka (*Nestor meridionalis*) weighing about 450 g.

Fox (1977) stated that, despite there being no records of the falcon nesting on sea cliffs, they prey on seabirds where their home range includes a coast line. Wilson (1959) described Cook's Petrel (*Pterodroma cookii*) in the diet of falcons breeding on Codfish Island. Hyde (unpubl. data) reported five species of seabirds (mainly petrels) and the coastal-dwelling Auckland Island Teal (*Anas aucklandica aucklandica*) in the diet of New Zealand Falcons on Adams Island in the Auckland Islands group.

Although Fox (1977) stated that wild New Zealand Falcons would probably show little interest in carrion, there are isolated reports of carrion consumption. The species involved included Chamois (*Rupicapra rupicapra*), Brushtail Possum (*Trichosurus vulpecula*) and Red Deer (*Cervus elaphus*). However, the New Zealand Falcon appears to take mainly live prey and carrion feeding is probably rare.

The aims of this paper were to determine: (1) the major items delivered to chicks by New Zealand Falcons breeding in a forest habitat; (2) whether falcons were size selective in their choice of prey or whether they capture prey in proportion to their availability; (3) the relative proportions of native and introduced species in their diet, and (4) whether dietary differences occur between eastern, bush and southern forms.

METHODS

The diet fed to chicks was studied for two pairs of forest-dwelling New Zealand Falcons (referred to as the 'Zig-Zag' and 'South' pairs) that bred successfully in the Mapara Wildlife Management Reserve, central King Country, North Island, New Zealand (38° 34'S, 175° 17'E), during the summer of 1993/94. The diet fed to the Zig-Zag brood was studied between 9 and 31 December 1993 and the diet fed to the South brood was studied between 12 December 1993 and 21 January 1994. Each pair of adults successfully hatched and fledged a single chick. The Zig-Zag pair had a male chick, while the South pair had a female.

Location of nests

Nests were located by visiting possible nesting areas and re-visiting areas that pairs of falcons were known to have occupied during the previous three years. Observations of falcons were plotted on a 1:10000 aerial photograph and areas of high falcon activity were identified. Nest trees were located by focusing searches on the high activity areas and observing falcon behaviour. The location of nests within trees was identified during incubation (i.e., when the female left the nest to receive prey items from the male).

Time lapse video

When the chicks were estimated to be about 10 days old and, therefore, able to thermoregulate (Fox, 1977), a Bischke CCD-FK-5612P colour video camera was installed at each nest site. The camera was attached to a wooden bracket, which was screwed to the trunk of the nest tree, so that the camera was about 1 m above the nest scrape. Recordings were made using a Gyr 1800 time-lapse video-recorder placed at the base of the nest tree.

Sampling strategy

The Zig-Zag chick hatched about 4 days earlier than the South chick and fledged about 16 days before the South chick. This meant that there was a period of overlap during late December when both chicks were still in the nest being fed by their parents. Because we had only one recorder, prey deliveries were filmed at each nest for 2 days every 6 days during the period of overlap. Prey deliveries were filmed every day during the period of non-overlap.

Identification of prey on video

Individual prey items that were delivered to the nest were identified using a professional Sony PVM-2130-QM monitor. Where possible, prey items were identified to species level. Because most prey deliveries involved plucked or dismembered individuals (usually decapitated), and because camera resolution was sometimes compromised by fogging, prey identification to the species level was not always possible. When birds were prey items it was not possible to distinguish adults from nestlings on video. Nestlings were identified from the analysis of prey remains collected from the nest site.

Five categories of prey items were recognised as being potential components of a falcon's diet: birds, mammals, invertebrates and reptiles. Prey items that could not be assigned to one of these classes were recorded as unidentified.

Prey items that were identified as birds were assigned to a size class. Size classes were defined on the basis of average body weights of all bird species available in the study area. The data were obtained from the National Museum of New Zealand. Size classes were small (i.e., between 5.7 and 13.5 g, mean 6.5 g), medium

(i.e., between 20.0 g and 35.0 g, mean 24.1 g), and large (between 70.0 g and 646 g, mean 154.0 g).

Because New Zealand Falcons are known to cache uneaten prey (Fox 1977; L. Barea pers. obs.), a single prey item could have been brought to the nest on more than one occasion. Adult falcons were often observed repeatedly bringing the same prey item to the nest, feeding the chick, and then leaving with the prey. By visually comparing each delivered prey item with preceding items for that day, prey items representing 'new' prey could be identified. Only items that were considered to represent new prey were included in the analysis.

Identification of prey remains

Prey remains were collected from the nest after chicks had fledged to avoid disturbance to the parents or premature fledging of the chicks. Only seven pellets were found in the Zig-Zag nest and no pellets were found in the South nest. The South nest also had fewer prey remains available for collection. In other falcon species, adults remove pellets from the nest as well as uneaten prey remains (Squires *et al.* 1989). Both adult female falcons were frequently observed removing partly eaten prey from the nest during filming. Therefore, the lack of pellets and remains available for collection may be due to this removal.

Pellets and prey remains were analysed using the method of Fox (1977). They were examined dry and teased apart in a white dissecting tray. All remains were separated, with more difficult items suspended in water to allow for a closer inspection and cleaning. All identifiable material was compared with the Museum of New Zealand skin, skeleton and spirit collection. Vertebrate prey items were identified to species level and counted to determine the minimum number of individuals in the sample. Some small contour feathers were examined microscopically (Brom, 1991). Partially decayed feathers, usually with only the rachis present, were separated and their size-class estimated.

Bird surveys

Bird surveys were conducted along transects within the adults' foraging areas so that prey use could be compared with the abundance of prey. Foraging areas in the South pair's home range included open agricultural land, forest habitats with a relatively uniform Tawa (*Beilschmiedia tawa*) canopy, disturbed habitats that included areas within forests that were regenerating after past logging and edge habitats that comprised the ecotone between forest and open habitats. Open agricultural land often contained small patches of native scrub in the heads of gullies, often only a few square metres in extent, where a number of bird species usually found only in forest were observed (e.g. Grey Warbler, Tomtit (*Petroica macrocephala*)). The foraging area of the Zig-Zag pair included all of the above as well as 'plantings habitat' (i.e., a relatively open area undergoing re-forestation) and 'rough pasture' (i.e., pasture land characterised by a mosaic of pasture, ferns and isolated stands of Tawa).

One 500 m transect was established in each habitat type for each pair of falcons. Ten sample stations were located along each transect at 50m intervals. Birds were surveyed using a 5-minute bird count method modified from Dawson & Bull (1975). All birds heard or seen within a 25 m radius of each station during a 5 minute period were counted after an initial waiting period of 2 minutes.

Each transect was sampled three times during the period chicks were being fed; the data were then pooled for each transect. An index of bird abundance was constructed for each habitat, consisting of the mean number of birds per sampling station. Bird prey size classes are expressed as percentages. To reduce between-sample errors caused by diurnal variation in behaviour patterns, and changes in weather, counts were only conducted between 0700 and 1000 h on fair-weather days.

Because birds flying in forest and disturbed habitats would be less obvious to the observer than birds flying over open or edge habitats, birds in flight were excluded from the data set.

Species specific attributes of potential bird prey species, (e.g., behaviour or habitat use) may result in a given species being unavailable to a foraging falcon, despite being present in the falcons home range. Therefore the results of these bird surveys are discussed in terms of presence and abundance rather than availability.

RESULTS

Prey delivered to nest

A total of 137 prey deliveries was recorded on video tape including 110 'new' individual prey items. Forty-eight percent ($n=53$) and 52% ($n=57$) of these were from the Zig-Zag and South pairs, respectively. We could not identify the type of prey item (e.g. bird, mammal) in 4% ($n=4$) of the deliveries to the Zig-Zag chick, and 7% ($n=8$) of the deliveries to the South chick.

All of the identified prey items were birds weighing less than 85 g. Table 1 shows the items identified to species level on video for both pairs. Six species were introduced and three species were native birds. It was not possible to differentiate between N.Z. Pipits (*Anthus novaeseelandiae*) and Skylarks (*Alauda arvensis*) on video.

Both pairs caught more medium-sized birds than small or large birds. Medium-sized birds comprised 48% ($n=23$) and 44% ($n=20$) of the prey fed to the chicks of the Zig-Zag and South pairs, respectively. Small birds were the next most common size class, comprising 35% ($n=17$) of the prey delivered to the Zig-Zag chick and 37% ($n=17$) of the prey delivered to the South chick. Large birds comprised a smaller proportion of the prey fed to the chicks of both pairs; that is, 17% ($n=8$) and 20% ($n=9$) for the Zig-Zag and South pairs, respectively.

TABLE 1 – Number of prey items identified from video, from prey remains, and from pellets at two New Zealand Falcon nests in the Mapara Wildlife Management Reserve.

Prey Species	“Zig-Zag” Pair			“South” Pair			Body mass g
	Video	Prey remains	Pellets	Video	Prey remains	Pellets	
NZ Pigeon (nestling) *		1					590
Long-tailed Cuckoo*		1					121
Silvereye	5	2		1	1		12
Grey Warbler		1					7
Blackbird		1		1			89
Song Thrush		1		1			69
NZ Pipit or Skylark+	1	1					32/33
Whitehead*		1					13
NZ Tomtit	1	1		3			9
Tui (adult)		1	1	1			105
Tui (fledgling)		1					-
Tui (nestling)		1			1		-
House Sparrow+		1					29
Chaffinch	1	1			1		21
Goldfinch+	1	1					14
Greenfinch+					1		24
Yellowhammer+	2	2			2		26
Starling+	2	3	1		1		75
Australian Magpie					1		320
Unidentified bird			3		4		-

+ indicates that species was only observed in open pasture habitats, *indicates that species was only observed in forested habitats. Mean body masses were sourced from the Museum of New Zealand

Analysis of prey remains and pellets

Sixteen species of birds were identified from the analysis of prey remains and two species of birds were identified from the analysis of pellets (Table 1). The sample included 44% (n=16) of the bird species present in the home ranges of both pairs of falcons (Appendix 1). Nine of the species identified in the total diet fed to chicks were introduced birds and seven were native. Six of the species in the diet were present only in open pasture (Table 1).

Three species recorded in the diet were only present in forest habitats and all were native species (Table 1). All other species were present in all other habitats. Both nests also contained chitin remains of numerous Manuka beetles (*Pyronota festiva*). The South nest contained the remains of seven chafer beetles (*Stethaspis longicornis*), one Giant Dragonfly (*Uroptela carovei*) and one cicada (Cicadidae).

Fewer prey remains were present in the South nest for collection, which was probably the reason why fewer prey species were identified for this pair. Seven species, five introduced and two native, were identified for the South pair. Fifteen species were identified for the Zig-Zag pair, eight of which were introduced birds.

TABLE 2 – Mean (\pm one s.e.) number of birds present (no. of birds per sample station, pooled for 3 transect counts) in different habitats in the territories of two pairs of New Zealand Falcons in the Mapara Wildlife Management Reserve.

Habitat	"Zig-Zag" pair	South pair
Edge	8.9 \pm 0.7	8.6 \pm 0.4
Forest	5.1 \pm 0.4	6.5 \pm 0.3
Plantings	5.1 \pm 0.5	habitat absent
Open	4.7 \pm 0.9	2.8 \pm 0.4
Rough Pasture	3.2 \pm 0.5	habitat absent
Disturbed	habitat absent	3.8 \pm 0.3

Prey abundance

Thirty-six species of birds were observed in the home ranges of both pairs of falcons (Appendix 1). Edge habitats contained more birds than any other habitat. Bird abundance was similar for plantings and forest habitats, but much less than that of edge. The abundance of birds was even lower in open habitats, rough pasture and disturbed habitats. In the South pair home range, the abundance of birds was lowest in open habitats (Table 2).

Comparison between the sizes of prey caught and their abundance

A comparison of the sizes of the birds preyed upon and their abundance in each pair's home range indicated that both pairs showed no size-based preferences (Figure 1). The size of prey selected by the South pair closely matched abundance. Use of small birds by the Zig-Zag pair was somewhat higher than their abundance and use of large birds was lower than their abundance. However, these differences were not statistically significant ($\chi^2 = 0.47$, d.f. = 1, n.s.).

DISCUSSION

Both pairs delivered mainly small to medium-sized birds to their chicks. No deliveries of mammalian prey were observed. The absence of Ship Rats (*Rattus rattus*) may reflect their low abundance in the reserve immediately after Department of Conservation control operations. Rabbits (*Oryctolagus cuniculus*) and House Mice (*Mus musculus*) were abundant in the area but were not brought to the nests.

These results differ from diet studies of eastern falcons, in which 38% (biomass) of the food brought to nests consisted of introduced mammals (mainly rabbits) (Fox, 1977). The smaller size of bush falcons (Fox, 1977), especially the males, may account for the absence of large mammals. The absence of juvenile rabbits and mice in the diet fed to chicks is however puzzling.

Lizards were also absent from the prey delivered to the nests of the falcons at Mapara. We saw no lizards in the area during the study, so their absence may reflect low abundance. Although both pairs caught some insects, their contribution to the diet of chicks was insignificant. Insects also comprised a small proportion

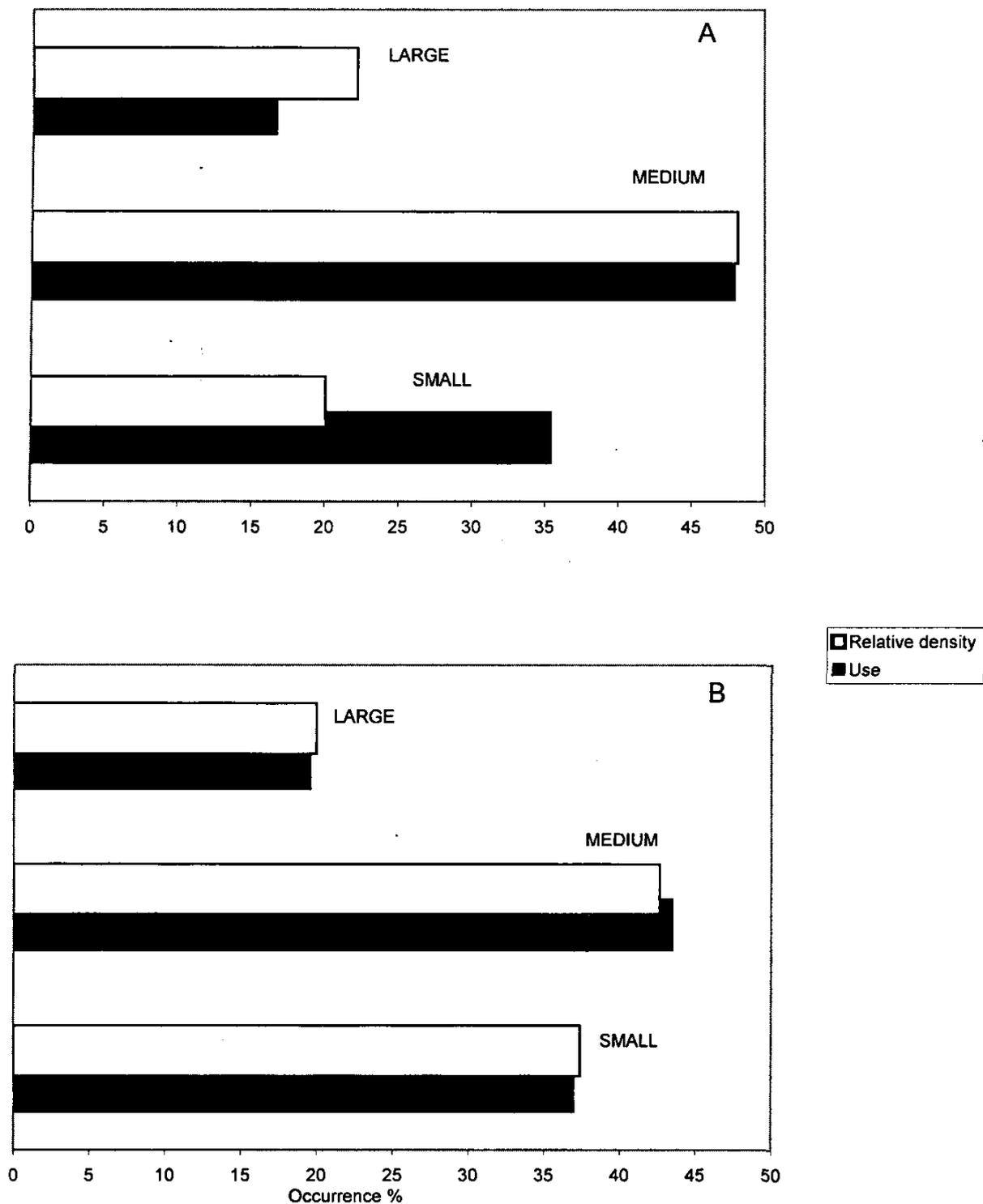


FIGURE 1 – The relative density (white columns) of different-sized birds on the territories of 2 pairs of New Zealand Falcons and their presence as prey delivered to nestlings (black columns) in the Mapara Wildlife Management Reserve. A, “Zig-Zag” pair; B, South pair.

(0.4%) of the diet in Fox's (1977) study of eastern falcons. In this study, Manuka beetles probably came from the crops of avian prey (e.g., Grey Warbler). Larger insects were probably incidental prey items caught by the adult female close to the nest. Both pairs also delivered nestling and fledgling birds to the nest and preyed on introduced birds in addition to native species.

Introduced birds comprised over half of the prey items we observed. All eight prey species identified by Fitzgerald (1965) in the diet of bush falcons near Gisborne were introduced birds common in the diet of the pairs we studied at Mapara. The diet of eastern falcons included 22 bird species of which 14 (64%) were introduced (Fox, 1977). The higher incidence of introduced birds in Fox's study may reflect their greater abundance in the eastern falcon's open high country habitat. Hyde (unpubl. data) identified 12 species of birds in the diet of southern falcons nesting on Adams Island (Auckland Islands), 11 of which were native; the introduced bird was a Blackbird (*Turdus merula*). Bush falcons inhabiting indigenous forest and southern falcons on the sub-Antarctic islands probably include indigenous birds in their diet more frequently than eastern falcons inhabiting open areas simply because the relative abundance of these birds is likely to be higher. Our data suggest that introduced birds are an important component of the diet of nesting bush falcons at Mapara.

We found 18 accounts of bush falcons either hunting or eating identifiable bird prey in the notes of the Ornithological Society of New Zealand (1984-1996). Fifteen of the prey species were introduced birds and three were native. The Raptor Association of New Zealand supplied us with 48 similar accounts, of which 39 were introduced birds and nine were native (S. Lawrence, *pers. comm.*). These observations support our observations that bush falcons include introduced species in their diet when available.

The two pairs of falcons we studied did not select prey on the basis of size, but rather preyed on birds in proportion to the abundance of size-classes. Sodhi & Oliphant (1993) reported that Merlins (*Falco columbarius*) in Saskatoon, Canada were not size-selective, but selected prey based on availability. A similar trend was reported by Joy *et al.* (1994) who found that Sharp-shinned Hawks (*Accipiter striatus*) preyed on birds in proportion to their abundance in the three main habitats around their nests.

Because prey remains were not collected from nests at discrete intervals (to avoid excessive disturbance), and individual prey items were often not identifiable to species level, only limited data were available on the abundance of particular species in the diet fed to chicks. The Zig-Zag pair took more Starlings, Yellowhammers and Silvereyes than other species. Yellowhammers and Starlings were observed only in open habitats during bird surveys, so they were likely to have been caught there, while Silvereyes were present in both habitats.

Six prey species were only present in open pasture habitats while three species were restricted to forest habitat. The rest were present in both habitats. This may indicate that these falcons were hunting more in open habitats than in forest, despite the lower bird numbers in the former. Our results suggest that this requires

further investigation. The New Zealand Falcon is an opportunistic predator which feeds on introduced birds when these are available. We conclude that it is unlikely to be threatened by the loss of traditional prey species so long as sufficient numbers of introduced prey are available.

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Appendix 1 – *Bird species identified from transect counts, and incidental observations* *: present within the habitats known to be included in the home range of two pairs of New Zealand Falcon studied in the Mapara Wildlife Management Reserve. #: indicates introduced species.

Paradise Shelduck *	<i>Tadorna variegata</i>
Mallard *#	<i>Anas platyrhynchos</i>
Grey Duck *	<i>Anas superciliosa</i>
Ring-necked Pheasant *#	<i>Phasianus colchicus</i>
Wild Turkey *#	<i>Meleagris gallopavo</i>
Clairfornia Quail *#	<i>Callipepla californica</i>
Spur-winged Plover *	<i>Vanellus miles</i>
New Zealand Pigeon	<i>Hemiphaga novaeseelandiae</i>
Eastern Rosella #	<i>Platycercus eximius</i>
Shining Cuckoo	<i>Cbrysococyx lucidus</i>
Long-tailed Cuckoo	<i>Eudynamys taitensis</i>
Morepork *	<i>Ninox novaeseelandiae</i>
New Zealand Kingfisher	<i>Halcyon sancta vagans</i>
Welcome Swallow*	<i>Hirundo tabitica</i>
Silvereye	<i>Zosterops lateralis</i>
Grey Warbler	<i>Gerygone igata</i>
Blackbird #	<i>Turdus merula</i>
Song Thrush #	<i>Turdus philomelos</i>
Dunnock #	<i>Prunella modularis</i>
Skylark #	<i>Alauda arvensis</i>
New Zealand Pipit	<i>Anthus novaeseelandiae</i>
North Island Fernbird *	<i>Bowdleria punctata vealeae</i>
Whitehead	<i>Moboua albicilla</i>
Fantail	<i>Rhipidura fuliginosa</i>
NZ Tomtit	<i>Petroica macrocephala</i>
North Island Kokako	<i>Callaeas cinerea wilsoni</i>
Tui	<i>Prosthemadera novaeseelandiae</i>
Bellbird	<i>Anthornis melanura</i>
House Sparrow #	<i>Passer domesticus</i>
Chaffinch #	<i>Fringila coelebs</i>
Redpoll #	<i>Carduelis flammea</i>
Goldfinch #	<i>Carduelis carduelis</i>
Greenfinch #	<i>Carduelis chloris</i>
Yellowhammer#	<i>Emberiza citrinella</i>
Starling #	<i>Sturnus vulgaris</i>
Australian Magpie #	<i>Gymnorhina tibicen</i>