Northern brown kiwi (*Apteryx australis mantelli*) in Tongariro National Park and Tongariro Forest — ecology and threats

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CONTENTS

Abstract

Major findings from a 14 month study of calling behaviour, range size, roost choice, feeding ecology, and threats to the conservation of northern brown kiwi (*Apteryx australis mantelli* Bartlett) in two conservation areas in Tongariro National Park and Tongariro Forest are summarised. In Tongariro Forest, 73% of calls were made by males. Temperature and rain accounted for 44% of the between-night variation in calling activity. The density of kiwi was about 1/km^2 in Tongariro National Park, and about 4/km^2 in Tongariro Forest. Calling activity was not linearly related to the number of kiwi present. Home ranges of the kiwi varied from 30.8 to 91.8 ha. Roosts associated with fallen trees and surface roots were most preferred. Higher numbers and a greater taxonomic diversity of invertebrates were found in Tongariro Forest than in Tongariro National Park, with 55% of taxa common to both areas. Food availability does not appear to account for current differences in the density of kiwi at the two sites. Possums, cats, dogs, stoats, and probably ferrets and pigs, were present in both locations. Predators pose a major threat to the continued survival of kiwi in the central North Island. Management recommendations are made.

1. Introduction

The decline in the number of kiwi on mainland New Zealand is an issue of national concern and a major focus of the Kiwi Recovery Plan (Butler & McLennan 1991). McLennan & Potter (1992) document evidence suggesting that kiwi numbers in Hawke's Bay have declined by at least 75% since the 1930s. Extremely low recruitment rates due to high levels of chick predation by introduced mammalian predators has probably been a major factor in this decline (McLennan & Potter 1993). Call surveys conducted over a number of years in the Tongariro/Taupo Conservancy suggest that kiwi in this region have suffered a similar decline in numbers, and concern was raised about whether variations in land management strategies in different parts of the conservancy place some kiwi at greater risk that others. The current study was initiated in response to this concern, and to improve our understanding of the ecology of kiwi in the central North Island.

The aim of this study was to identify threats to the continued survival of northern brown kiwi *Apteryx australis mantelli* in Tongariro/Taupo Conservancy and, where appropriate, to recommend changes to management practices so as to benefit kiwi. Two adjacent kiwi populations in the conservancy were studied, one within Tongariro National Park (T.N.P.). Here hunting, dogs, and trapping is strictly regulated by a permit system (National Parks Act 1980), and extermination of introduced flora and fauna in the park is pursued in accordance with the National Parks Act 1980, and the Wild Animal

Control Plan, 1988. The other population was in Tongariro Forest (T.F.), where hunting, dogs, and trapping are harder to control. The comparative study of kiwi in these two areas was designed to help determine whether current management practices adversely affected kiwi in T.F. Intensive call surveys were conducted to compare kiwi density and calling activity at the two sites. Home range size, habitat use, roost quality, resource availability and its utilisation were measured, and predator indexing was conducted.

This report provides a summary of the major findings of this study. For further discussion see Miles (1995).

2. Study area

The study was undertaken at two sites in the central North Island (Figure 1). The main study area was situated in Tongariro Forest (NZMS S19, 237367) 19 km north/west of the. This site, formally a lowland podocarp forest, has been logged and burnt from 1903 through to 1972. The landscape comprises a nearly even blend of toetoe (*Cortaderia toetoe*), with remnant stands of podocarp forest rimu (*Dacrydium cupressinum*), miro (*Prumnopitys ferruginea*), and totara (*Podocarpus hallii*). The valley floor is 500 m a.s.l. and is flanked by steep hills rising to 900 m a.s.l. During the study the mean annual daily temperature ranged from 9 ^{o}C to 18 ^{o}C, and average rainfall in 1993 was 101.64 mm per month (Whakapapa meterological station).

The second study area in Tongariro National Park. (NZMS S20, 240185) was situated on the western side of Mt. Ruapehu. Here the forest consists of a canopy dominated by mountain beech (*Nothofagus solandri var cliffortioides*), with occasional emergent kaikawaka (*Librocedrus bidwillii*) and Hall's totara (*Podocarpus hallii*). The understorey contains a diverse array of species: mountain beech, kaikawaka, and totara saplings, mountain toatoa (*Phyllocladus aspleniifolus*), *Coprosma* spp., mingimingi (*Leucopogon* spp., bush lawyer (*Rubus cissoides*), and many other divaricating species, all forming an extremely dense wall of vegetation. From highway 47 on the western side of Mt. Ruapehu, the Mangahuia track climbs from 883 m a.s.l. to the study area at 1026 m a.s.l. During the study, the mean annual daily temperature ranged from 2.1^{o}C to 11.3 ^{o}C, and the average monthly rainfall in 1993 was 169.4 mm.

3. General methods

3.1 CALL SURVEYS

Call surveys were used to determine the comparative densities of kiwi in each area. During each listening period the time of the call, the sex, approximate location, and the approximate distance to the birds that called were recorded

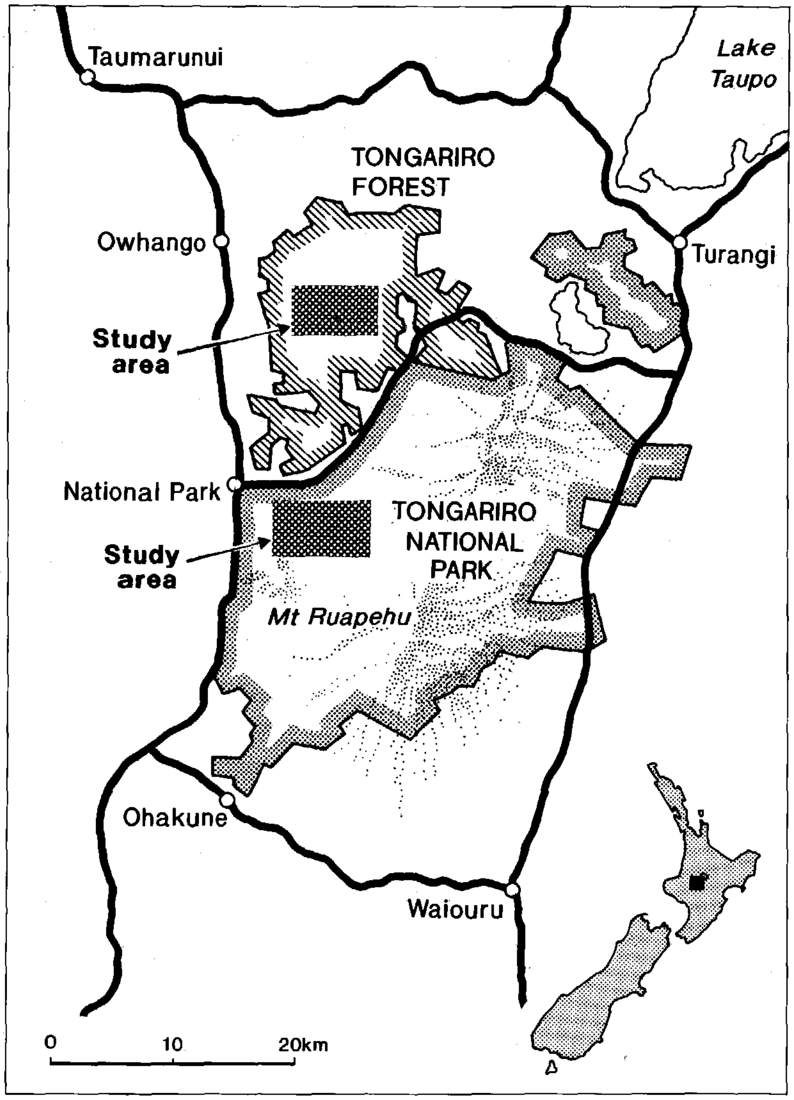

FIGURE 1. LOCATION OF TONGARIRO NATIONAL PARK AND TONGARIRO FOREST, AND THE TWO STUDY AREAS.

along with data on twelve environmental variables (wind, rain, actual temperature, apparent temperature (cold, mild, warm), ground conditions, moonlight, moon phase, possum calls, morepork calls, background noise, cloud cover and habitat type). Nine of these are listed on standard Department of Conservation kiwi call cards.

Approximately 40% of the time spent call surveying was dedicated to testing the value of broadcasting taped male and female calls to enhance "natural" call rates in different densities of kiwi. Calls were broadcast every 10 to 15 minutes in alternately the first and second hour over consecutive nights.

3.2 HOME RANGE SIZE AND ROOST CHOICE

3.2.1 Capture of kiwi

Kiwi were attracted by means of a whistle or taped calls. They were then spotlighted and run down. Following capture each kiwi was banded (New

Zealand National Banding Scheme size "R" bands), fitted with a radio transmitter, weighed and measured (Appendix 1), then released.

3.2.2 Telemetry

Radio telemetric techniques and transmitter design were similar to those described in McLennan *et al.* (1987), and Potter (1990). Radio-tagged kiwi were recaptured every 2.5–3 months for weighing and to check transmitters and transmitter bands.

During the day, kiwi were either tracked to their roost, or their location determined using cross bearings (triangulation) from 10 tracking stations. Locations were then transcribed into co-ordinates and recorded on a NZMS map. Habitat type at each location was also determined and recorded. Kiwi were also tracked at night, but these data were not included in range estimates because of the difficulties in obtaining accurate location estimates.

3.2.3 Estimation of range size

Three methods were used to determine range size: the convex polygon method (Mohr, 1947); the field worker method (Macdonald *et al.*, 1980); and the adaptive kernel method (Taborsky and Taborsky, 1992).

3.2.4 Habitat analysis

1. **Availability**: availability was calculated as the apparent amount of each habitat type within the bounds of each kiwi's home range estimated by the convex polygon method.
2. **Utilisation**: the daytime location of each kiwi was classified according to the habitat type, and the percentage of time each kiwi roosted in a particular habitat type within their home range was calculated.
3. **Preference**: preference refers to whether kiwi selected some habitat types over others, and therefore spent more time in these habitats (and less time in the remaining habitats) than would be expected based on the availability of each habitat type. A standard approach to testing the hypotheses of preference is presented in Neu *et al.* (1974), and is explained in detail in Miles (1995).

3.3 FOOD AVAILABILITY AND UTILISATION

3.3.1 Food availability

The techniques used to sample invertebrates were similar to those of Moeed and Meads (1985, 1986). Each site had five 12 cm diameter pitfall traps distributed over an area of approximately 100 m^2. Litter and soil samples were collected from separate but neighbouring sites of equivalent size. Each site was sampled on average every 45 days from December 1992 to January 1994. The nine sample dates were then grouped by season: summer (December–February); autumn (March–May); winter (June–August); and spring (September–November).

3.3.2 Utilisation

Kiwi faeces were collected over 14 months and stored individually in 75% alcohol. Samples were then washed through a gradation of sieves to separate invertebrate remains. Apart from earthworms, all invertebrate food items (numbers of individuals) within the faeces were counted under a × 10 binocular microscope. The number of species of each taxon in each dropping was determined by counting the most conspicuous remains.

Thirteen non-annelid taxa were identified as common in faeces collected in both areas. Ten samples of each taxon were selected from invertebrate sampled material and weighed to give an estimation of individual biomass.

Earthworm chaetae in faeces were counted, but estimations of the numbers of earthworms consumed was not attempted as chaetae give an unreliable indication of the number of worms eaten. This is because the number of chaetae per worm varies between species (130 species of earthworms live in New Zealand) and between different sized worms of the same species (Wroot, 1985).

The presence of identifiable plant remains (i.e., seeds and fruit) was recorded. Identification of plant fragments by their cuticle patterns was not attempted.

3.4 INDEXING MAMMALIAN PREDATORS

The presence of mammalian predators in each study area was determined by establishing and monitoring a trap-line, by noting any other predators seen, and by analysing data from the DoC (Whakapapa) Pest Control Diary.

3.4.1 Trap layout and trapping tunnels

Twelve trapping tunnels were placed at 500 m intervals, 5–10 m in from the main access ways, along 6 km transects down both the Mangahuia track in T.N.P. and Slabb Road in T.F. Traps were set for 14 consecutive days each month from July to September 1993, providing a total of 504 trap nights.

Each trapping tunnel was 600 mm long with a cross section 180 mm high x 150 mm wide. Two 300 mm lengths of 150 mm diameter Nova pipe were fastened to each end of the main tunnel by two vertical wire bars. Two Mark IV Fenn Humane Traps were set near the centre of each tunnel with the bait between them.

Dilks *et al.* (1992) compared various bait types and found that stoats appeared to have a significant preference for traps baited only with eggs. Accordingly, each trap was baited with two hen eggs; one whole, and one punctured.

Traps were checked and every day and reset if necessary. Dead animals were collected and autopsied following the methods of King and Moody (1982a, 1982b).

3.4.2 Hunter questionnaires

Hunter questionnaires were designed and distributed in conjunction with the Conservancy Hunter Diary system.

4. Summary of results

4.1 CALL SURVEYS

1. Call surveys were conducted between November 1992 and January 1994. A total of 14 calls were heard during the 133 hours (mean = 0.1 calls $hour^{-1}$) spent surveying in T.N.P., compared with 1065 calls heard during 345 hours (mean = 3.0 calls $hour^{-1}$) in T.F. Call surveying coupled with radio-telemetry indicated that T.N.P. contained one kiwi/km^2, while the density in T.F. was estimated to be four kiwi/km^2. In these low-density populations, therefore, kiwi call rates did not correlate linearly with kiwi density.

2. In T.F., male calls accounted for 73.5% of all calls heard. This ratio (3 males:1 female) changed seasonally, with a larger proportion of female calls being heard in the winter and spring months when many of the males would have been on nests. Males and females often called together (within 2 minutes of each other). The majority of these duets (87%) were performed by members of bonded pairs (Figure 2). Calling started later over the winter months than in the other seasons, with the time to the first call appearing to be proportional to night length (Figure 3). Kiwi called in two bouts during the night, with call rates being highest during the first 2–3 hours of darkness (Figure 4). The second peak occurred shortly before dawn. This bimodal pattern persisted throughout the year.

3. Breeding behaviour accounted for some variation in call rates, with calls increasing steadily from autumn to a peak lasting through to the end of spring (Figure 5). Irrespective of season, kiwi called less on some nights than others. Temperature and rain accounted for 44% of the between night variation, with call rates being lowest on cold nights with moderate to heavy rain (Figure 6). Kiwi were also less vocal on the first wet night following a dry spell. Reduced call rates did not correlate with light levels, or with the phase of the moon.

4. Approximately 40% of the time spent call surveying was dedicated to testing the value of broadcasting taped male and female calls to enhance "natural" call rates. Significantly more calls were heard when calls were broadcast (Table 1). However, broadcasting appeared to elicit responses only from kiwi in the higher density population in T.F. There was no difference in call rate as a result of either broadcasting in the first hour or not doing so (Table 2). This was also the case for the second hour (Table 3). Both males and females responded more to a taped female call than to a taped male call. Overall, taped calls of either sex elicited significantly more responses from males than from females.

5. Four to five consecutive nights of data were needed to accurately estimate average call rates in an area (Figure 7). This level of monitoring also enabled an accurate assessment of the density of kiwi on the ground in Tongariro Forest, but not in Tongariro National Park.

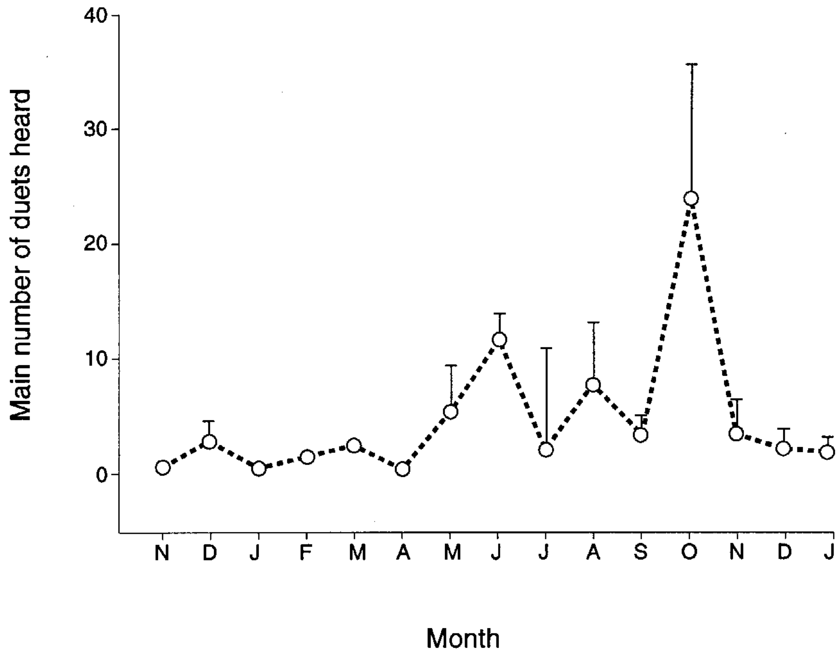

FIGURE 2. AVERAGE NUMBER OF DUETS (t SE) HEARD FOR EVERY 24 HOURS OF LISTENING, NOVEMBER 1992 TO DECEMBER 1993, IN TONGARIRO FOREST.

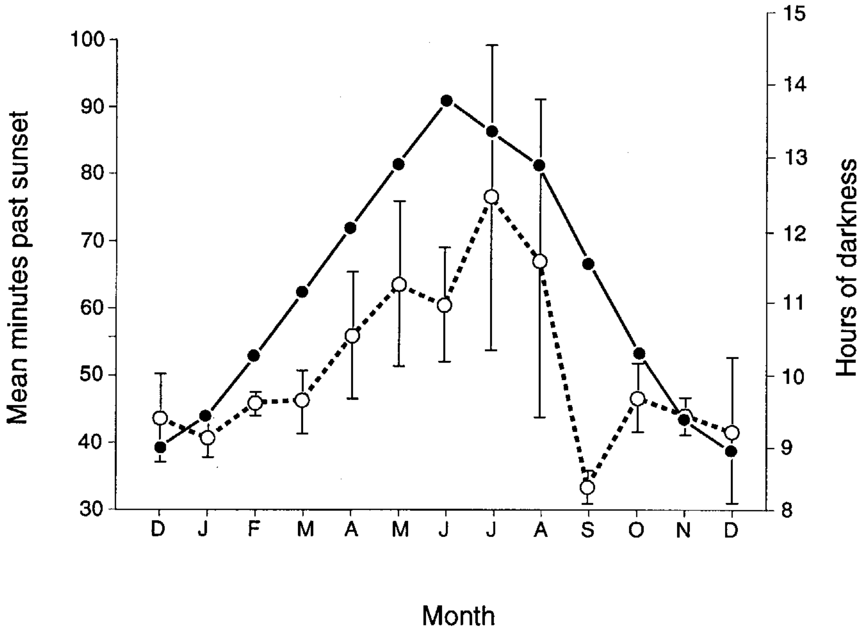

FIGURE 3. TIME AFTER SUNSET WHEN THE FIRST KIWI CALL (----------) WAS HEARD DURING DIFFERENT MONTHS AND NIGHT LENGTH (HOURS OF DARKNESS:) I N TONGARIRO FOREST, DECEMBER 1992 TO DECEMBER 1993.

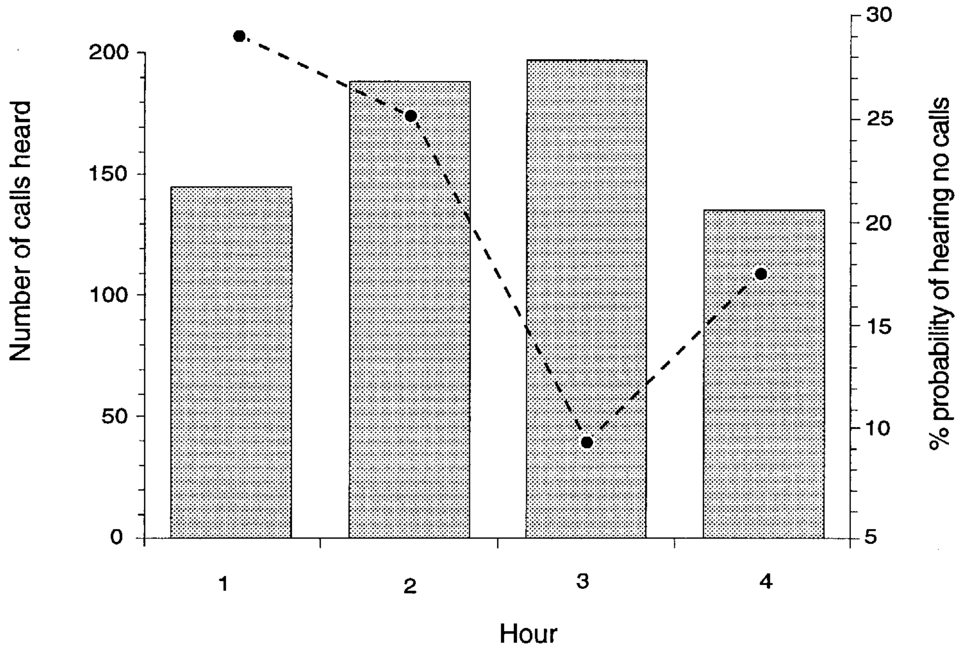

FIGURE 4. TOTAL NUMBER OF CALLS HEARD IN THE FIRST FOUR HOURS OF DARKNESS (HISTOGRAMS). THE LINE REPRESENTS THE PERCENTAGE PROBABILITY OF NO CALLS OCCURRING IN THAT PARTICULAR HOUR.

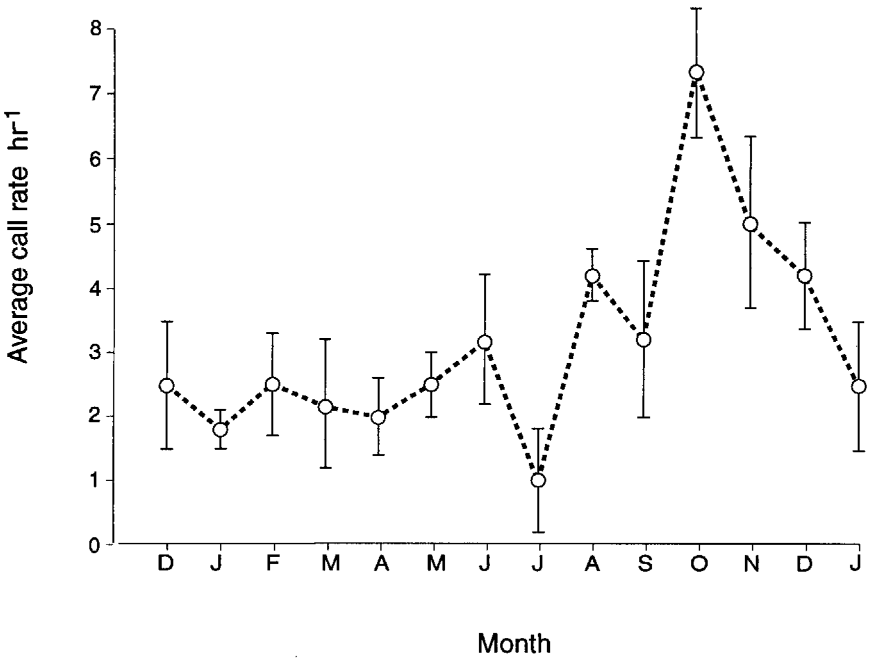

FIGURE 5. SEASONAL VARIATION IN THE CALLING RATES OF KIWI IN TONGARIRO FOREST, DECEMBER 1992 TO JANUARY 1994.

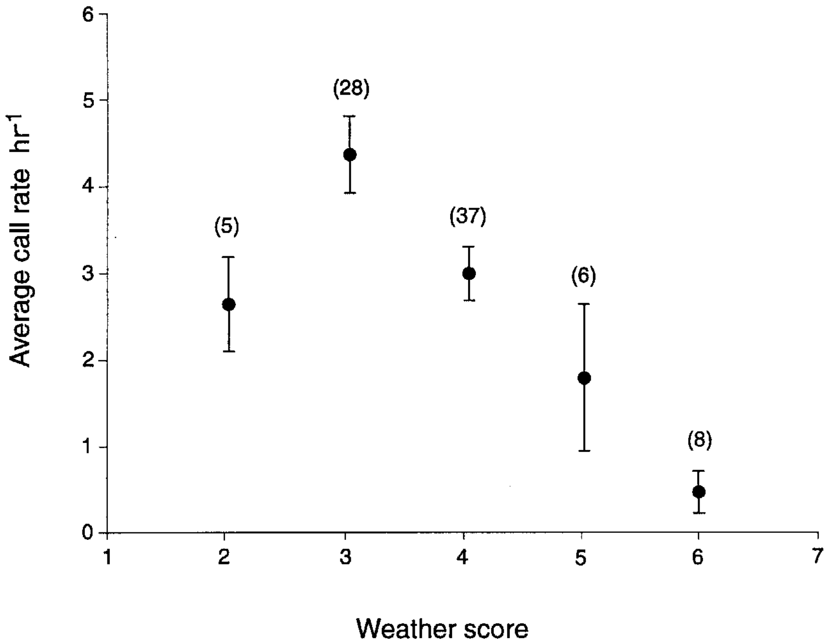

FIGURE 6. AVERAGE CALLING RATES (t SE) OF KIWI IN TONGARIRO FOREST IN RELATION TO WEATHER. RAIN WAS SCORED ON A 1 - 3 SCALE, WITH 1 REPRESENTING NO RAIN, 2 LIGHT RAIN, AND 3 MODERATE/HEAVY RAIN. TEMPERATURE WAS ALSO SCORED ON A 1 - 3 SCALE, WITH 1 REPRESENTING WARM TEMPERATURES, 2 MILD, AND 3 COLD. THE TWO SCALES WERE ADDED TOGETHER TO GIVE THE WEATHER SCORE. NUMBERS IN BRACKETS REFER TO SAMPLE SIZE.

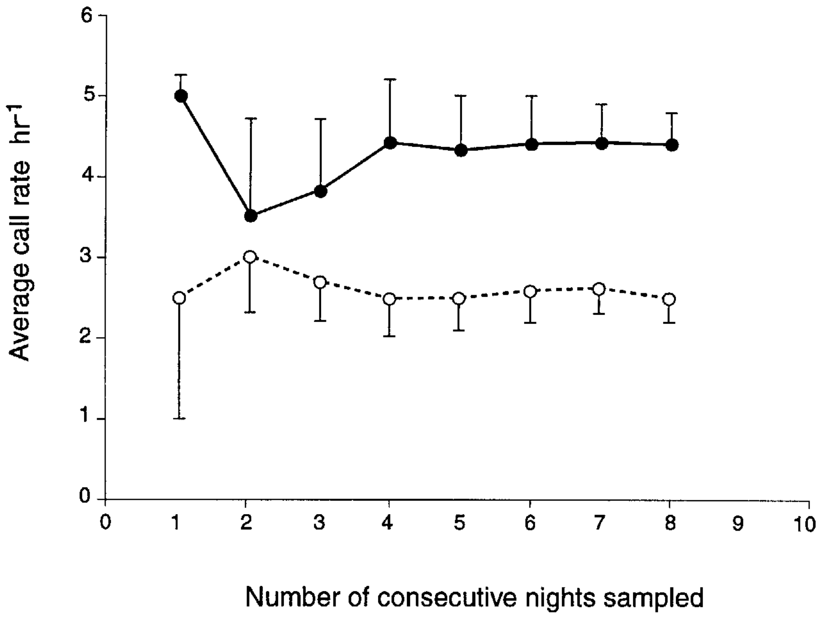

FIGURE 7. EFFECTS OF INCREASING SAMPLE SIZE ON ESTIMATES OF AVERAGE CALLING RATE (t SE). --------- = TONGARIRO FOREST IN MARCH 1993; _ TONGARIRO FOREST ON OCTOBER/NOVEMBER 1993.

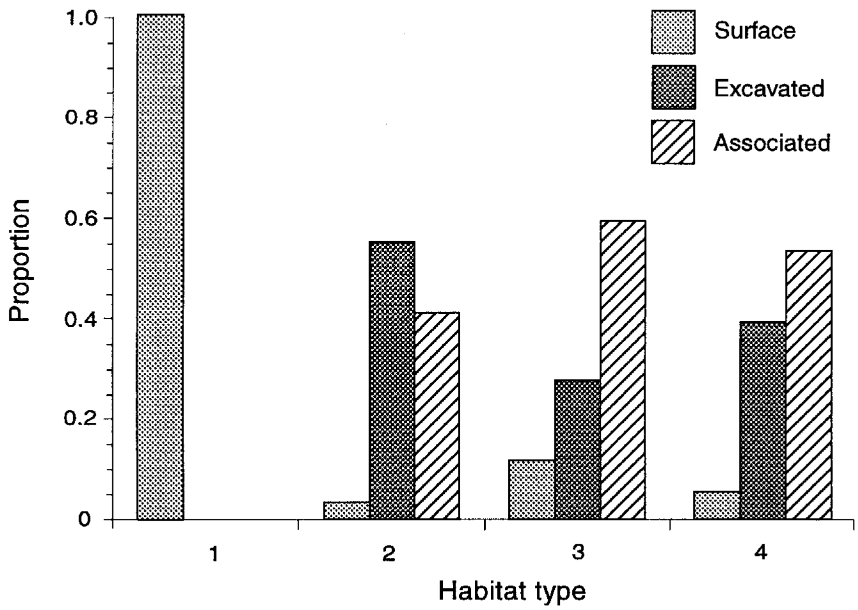

FIGURE 8. PROPORTION OF ROOST TYPES FOUND IN THE FOUR MAIN HABITAT TYPES (1 TOETOE, 2 SELECTIVELY LOGGED, 3 UNLOGGED, AND 4 BROADLEAF/SCRUB) WITHIN KIWI RANGES IN TONGARIRO FOREST.

TABLE 1. CHANGE IN AVERAGE CALL RATE HR-' (t SE) IN RESPONSE TO BROADCAST CALLS, DECEMBER 1992 TO NOVEMBER 1993. CALLS HEARD IN THE ABSENCE OF BROADCASTING COMPRISE THE "NATURAL" CALL RATE.

HOUR WHEN BROADCASTING	HOUR WHEN NOT BROADCASTING
N Mean ± SE (61) 3.41 ± 0.33	N Mean ± SE (61) 2.46 ± 0.30

(t-test; t = 2.12, df = 119, P = 0.036)

TABLE 2. CHANGE IN AVERAGE CALL RATE HR-' (t SE) IN RESPONSE TO BROADCAST CALLS IN THE FIRST HOUR OF DARKNESS.

BROADCASTING IN FIRST HOUR	NOT BROADCASTING IN FIRST HOUR
N Mean ± SE (37) 3.30 ± 0.45	N Mean ± SE (37) 2.95 ± 0.43

(t-test; t = 0.56, df = 59; P = 0.58)

TABLE 3. CHANGE IN AVERAGE CALL RATE HR-1 (t SE) IN RESPONSE TO BROADCAST CALLS IN THE SECOND HOUR OF DARKNESS.

BROADCASTING IN SECOND HOUR	NOT BROADCASTING IN SECONDHOUR
N Mean ± SE (24) 2.96 ± 0.58	N Mean ± SE (24) 3.21 ± 0.57

(t-test; t = 0.31, df = 45, P = 0.76)

4.2 RANGE SIZE AND ROOST CHOICE

1. Six kiwi (4 males and 2 females) were caught, fitted with transmitters, and tracked for up to 58 weeks. A total of 904 location records were collected, comprising 377 daytime, and 527 nightime fixes. Home range sizes as determined by the convex polygon, field worker, and adaptive kernel methods are presented in Appendix 2. The convex polygon estimate of ranges varied from 30.8 to 91.8 ha. Field worker estimates were approximately 8–23% smaller ranging between 26.1 to 82.6 ha, and the adaptive kernel estimate ranged from 28.2 to 74.8 ha.
2. Mean range size of paired females tended to be larger than that of paired males. The unpaired male home range was significantly larger than that of both paired males and paired females. Home range size of kiwi in T.N.P. and T.F. were remarkably similar to those of Hawke's Bay kiwi (McLennan *et al.*, 1987) and Paerata kiwi (Potter, 1989). Home ranges of females showed more overlap than male home ranges.
3. The kiwi were selective in their choice of roost sites, with toetoe being used less than expected given its abundance, while unlogged and broadleaf/scrub habitats were used more than expected (Appendix 3).
4. Kiwi varied greatly in the types of roosts they used and their choice of roost site was highly dependent on habitat (Figure 8). Roosts associated with fallen trees and surface roots were used most frequently. Surface vegetation tended to be used most in summer, excavated roosts most in winter and spring, and roosts associated with logs and roots were used most in autumn and winter. Male kiwi used surface vegetation more than expected, while females favoured roosts associated with hollow logs, and/or roots. Both sexes made similar use of excavated roosts. On only one occasion was a pair found roosting together. Kiwi rarely used any roost site more than once.

4.3 FOOD AVAILABILITY AND UTILISATION

1. Over 14 months of field work, 12594 surface, litter, and soil dwelling invertebrates were caught. Higher numbers of invertebrates and greater taxonomic diversity were found in T.F. (n = 7725; no. of taxa = 189) than in T.N.P. (n = 4869; no. of taxa = 156), with 122 taxa common to both areas. Invertebrate availability and taxonomic diversity varied with season, with invertebrates being least abundant in winter.
2. There was more variation in the numbers of invertebrates caught between sampling sites in T.F. than in T.N.P. where little variation was evident. This appeared to relate to the relatively uniform habitat in T.N.P., compared with the diverse array of habitat types in T.F.
3. A wide range of invertebrates were recorded in kiwi faeces, but only cicada nymphs and scarabaeid larvae were consistently found in faeces in higher numbers than expected from their relative abundance in the invertebrate surveys. This suggests that both are preferentially selected food items.

4. Kiwi in both T.F. and T.N.P. appeared to favour soil-dwelling taxa but did not utilise them in proportion to what would be expected if invertebrate size (weight) was an "important consideration" when feeding.

5. Similar numbers of litter and soil dwelling invertebrates were available to kiwi in both T.N.P. and T.F., while higher numbers of surface dwelling invertebrates were available to kiwi in T.F. Differences in numbers and in taxonomic diversity of invertebrates suggests that T.F. should have a higher kiwi carrying capacity than T.N.P. However, only a small proportion of this taxonomic diversity seem to be targeted by kiwi, and at current densities neither site is likely to be food limiting.

6. Several types of seeds, especially those with fleshy fruits (rimu, *Dacrydium cupressinum*, and *Coprosma* spp.) were identified in kiwi faeces found in T.N.P. and T.F. Their abundance in particular faeces suggests that they were selectively eaten when available, and are a component of kiwi diet.

4.4 POTENTIAL THREATS: PREDATOR INDEXING

1. Predator surveys indicated possums, cats, dogs, and stoats were present in both T.F. and T.N.P. One ferret was caught in T.N.P., and pigs were only observed in T.F. It is probable, however, that ferrets and pigs occur in both areas.

2. Data obtained from the Whakapapa Pest Control Diary indicate that stoats are most frequently seen around residential areas and huts in T.N.P. and T.F. from August through to May while cats are most frequently recorded from July through to February.

3. Body and skull measurements for stoats caught in T.F. and T.N.P. (Appendix 4) suggest that a morphological difference exists between stoats in these two areas, with stoats in T.N.P. being generally larger than their counterparts in T.F. This difference may be habitat and temperature related.

4. Thirteen stoat stomachs were analysed (Table 4). Of the identified prey species 60% are active mainly at night. Five (15%) of the guts contained bird remains.

TABLE 4. PREY IDENTIFIED IN STOAT STOMACHS (N = 13).

PREY ITEMS	NO. OF OCCURRENCES	FREQUENCY OF OCCURRENCE (%)
Possum	3	9.1
Rat	4	12.1
Mouse	2	6.1
Bird	5	15.2
Birds egg	2	6.1
Tree weta	8	24.2
Carabid beetle	2	6.1
Spider	1	3.0
Stream invertebrate	1	3.0
Other Arthropods	2	6.1
Unidentified food	3	9.1

5. Differences existed between areas in the occurrence of medium to large sized prey in the stoats' stomachs (Table 5). Stoats in T.F. ate more possums and rats and fewer mice than those in T.N.P.

TABLE 5. NUMBER AND PERCENTAGE FREQUENCY OF OCCURRENCE (IN BRACKETS) OF PREY IN STOAT STOMACHS (AD.M = ADULT MALE, SA.M = SUBADULT MALE, AD.F = ADULT FEMALE, AND SA.F = SUBADULT FEMALE).

PREY	T.F. ad.M	T.F. Sa.M	T.F. ad.F	T.F. Sa.F	T.N.P ad.M
Possum	3(75)	_	_	_	_
Rat	3(75)	1(50)	_	_	_
Mouse	_	_	_	_	2(40)
Bird	2(50)	_	1(100)	_	2(40)
Bird egg	1(25)	1(50)	_	_	_
Tree weta	1(25)	2(100)	1(100)	1(100)	3(60)
Carabid beetle	_	1(50)	_	1(100)	_
Spider	_	1(50)	_	_	_
Stream invert.	_	_	_	_	1(20)
Other Arth.	_	_	1(100)	_	1(20)
Unident. food	2(50)	_	_	1(100)	_
No. of stoats	4	2	1	1	5

6. 156 hunter questionnaires were returned for the 1992–1993 hunting period in T.F. Of these, 40% reported hunting within the study area. Sixteen percent of hunters reported using dogs. However, the number of dogs sighted in the study area suggests that the use of dogs is higher than this. Some hunters were known to allow their dogs to roam unattended for up to three hours, or over-night, when the dogs failed to return when called. Also an unattended dog, and dog tracks, were observed within T.N.P.

7. Predator pressure has almost certainly been a major contributing factor in producing the current fragmented distribution of kiwi in the forests that make up T.N.P. and T.F. These predators pose a major threat to the long-term survival of kiwi in the conservancy. The development of cost effective methods of predator control applicable on a large scale should be a high priority.

5. Recommendations

1. Call surveys of kiwi in T.F. should be continued. Monitoring methods should be kept as consistent as possible (see recommendations in McLennan 1992). More populations should be monitored so that population trends can be determined.

2. Park status ensures protection of the kiwi habitat in T.N.P. and T.F. Elsewhere, however, areas with high numbers of kiwi need to be identified and protected.
3. The well-being of radio-tagged kiwi in T.F. should continue to be monitored. Kiwi should also be radio-tagged elsewhere in Tongariro/Taupo Conservancy to provide an indication of population trends and threats in these populations.
4. Signs should be erected at main accesses to hunting areas indicating the presence of kiwi, and highlighting the vulnerability of kiwi to uncontrolled dogs.
5. Hunting permits issued for areas containing kiwi should highlight the need for hunters using dogs to maintain tight control over them.
6. The predator control scheme started in 1994 in T.F. should be maintained. The benefits of this can be assessed by monitoring radio-tagged birds and by analysing trends in the annual call survey data. Nationally, cost-effective methods of predator (chiefly mustelid) control need to be developed.
7. A multidisciplinary group to co-ordinate and prioritise work on mammalian predators should be established.

6. Acknowledgements

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APPENDIX 1. MEASUREMENTS OF KIWI IN TONGARIRO FOREST AND TONGARIRO NATIONAL PARK, 1992-94.

					RIGHT MIDDLE TOE (mm)				TARSUS (mm)			BILL (mm)		
BIRD	BAND #	DATE	WEIGHT (kg)	LENGTH (mm)	NAIL	PAD	WIDTH	DEPTH	LENGTH	DEPTH	BREADTH	CERE	GAPE	WIDTH
M.51	R-46251	15.12.92	1.80	755	40.7	48.7	10.5	13.9	86.4	17.4	11.1	99.6	122.0	23.4
		21.2.93	1.90									98.8		
		11.5.93	2.10	740	40.0	47.0	10.2	13.6	85.2	15.1	11.2	97.3	123.4	24.3
		19.2.94	2.00	750	41.6	47.6	9.4	14.4	86.7	18.0	10.8	98.7	124.4	25.7
		1.4.94	2.05	747	42.7	47.4	9.7	14.1	86.3	15.4	11.9	99.1	121.0	26.6
M.52	R-46252	17.12.92	2.75	689	45.6	46.0	9.3	14.3	86.7	17.0	12.0	99.7	125.0	22.2
		21.3.93	2.60	-	45.6	48.1	9.7	14.7	87.3	16.4	12.4	99.2	125.1	-
		22.4.93	2.68									-		
		27.11.93	2.60									99.1		
F.57	R-46257	11.2.93	2.80	883	50.4	53.0	12.3	16.8	102.0	13.6	18.5	132.9	151.7	28.3
		20.3.93	2.60									132.3		
		21.4.93	2.70	883	51.4	55.0	12.0	17.0	101.0	14.0	18.8	132.8	153.5	29.4
		8.8.93	2.50									131.9		
		26.11.93	2.90									131.5		
		3.1.93	2.50									131.6		
		20.1.94	2.55	880	50.8	54.1	11.7	16.2	101.8	13.8	17.7	132.8	156.0	-
		1.4.94	2.60	895	50.1	53.6	12.0	17.6	100.9	14.1	17.8	133.7	153.4	27.5
M.58	R-46258	23.2.93	2.10	745	44.7	51.0	10.2	15.7	90.3	13.5	17.8	98.6	115.7	23.1
		18.5.93	2.17	743	45.2	49.4	11.4	15.6	92.9	12.5	16.9	97.4	115.3	23.7

					RIGHT MIDDLE TOE (mm)				TARSUS (mm)			BILL (mm)		
BIRD	BAND #	DATE	WEIGHT (kg)	LENGTH (mm)	NAIL	PAD	WIDTH	DEPTH	LENGTH	DEPTH	BREADTH	CERE	GAPE	WIDTH
F.53	R-46253	2.6.93	2.50	847	47.5	52.0	10.5	15.7	93.0	13.2	17.8	125.8	147.4	27.5
		3.7.93	2.50	-	-	-	-	-	-	-	-	126.3	-	-
		6.8.93	2.50	-	-	-	-	-	-	-	-	126.1	-	-
		16.10.93	2.55	-	-	-	-	-	-	-	-	126.1	-	-
M.54	R-46254	17.11.93	1.90	734	43.6	47.6	9.8	13.0	85.0	12.7	13.0	96.3	115.3	24.9
		1.4.94	1.95	736	43.6	46.7	10.0	13.8	86.3	11.9	14.2	95.6	116.1	25.7

APPENDIX 2. RANGE SIZE (ha) OF KIWI IN TONGARIRO FOREST AND TONGARIRO NATIONAL PARK, 1992-94. ESTIMATES WERE CALCULATED BY THE CONVEX POLYGON METHOD, FIELD WORKER METHOD, AND THE ADAPTIVE KERNEL METHOD (SEE TEXT FOR EXPLANATIONS).

BIRD	T.F.		RANGE SIZE (ha)		
	RADIO FIXES	WEEKS TRACKED	CONVEX POLYGON	FIELD WORKER	90% ADAPTIVE KERNEL
M.51	65	58	30.29	26.14	28.43
M.52	92	58	91.79	82.58	74.83
M.54	2	1	-	-	-
F.57	82	49	34.18	29.49	28.22
F.53	54	26	52.79	44.21	52.75
BIRD	T.N.P		RANGE SIZE (ha)		
M.58	36	40	38.16	31.79	47.70
Mean	65.8	46.2	49.44	42.84	46.39
Total	329	231			
mean male	50.5	49	34.23	28.97	38.07
mean female	68	37.5	43.49	36.85	40.49

APPENDIX 3. HABITAT PREFERENCE AND AVOIDANCE BY FOUR KIWI TOWARDS SIX HABITAT TYPES IN TONGARIRO FOREST, 1992-94.

*				HABITAT TYPE					
KIWI	X^2	df	PROBABILITY	TOETOE	LEPTO/SCR	SELEC LOGD	UNLOGGED	SWA/BG	BRDLF/SCR
M.51	5.45	3	0.025<P<0.01	x	-	x	x	-	x
M.52	18.19	2	P<0.001	Avoided	-	x	-	-	Preferred
F.57	4.64	3	0.50<P<0.25	x	-	x	x	x	x
F.53	16.20	3	0.005<P<0.001	x	x	Preferred	Avoided	-	x
Combined	44.48	11	P<0.001	Avoided	x	x	Preferred	x	Preferred

LEPTO/SCR = *Leptospermum* scrub
SELEC LOGD = selectively logged
SWA/BG = swamp/bog
BRDLF/SCR = broadleaf scrub

APPENDIX 4. BODY AND SKULL MEASUREMENTS OF STOATS COLLECTED IN TONGARIRO FOREST AND TONGARIRO NATIONAL PARK FROM JULY TO SEPTEMBER 1993.

STOAT #	DATE CAUGHT	WHERE CAUGHT	SEX	AGE CLASS	WEIGHT (g)	LENGTH (mm)	TAIL LENGTH	HIND FOOT	CB[1]. LGTH	BACULUM (mg)
1	14.7.93	T.F.P	Female	Unclassed	143.69	107.1	83	15.7	42.1	_
2	14.7.93	T.F.P	Male	Adult	395.11	282.3	104	21.3	49.3	60
3	5.8.93	T.F.P	Male	Adult	470.4	283	107	23	54.6	53
4	5.8.93	T.F.P	Male	Adult	446.33	239	109	20.7	50.2	62
5	7.8.93	T.F.P	Male	Subadult	262.51	240	94	17.8	44.1	23
6	9.8.93	T.F.P	Male	Subadult	170.09	229	101	15.5	40.2	20
7	21.8.93	T.F.P	Male	Adult	353.50	267	109	21.8	52.1	66
8	21.8.93	T.F.P	Female	Adult	249.45	257	88	20.4	45.1	_
9	1.9.93	T.N.P	Male	Adult	315.7	267	99	20.5	50.3	53
10	1.9.93	T.N.P	Male	Adult	358.33	273	107	21.6	51.2	64
11	1.9.93	T.N.P	Male	Adult	327.5	285	102	22.2	55.1	69
12	1.9.93	T.N.P	Male	Adult	406.08	297	106	20.2	51.3	37
13	5.9.93	T.N.P	Male	Adult	394.89	276	109	22.1	51.0	62

1: Condylobasal length.