A BANDING STUDY OF NORTH ISLAND BROWN KIWIS IN AN EXOTIC FOREST

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ABSTRACT

Territory, distribution and dispersal of the North Island Brown Kiwi *(Apteryx australis mantelli)* were studied at Waitangi State Forest, Northland, from February 1981 to July 1982.

In all, 84 kiwis were banded and individually coded and 220 resightings were recorded. Weights and bill measurements are given, together with some growth rate data. Territories of 23 birds are shown and these approximate 5 ha per adult pair, but territory size may decrease with greater abundance of food and with immigration from logged areas. Kiwis frequent many burrows within fixed territories, and males defend these territories from other pairs, primarily by calling. Juveniles under 1 year old are accepted in these ranges, whereas larger juveniles and some females do not have regular haunts.

Kiwis try to retain their territories in the face of logging and other forest management practices and this behaviour demonstrates the importance of site attachment. Swamp margins and swamp arms are important to kiwis as a temporary refuge after clearfelling and as feeding areas during dry periods of the year. Despite the forestry practices the Waitangi kiwi population is thought to be viable.

INTRODUCTION

Ever since its discovery the kiwi has generated scientific curiosity. However, owing to the species' nocturnal habits and wariness, which makes it difficult to study in the field, most research has centred around anatomy, evolution and taxonomic affinity, and physiology. No detailed studies have been published of the ecology of kiwis in the wild.

Corbett surveyed the North Island Brown Kiwi population in Waitangi State Forest by means of a systematic vocalisation count from July until November 1978. His unpublished report (Corbett *et al.* 1979) includes a map giving the location of kiwi pairs and single birds within the forest. This map shows areas of high kiwi densities and areas with almost no kiwis.

The New Zealand Forest Service decided to fund a further ecological study of the Brown Kiwi population in Waitangi State Forest, covering topics such as feeding ecology, movements and dispersal, and the influence of exotic forest management. The field work for this study was done from February 1981 to July 1982 in liaison with the

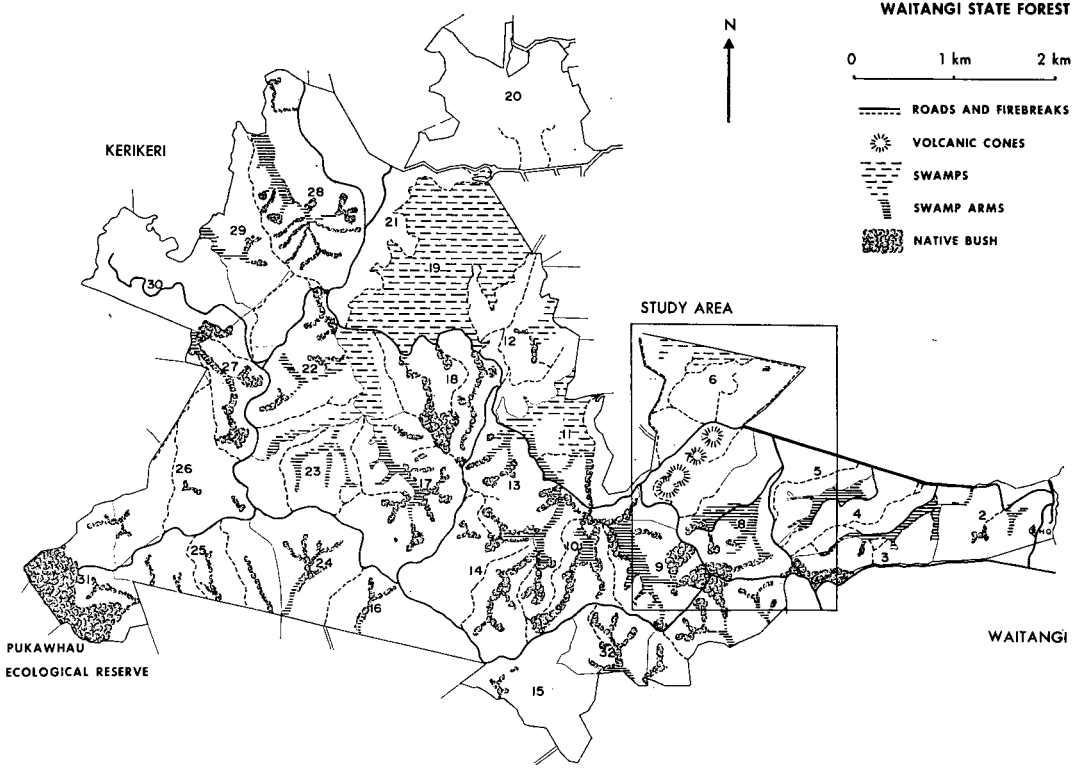

FIGURE 1 — Map of Waitangi State Forest, showing the location of the study area

Wildlife Service (Department of Internal Affairs) and the Entomology Division of DSIR.

STUDY AREA

Waitangi State Forest (Fig. 1) is a small exotic plantation situated between Waitangi and Kerikeri in the Bay of Islands (35°15'S 174°02'E). Of its 2888 ha, 2000 ha are planted in exotic trees, mostly pines, and the rest is remnant native bush, particularly in the steep gullies, and extensive swamp fingers in the valleys. The chosen study area, encompassing compartments 5, 6, 7, 8 and 9, lies within the eastern half of the forest, measures approximately 350 ha, and contains a medium to high density of kiwis in a diverse range of habitat types. Until recently *Pinus elliottii* was the most common crop but a policy of replanting with *P. radiata* has changed that rapidly. The topography consists of a system of ridges and gullies with steep slopes (compartments 5, 8 and 9) with moderately leached podsolized clays that are very muddy in winter and rockhard in summer. Flat areas broken by volcanic cones around compartments 6 and 7 consist of rich black soils of volcanic origin.

In an exotic production forest the plant cover constantly changes. Compartments are logged, the ground is bulldozed or burnt, trees are planted, sprayed, thinned, pruned, and logged again, to complete the cycle. In this situation successional stages of undergrowth proceed from bracken *(Pteridium aquilinum)* and inkweed *(Phytolacca octandra)*, to gorse *(Ulex europaeus)* and manuka *(Leptospermum scoparium)*, and later, as the pine stand matures, to mingimingi *(Cyathodes fasciculata)*, treeferns *(Alsophila tricolor* and *Sphaeropteris medullaris)*, tobacco weed *(Solanum mauritianum)*, hangehange *(Geniostoma ligustrifolia)* and a variety of native shrubs. Logging of mature pines and subsequent burning of the slash were proceeding in compartment 8 during our study.

METHODS

The Brown Kiwi population in the study area was surveyed in the first three months of the study to get an impression of numbers and distribution of the birds. This survey was carried out by monitoring kiwi vocalisations from permanent listening stations which were regularly spaced along roads and ridgetops.

In places with dense obstructing undergrowth, tracks were cut for easier access at night. Kiwis were caught by hand after chasing on foot and banded with a metal serial band (R-size; butt-ended). Self-adhesive reflective tape (Scotchlite; available in seven colours) was fixed to the bands in various combinations enabling each bird to be individually colour coded. To increase the number of possible colour combinations, a plastic leg band with reflective tape was sometimes used on the other leg. Reflective tape not only made a kiwi more conspicuous during a pursuit in torchlight but made recognition of individuals possible without resorting to recapture.

Each captured kiwi was weighed with a Pesola spring balance, accurate to ± 0.03 kg and the bill length (from the tip of the upper mandible to the concave of the cere) was measured with vernier calipers accurate to ± 0.03 cm. The sex of the bird was determined by the call it made before it was pursued or if it did not call, by the length of the bill. Kiwis with bills longer than 11.7 cm were considered to be females (Reid & Williams 1975) while those with bills shorter than 11.7 cm could be males or juveniles. Males may also show conspicuous brood patches during the incubation period.

Sites of capture, resighting or recapture of each bird were carefully plotted on transparent sheets over a map of the study area so that territory, movements, and the spatial relationships of neighbouring kiwis could be determined.

RESULTS AND DISCUSSION

Weight and bill length

Females at Waitangi were, on average, 16.5% heavier than males and their bills were 24.4% longer. The range of weights of 31 adult females was 2.06-3.85 kg (mean 2.54) and of 15 adult males was 1.72-2.73 kg (mean 2.12). The mean bill length for 40 adult females was 13.02 cm (range 11.70-14.20) and for 22 adult males was 9.84 cm (range 8.98-10.56).

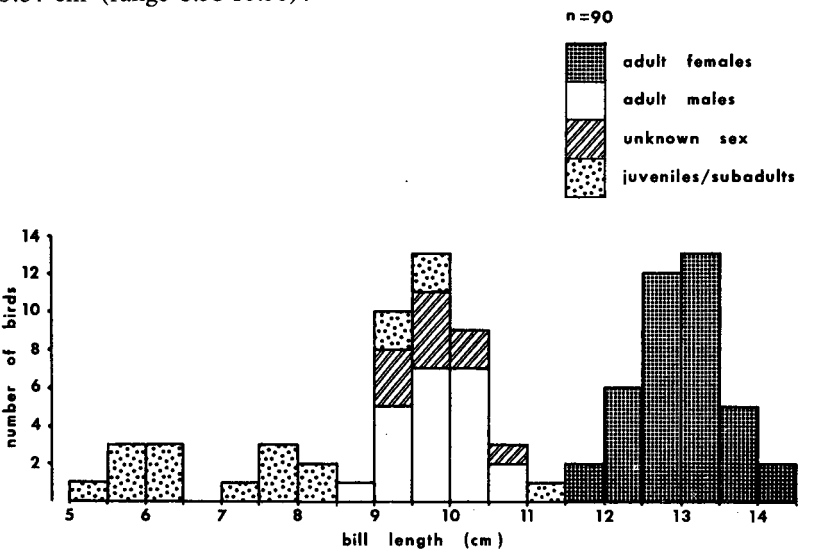

FIGURE 2 — Histogram of North Island Brown Kiwi bill lengths from Waitangi State Forest

Bill measurements gave a bimodal distribution separating the adult sexes without overlap (Fig. 2). No adult male in the sample had a bill longer than 10.60 cm. The weights of kiwis (Fig. 3) showed much overlap between the sexes. On average, females were larger, but only 16% of the females were consistently heavier than the heaviest recorded male.

Most measured adults lost weight (up to 16%) from late November 1981 to mid-February 1982 (Fig. 4). The most important cause was considered to be the sharp decline in soil penetrability due to the " drought " conditions of summer because a female occupying a territory in an irrigated part of the forest was the only bird, other than chicks, that gained weight during this period. However, other factors could contribute to weight loss. In summer most of the permanent soil-dwelling invertebrates (e.g. earthworms) migrate to the moister, lower, soil levels and other important soil-dwelling invertebrates (e.g. cicada nymphs and scarabaeid larvae) emerge in summer, temporarily decreasing the amount of food in the soil. Moreover, in Northland, nights in midsummer are about 5 hours shorter than in midwinter and so time available for feeding is less.

This summer weight loss was not related to breeding because the peak egg-laying period was from July to September (Colbourne & Kleinpaste, in prep.) and only one male captured in summer had a brood patch.

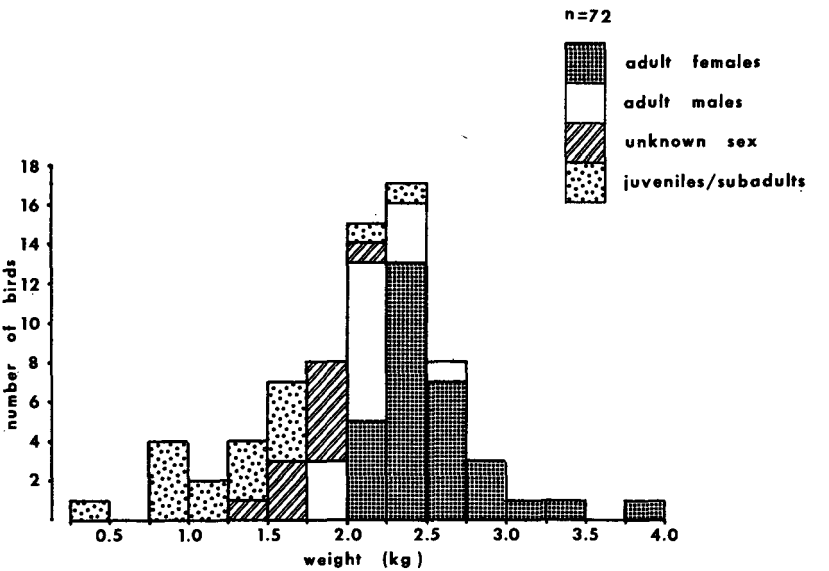

FIGURE 3 — Histogram of North Island Brown Kiwi weights (weights at first capture) from Waitangi State Forest

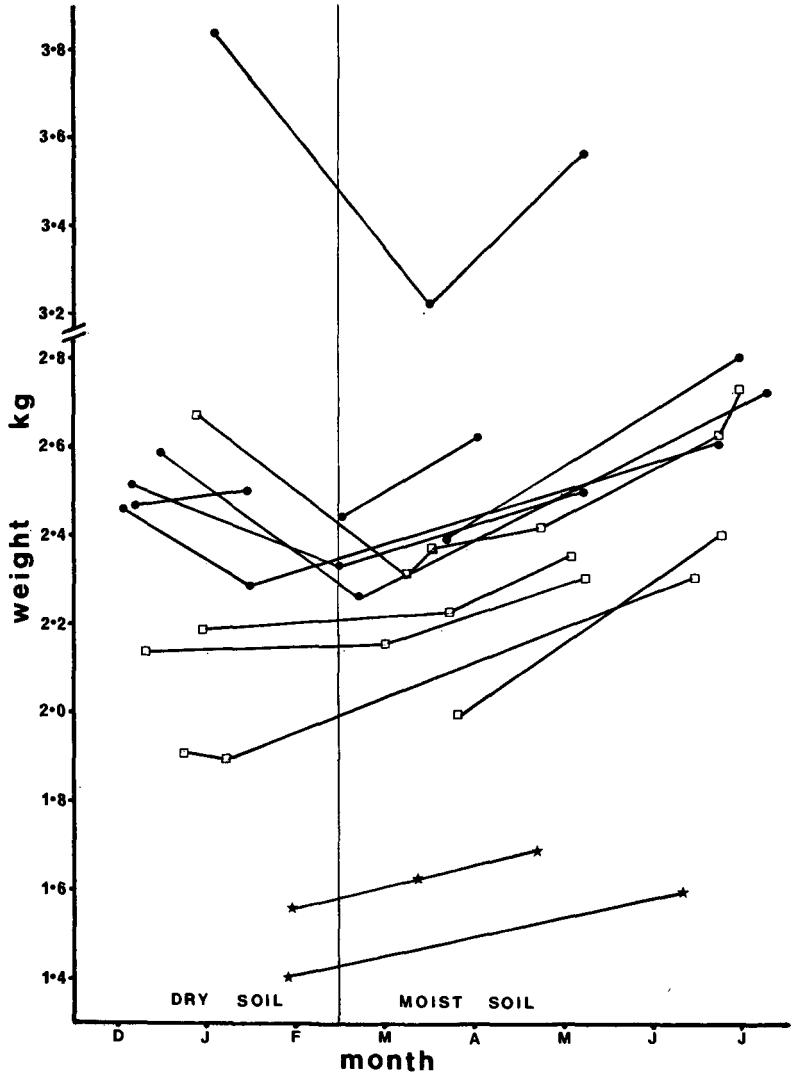

FIGURE 4 — Weight changes of Brown Kiwis from December 1981 to July 1982 (females, black dot; males, box; and juveniles, star)

Kiwis carry an exceptional amount of subcutaneous fat, which can represent 30% of the body weight, and so they can survive for three weeks without food (Reid & Rowe 1978). The importance of fat can be attributed to the males' reduced foraging while incubating, to the females' higher energy requirements before egg laying, and to the need to survive the regular dry periods in summer, when food is in short supply.

If, indeed, bill growth is fastest shortly after hatching and progressively decelerates with increasing age until a limit is reached, then by measuring changes in bill length, over time, we should be able to provide information to separate juvenile females from unconfirmed males, male juveniles from female juveniles, and subadults from adults.

A chick estimated to be 1 month old when first caught (bill 5.09 cm, weight 0.36 kg) showed a bill-length increase of 13.2 mm in 70 days (a growth rate of 5.7 mm per month). Juveniles estimated at 1-1.5 years old had an average bill growth rate of 1.5-3.0 mm per month. Kiwis 1.5-2 years old had reached the body size of adult males but, because some bills were still growing, we could distinguish juvenile and subadult females from adult males. As shown in Figure 5, the bill growth rate of one juvenile tapered off at approximately 9.5 cm, indicating that it was a male, whereas the bills of other birds continued growing steadily at 2.0 mm per month past this limit, perhaps showing that the birds were females. From only one measurement, bill length gives no indication of an adult's age. Although some females' bills had stopped growing at about 12.2 cm, one female's bill was slowly increasing at 14.0 cm.

The measured bill length of one male actually regressed by −0.7 mm. This bird was at its maximum weight in June and due to 'obesity' the cere had pushed forward over the bill making the bill seem shorter. There was no correlation between bill length and weight within each sex (Pearson's correlation test; females: $r = 0.09$; males: $r = -0.12$).

Eggs

Two empty egg shells were found measuring 13.51 x 8.02 cm (compartment 31 : indigenous forest) and 13.47 x 8.00 cm (compartment 9 : *Pinus radiata*). Compared with measurements of 107 wild North Island Brown Kiwi eggs (Reid 1981), these are among the largest found to date. Two eggs from a nest measured 12.10 x 8.23 and 11.97 x 7.64 cm (compartment 5 : *Pinus elliottii,* 19 August 1982).

Moult

No detailed data were collected on kiwi moult. However, we found new feathers emerging from the skin in most months, and so moulting may be continuous. In midwinter, feathers were noticeably larger than in summer (pers. obs.), which may indicate better nutrition in winter rather than a specific moulting season.

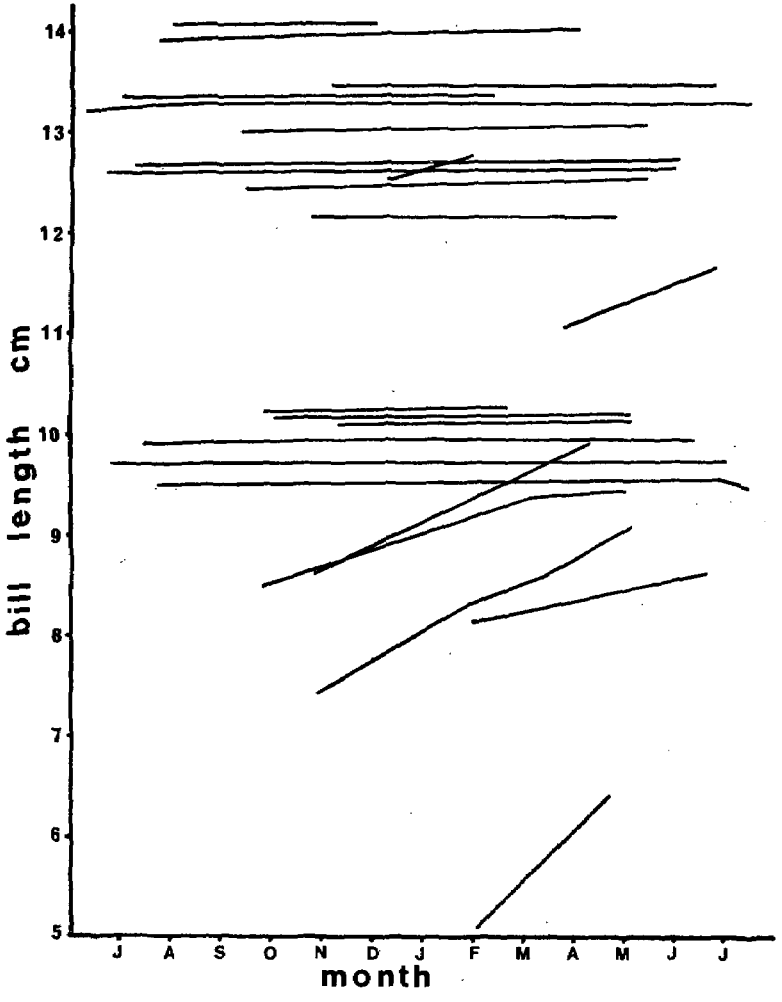

FIGURE 5 — Kiwi bill lengths and growth rates, July 1981 to July 1982

Distribution and territory size

The estimated positions of calling birds were combined with later sightings of banded and non-banded individuals to give the distribution of kiwis within the study area as shown in Figure 6.

From May 1981 to July 1982 we banded 84 kiwis: 38 adult females, 22 confirmed adult males, 10 juvenile females/unconfirmed males and 14 juveniles. In addition, four chicks were captured but

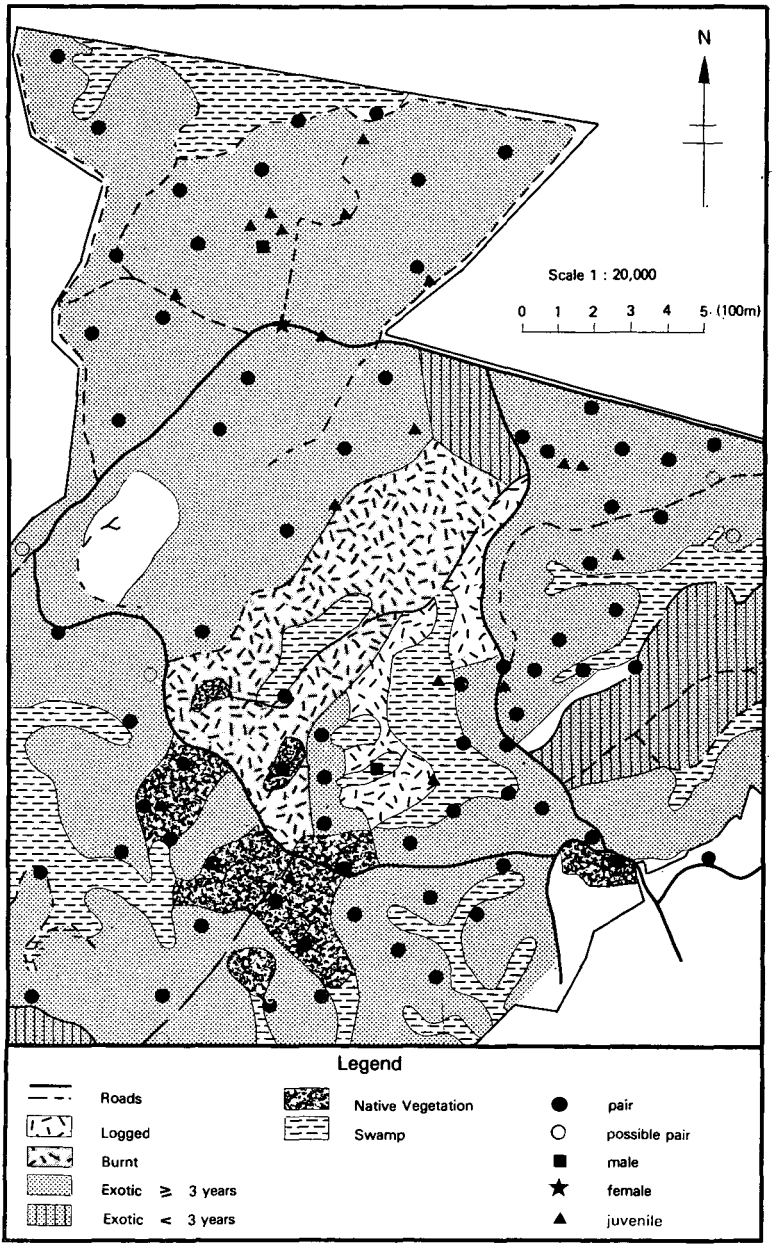

FIGURE 6 — Distribution of Brown Kiwi in the habitat types of the study area, Waitangi SF, 1981-1982

were too small to band. Females, although less vocal, were caught more often than males, which can be explained as follows. A number of males are incubating eggs for at least 2½ months of the year and leave their nests only infrequently or for short periods to feed (Buller 1888; Robson 1947; Reid & Williams 1975; Reid & Rowe 1978). Moreover we found that males are more wary of human noises, run faster than females, often in a zig-zagging fashion, and are more likely to "freeze" suddenly or hide under ferns or behind logs when pursued. They are therefore very hard to catch.

A total of 220 sightings and recaptures of 59 banded birds gave a series of sites which were plotted on maps. Figure 7 shows the results of repeated recaptures or resightings of 23 banded birds within the northern part of the study area. The accuracy with which a territory can be plotted on the map depends on the number of recaptures of a bird. In the generally flat and undisturbed compartments 6 and 7, the territorial areas of kiwis recaptured 15 times or more all approximated 5 ha.

The peripheries of territories often followed physical boundaries such as differences in vegetation and age of plantings, ridges, valleys, volcanic cones, roads and firebreaks. Areas of overlap occurred between neighbouring pairs, but the epicentres of the plotted territories were rather evenly spaced. Mean distance between epicentres was 250 metres. Territories which included swamp valleys and native bush gullies tended to be somewhat smaller, and we thought this to be partly food related. Significantly more invertebrate food is available to kiwis in the soil and litter at the bottom of the slopes and at swamp margins than higher up on the ridegetops ($ts = 3.13$; $x = 0.05$; 22DF; Kleinpaste & Colbourne, in prep.). The soil in the valleys and native bush gullies is also moister and so easier for kiwis to probe. In terms of biomass, the native bush gullies contain 35-95% more invertebrates in the soil and litter than do the drier pine stands (Kleinpaste & Colbourne, in prep.). As a result kiwis inhabiting these valleys and gullies could subsist in a somewhat smaller territory than those inhabiting higher or drier areas.

In the southern and eastern edge of compartment 8 and in compartment 5, the density of kiwis was much higher than average, territory size being approximately 3 ha. We believe that past logging operations elsewhere in compartment 8 and in compartment 4 had forced kiwis out of their initial territories into the adjacent intact pine stands. No territories were found smaller than 3 ha.

Multiple burrows — movements within territories

We use the term "burrow" for a kiwi daytime shelter site. Over 95% of the burrows found in Waitangi State Forest were at ground level in vegetation such as large clumps of toetoe *(Cortaderia toetoe)* or under dense bracken cover, hanging dead treefern fronds, or pine slash covered with a thick layer of fallen pine needles. In

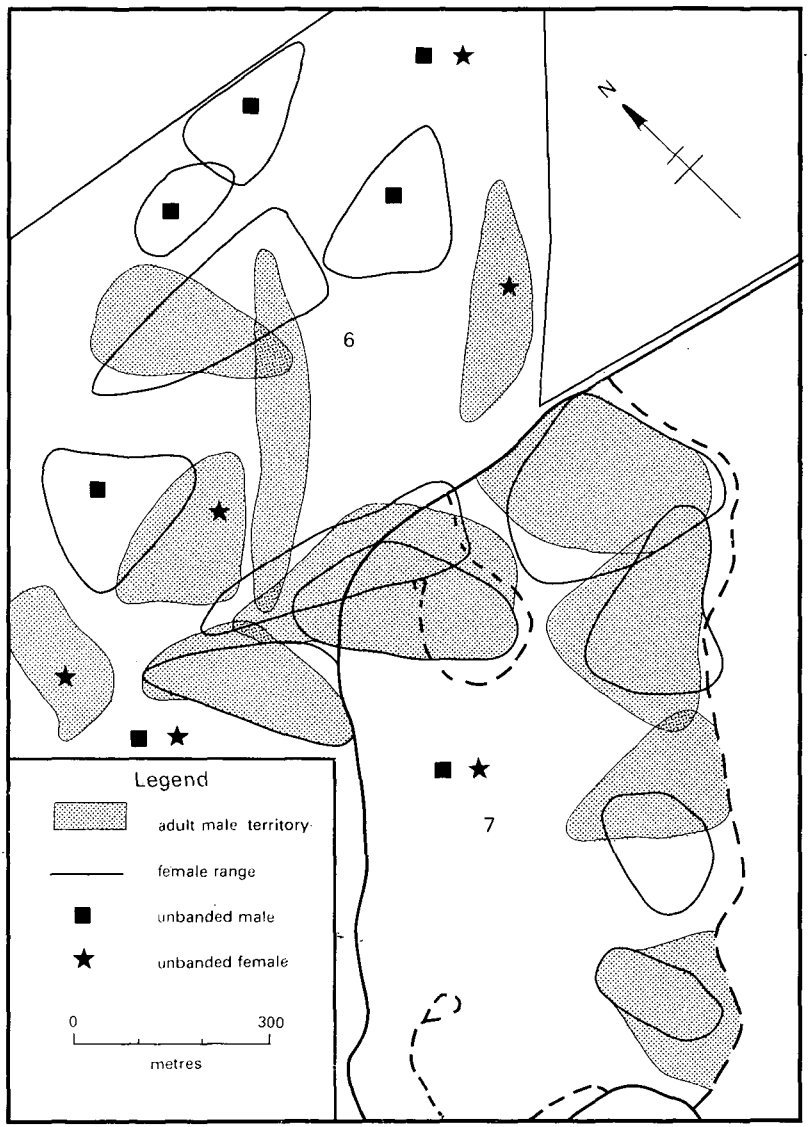

FIGURE 7 — Kiwi territories, determined from banding recoveries in compartments 6 and 7, Waitangi SF, 1981-1982

addition, hollow logs and piles of volcanic boulders provided convenient natural burrows, requiring little excavation. We found only four elaborate burrows dug into banks, each with an entrance (diameter c. 13 cm) which led gently downwards to a chamber of about 27 cm wide by 27 cm high at a depth of 30-75 cm. Eggshell fragments showed that these burrows had been used for breeding. Other nests resembled the daytime shelter sites and one nest with two eggs was merely a simple cavity in the pine litter on the forest floor.

Each territory had many burrows, some of which were in use from time to time. We often saw banded kiwis emerging from their burrows shortly after sunset but, on our return to these locations the next evening, would see no birds. Some of these same birds were seen emerging from other burrows elsewhere. The " waking-up " calls of a bird shortly after sunset also indicated the position of its sleeping site; often these calls came from quite different directions on successive nights.

Similarly, feeding places changed within territories, judged by the distribution of fresh probing sign. A kiwi would work over a certain area of its territory for a variable number of nights and then shift to another area within its territory. Changes of feeding area were unpredictable. These and the foregoing observations suggest that the territory of a pair is an accumulation of smaller ranges, centred around various burrows.

Seasonal movements within territories

During the driest months of the year, December to February, the soil on the mid and upper slopes of the hills in the forest became rock hard and almost impenetrable for kiwis. As the kiwi at Waitangi extracts approximately 78% of its food from the soil (Kleinpaste & Colbourne, in prep.), these dry conditions are unfavourable for the birds. In spite of this, kiwis were seen feeding on ridgetops, particularly on the grassy road verges where black field crickets *(Teleogryllus commodus)* occurred in high numbers. However, field observations and the results of faecal analysis showed that, during drought, kiwis spent more time feeding along lower slopes and moist swamp margins than on the mid and upper slopes. Birds occupying territories that did not include swamp areas were not seen moving out of them in a desperate search for food, but they did lose much weight.

Juveniles and straying adults

Younger juveniles and chicks regularly frequented areas which were often congruent with the territory of an adult pair. Most of the juveniles and all of the young chicks found were wandering by themselves with no indication of the nearby presence of adults. Several family groups of three kiwis, including juveniles, were seen feeding close together, suggesting that juveniles are tolerated within their parents' territory for at least 1 year. Robson (1947) found that juveniles do not make the adult call until they are 1 year old.

When these birds had left or had been evicted from their parents' territory, they were found roaming randomly (Fig. 8). The youngest ages reported for sexual maturity of captive North Island Brown Kiwis are 2 years for a female and 14 months for a male (Calder & Rowe 1977). Presumably, a pair bond takes longer to establish in the wild, as young males first have to find and secure a territory before starting to solicit for a mate. If space is not available for young to establish territories, it could be expected that, in a stable environment, a kiwi population would disperse by means of its juveniles.

A few banded adult kiwis in Waitangi State Forest did not seem to hold a territory (Fig. 8). Three females were recaptured 600, 1000 and 1200 metres away from their respective initial capture sites. One female seemed to commute between two areas about 1000 metres apart and separated by a volcanic cone. This bird was once seen with a possible mate in compartment 7, but the other straying birds were thought to be unpaired.

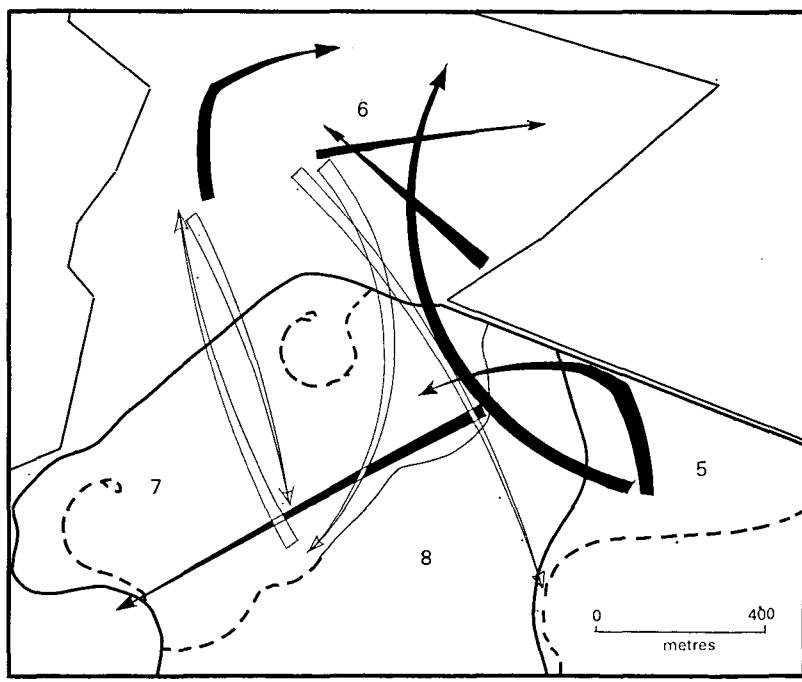

FIGURE 8 — Movements of six juveniles (dark arrows) and two females (light arrows) in the northern half of the study area

Repercussions of forest management

Clearfelling of exotic stands in winter, spring and summer and the subsequent burning of the slash and litter in autumn are management practices that modify the kiwis' physical environment to the extreme. The New Zealand Forest Service management policy for Waitangi State Forest deliberately excludes the modification by logging or burning of remnant swamp areas and native bush gullies. We followed the movements of eight banded birds occupying territories in a logging area in compartment 8, and all kiwis were accounted for during those operations.

When a territory was logged, the occupants were seen to be feeding in the open for periods up to 7 weeks, thus showing a considerable reluctance to vacate their heavily modified environment. We did not discover whether they slept in the logged areas under the extensive piles of slash or commuted from nearby swamps or native bush gullies.

Gradually the " logged-out " kiwis established themselves around the swamp margins, from where they later dispersed to adjacent pine stands. By the time of the burn-off, 2-6 months after clearfelling, these kiwis had vacated their logged territories, thus surviving the danger carried by this aspect of forest management.

One factor inducing the birds to leave is the gradual but eventually drastic decline of invertebrate populations in litter and soil due to drying out by wind and direct sunlight. In a burnt area the litter invertebrates are absent altogether and soil-inhabiting invertebrates have moved to deeper moister levels (Kleinpaste & Colbourne, in prep.). Occasionally, probing sign was found in burnt compartments and one female, banded two weeks before her territory was logged, was recaptured 6 months later at the same site a week after the burn-off. Her initial range included part of a small native bush gully and she may have stayed there after clearfelling and during the fire.

Although kiwi habitat is destroyed by logging in an exotic forest, replanting creates new habitat. A survey in Puhipuhi State Forest (Colbourne 1982) revealed a high density of Brown Kiwis when all of that exotic forest was into its second production cycle. Therefore, current forest management practices and a large viable kiwi population may be compatible. However, we stress that the length of time between clearfelling and burning should not be less than 2 months, thereby allowing the soil to dry out and the birds to leave their clearfelled territories. This would greatly enhance the birds' chances of survival at that stage.

Aspects of behaviour and social structure

A nocturnal ground-dwelling bird with limited eyesight such as the kiwi faces a different set of problems than its diurnal free-flying counterparts. It cannot overlook its territory at a glance and has to rely on its well-developed senses of smell and hearing for its feeding,

territorial spacing and survival. It could be advantageous for a kiwi to be intimately familiar with all parts of its territory. This seems to be so because birds chased for banding know exactly where to go at a fast pace without crashing too much into tree trunks or other obstacles. They usually run straight to the nearest thick cover in the form of a dense bracken patch or impenetrable slash or swamp. With fixed territory, birds can acquire detailed knowledge of the best feeding sites, sleeping sites, and in the breeding season, of the best nesting sites (Tinbergen 1964).

In the undisturbed compartments 6 and 7, kiwi pairs frequented the same territories for more than a year, which, with the observed territory familiarity, could indicate that the pair bond is long lasting and that the territories remain the same from year to year. Further study of the banded kiwis could clarify these points. The territorial borders of kiwi pairs are probably maintained by the relative calling positions of neighbouring birds, topographical familiarity and occasional border fights. Tinbergen (1957) considered site attachment and intra-specific hostility (which includes attack and avoidance) to be the key factors in the concept of territory.

The visual aspect of territorial behaviour has not been recorded in kiwis and is thought to be non-existent (Robson 1947; Rowe 1974; Reid & Williams 1975), but aggressive threat behaviour in the form of vocal duels between males seems to be important. In most bird species singing is widely used by the male to assert the occupancy of its territory (Thorpe 1964). Of 1032 callings noted, 75.3% were made by male kiwis and the calling frequency peaked conspicuously in the first months of the breeding season (Colbourne & Kleinpaste, in prep.). Excited vocal display of male kiwis was heard or observed often when a neighbouring male ventured too close to a bird feeding on the perimeter of its territory, and trespassing, responsible for the overlaps of territory shown in Figure 7, occurred only at times when the resident bird was feeding at the opposite side of its territory. Females showed a slightly greater overlap than males, probably because they posed less of a threat to the stability of the male's territory. Males may also be rather reluctant to attack females, which are physically the stronger of the two. We saw attacking and especially avoidance behaviour much less in females than in males, which may explain why females were easier to catch.

We twice watched at close quarters actual fighting between rival males. In one case, growlings and vigorous movements in the undergrowth culminated in chase, during which the resident male stopped three times to call excitedly. The ejected male called four minutes later from its own territory. Reischek (1930) and Robson (1947) also noted that males fight aggressively, especially in the breeding season, and Buller (1888), Robson (1947), Reid & Rowe (1978) and H. Corbett (pers. comm.) recorded vigorous attacks on humans venturing too close to a nest site. These observations and the presence of a

few straying adult females suggest that, in the North Island Brown Kiwi, the male is territorial and the female is faithful to her mate. Thus, when the male of a pair dies, the female may mate with a subadult male or leave the territory entirely in search of a new mate.

Falla (1979) suggested that kiwi behaviour seen during the breeding season indicates the possibility of polyandry, and Buller (1888) recorded this phenomenon to be a Maori belief. However, in most polyandrous bird species, males are believed to outnumber the females (Armstrong 1964). This appears not to be the case with the kiwis in our study area as the sex ratio was found to be about equal. If kiwis were polyandrous we could reasonably expect that the range of a female would be at least twice that of a male. Apart from three straying females, the range of females closely coincided with that of their mates. However, as polyandry, which is rare amongst birds, occurs within the group of ratite orders (e.g. *Rhea americana*) and the closely related Tinamous *(Nothocercus bonapartei* and *Crypturellus variegatus)*, we hesitate to label the rather puzzling movements of one of the females (Fig. 8) simply as " straying."

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