

Behavioural vulnerability of juvenile brown kiwi: habitat use and overlap with predators

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Behavioural vulnerability of juvenile brown kiwi: habitat use and overlap with predators

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ABSTRACT

Habitat use by juvenile North Island brown kiwi (*Apteryx australis mantelli*) was investigated (using radio telemetry) at Trounson Kauri Park, in the far north of the North Island, New Zealand. Juvenile kiwi tended to select seral vegetation over mature forest types more often than would be expected based on the availability of these habitat types at Trounson; they also used grazed pasture surrounding the park, especially during autumn, and exhibited significant seasonal differences in habitat use. Very young kiwi tended to remain close to their nest sites. As they grew older, they travelled further from their natal areas and utilised a greater range of habitat types. No evidence was found of adult kiwi excluding juvenile kiwi from their territory, but the two groups did exhibit significantly different habitat use, possibly reflecting partitioning of food resources. The habitat of juvenile kiwi appeared to overlap most of the habitat of feral cats and stoats around the forest edge at Trounson. The distribution of juvenile kiwi found dead in the park demonstrated that predator control must be carried out within the park as well as around its edges. Some recommendations for future management at Trounson are made.

Keywords: Radio tracking, radio telemetry, predation risk, *Apteryx australis*, vegetation analysis, habitat selection

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1. Introduction

Trounson Kauri Park is located in the far north of the North Island of New Zealand. In recent years it has been subject to intensive conservation management as one of the Department of Conservation's 'mainland island' management sites. Studies by Chan (1999) and Gibbs (2000) investigated habitat overlap between juvenile North Island brown kiwi (*Apteryx australis mantelli*) and predators at Trounson. Chan (1999) investigated the influence of habitat over the movement of kiwi chicks at Trounson Kauri Park, how it affects dispersal and how chicks move and behave at night. Although Chan's study initially focused on micro-habitat use of juvenile kiwi, preliminary investigations into macro-habitat use were also undertaken. Some dietary analysis was also conducted to yield further information on the feeding habits of juvenile kiwi.

Gibbs (2000) standardised the methodology developed by Chan (1999) and continued investigations into the macro-habitat use of juvenile kiwi. She explored possible reasons for the habitat use observed in the two studies and habitat overlap between juvenile kiwi and predators. This report provides an overview of both studies.

2. Micro-habitat use

Observations from a pilot study at Trounson Kauri Park at the beginning of the project suggested that juvenile kiwi preferred, and selected, dense vegetation (Chan 1999: 18-22). The micro-habitat study undertaken by Chan (1999: 22) was designed to test this hypothesis.

Metal 'identification' bands covered in reflective tape and radio-transmitters fitted with light-emitting diodes (LEDs) were fitted to three juvenile kiwi. A total of 50 observations were made of the 3 individuals using night-vision goggles (ITT 'Nightmariner™') (Chan 1999: 28). At each site where a bird was observed, a point-centred quadrant (PCQ) was established, consisting of a circular plot with a 5-m radius, centred around the point where the bird had been observed feeding. Vegetation growing within the plot was classified, on the basis of height and diameter of the trunk at breast height (dbh), as small seedlings, established seedlings, saplings, poles and trees. Ground cover was classified as litter, fronds, roots, dead wood, mosses or bare ground. Percentages of each category of ground cover were then calculated. Soil penetrability was measured using a 'Procter' needle penetrometer (Chan 1999: 24-25).

Vegetation collected from these sites (n = 50) was compared with vegetation data collected in the same way from 50 sites selected randomly throughout Trounson Park, using student t-tests. Variation in vegetation composition between sites was analysed using 'PATN', a multivariate pattern analysis computer programme. The

results were displayed as scatter plots and dendrograms using a detrended correspondence analysis ('DECORANA') and a classification programme ('TWINSPAN') (Chan 1999: 26-27).

Overall, the student t-tests indicated that there was little difference between observed and randomly selected sites. Although there was significantly less vegetation at the tree and shrub level in sites at which kiwi were observed, it was later concluded that this may have been influenced by problems inherent in the observation of study subjects in dense vegetation (Chan 1999: 28, 46). No significant difference in understorey vegetation, tree diameter and litter depth was observed. Soil penetrability data were discarded because of large inter-site variations relative to sample size (Chan 1999: 28-29).

Chan (1999: 46) concluded that the results gained were '... not necessarily indicative of a lack of habitat selectivity ...', but should, instead, be taken as an indication that '... the variation in micro-habitat characteristics indicates that selection needs to be studied at a more general scale.'

3. Macro-habitat use

The macro-habitat component of Chan's study (1999: 47) focused on how immature kiwi were distributed within the dominant forest community types found at Trounson Kauri Park. This was determined by overlaying the locations of juvenile kiwi onto a map of the main forest communities found within the park.

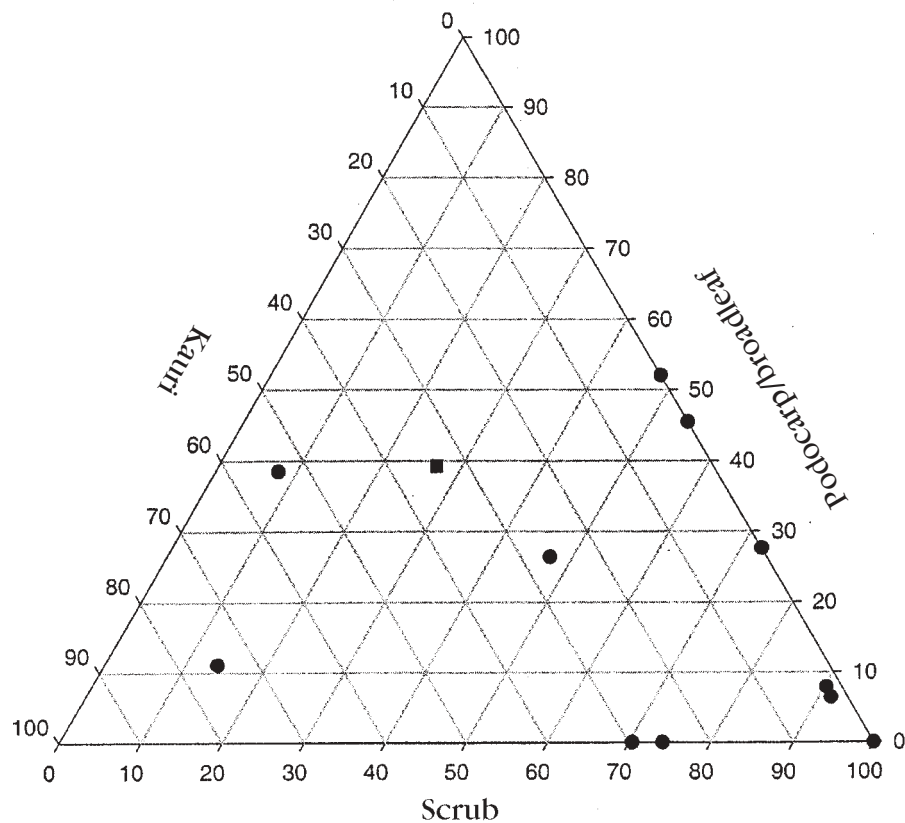
The main forest community types found within Trounson were initially defined and mapped using information from a 1973 topographic map constructed by the former Department of Lands and Survey, aerial photographs taken in 1985 and 1993, and an environmental impact assessment written in 1980 (Chan 1999: 50-51). Eight forest types were identified (Chan 1999: 54) and mapped. These eight forest types were later further amalgamated into three main groups: scrub, podocarp/broadleaf and kauri (Chan 1999: 62-65).

One of the purposes of Chan's (1999: ii) study was to '... lay the groundwork for further planned studies ...' Consequently, four techniques were used to determine the positions of kiwi in the macro-habitat component of his study (Chan, 1999: 48-50). These were:

- Direct visual observation
- Getting close to the bird using telemetry equipment and a 20dB attenuator, but not actually maintaining visual contact
- Calculating the position of birds by biangulating compass bearings taken on radio-signals from bait stations spread throughout the park
- Estimating the position of birds based on the strength and bearing of a single radio-signal

Vector- and raster-based maps, showing the ranges of juvenile kiwi (n = 11) in relation to vegetation types (n = 8), were constructed based on locational information collected both at night and during the day (Chan 1999: 51-60).

Figure 1. Ternary plot of the three main forest community types. Relative percentage proportions of each forest type were calculated for each bird based on their convex polygon ranges. The relative percentage proportions were also calculated for the park and are shown as the square plot (Chan 1999: 63).



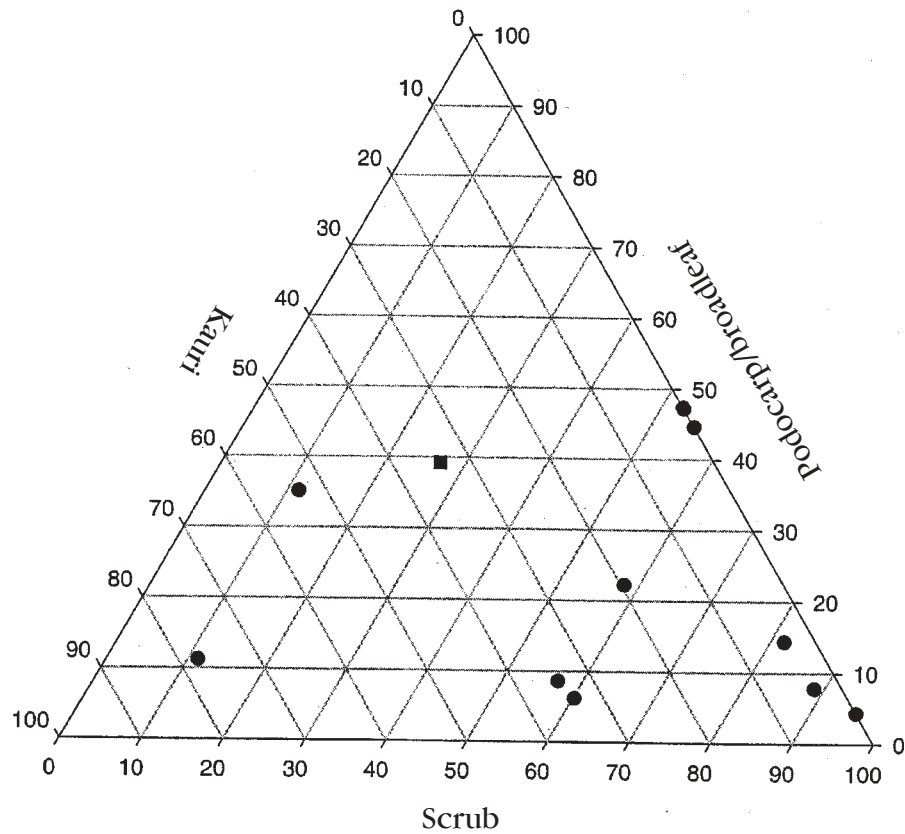
Two methods—convex polygon and grid cell—were used to calculate the home range of each individual. Based on these habitat maps and the home ranges of individual birds, ternary plots were constructed to illustrate the relative proportion of times each bird was located in the three main community types (Chan 1999: 63–64). These are shown in Figs 1 and 2.

From his results, Chan (1999) concluded that:

- Juvenile kiwi were capable of travelling large distances while dispersing from their natal area. It was suggested that the juvenile kiwi observed were ‘... searching for a suitable area to ‘settle’ in ...’
- The data show a clear and significant habitat preference by young kiwi for scrub and regenerating bush over the two other main forest communities in the park (mixed podocarp/broadleaf and kauri-dominated forest).’ (Chan 1999: 67).
- The lack of observations confirming that juvenile kiwi crossed the river or fenceline separating the forested area of the park from the surrounding pasture indicated that these features formed ecological barriers to juvenile kiwi (Chan 1999: 67–68).

Based on the results and recommendations of the previous study (Chan 1999: 46), Gibbs (2000) also focussed her investigations into habitat use of juvenile kiwi on macro-habitat. The available sample of juvenile kiwi ($n = 10$) used was determined by the number that had been radio-tagged by permitted Department of Conservation staff (Gibbs 2000: 20). Gibbs (2000: 20–24, 27–28, 112–118) standardised the biangulation methodology used by Chan (1999) and redefined four habitat types at the park (Gibbs 2000: 24–27).

Figure 2. Ternary plot of the three main forest community types. Relative percentage proportions of each forest type were calculated for each bird based on grid cell ranges. The relative percentage proportions were also calculated for the park and are shown as the square plot (Chan 1999: 64).



Results obtained by Gibbs (2000: 32, 38) supported Chan's (1999) conclusion that juvenile kiwi demonstrated a preference for seral vegetation over mixed podocarp/broadleaf and kauri-dominated forest communities. However, in contrast to Chan (1999), Gibbs (2000: 32-35, 39-44) found that the river and fence line did NOT form a barrier that juvenile kiwi were unprepared to cross. On the contrary, she found that the grazed pasture that surrounded the park was strongly selected for by juvenile kiwi during autumn. The differences between the two studies were attributed mainly to data for the two studies being collected over different seasons and partly to differences in methodology (Gibbs 2000: 40-41, 92). Bias in sample selection (almost all chicks fitted with transmitters by Department of Conservation staff were from nests around the perimeter of the park) was also a potential confounding factor.

4. Seasonal differences in habitat use

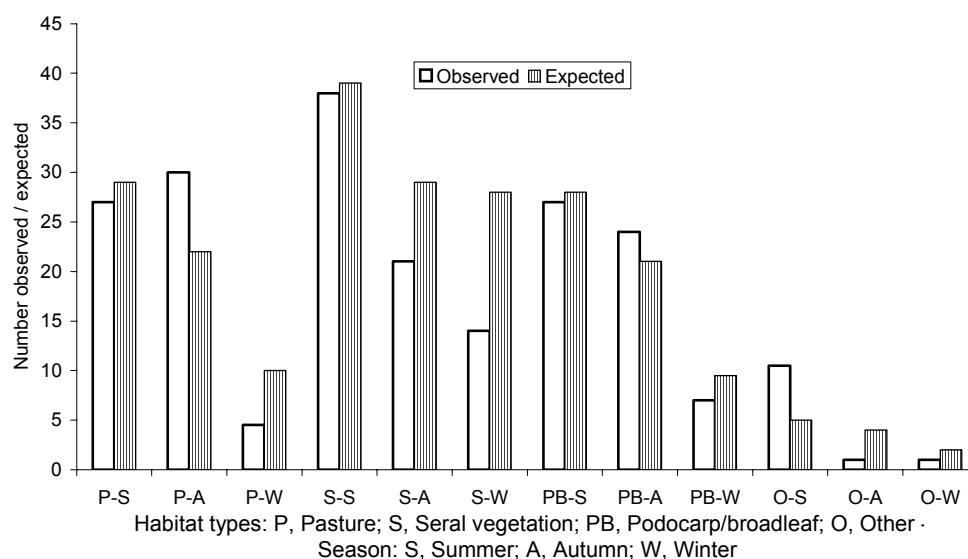
Gibbs (2000: 36) assessed seasonal differences in habitat use by constructing a contingency table and using a chi-squared analysis (Table 1). The data showed a significant difference in expected and observed habitat use between different seasons (Gibbs 2000: 37). This difference appeared to be due to juvenile kiwi spending more time than expected in pasture during the autumn, in seral vegetation during the winter and in some mature vegetation types during summer (Fig. 3). They also spent less time than expected in pasture in the winter.

TABLE 1. CHI-SQUARE ANALYSIS OF SEASONAL VARIATION IN HABITAT USE (GIBBS 2000: 37).

	PASTURE	SERAL VEGETATION	PODOCARP/ BROADLEAF	OTHER
Summer (observed)	27	38	27	11
Summer (expected)	29.7	39.3	28.3	5.7
Autumn (observed)	30	21	24	1
Autumn (expected)	21.9	29.0	20.9	4.2
Winter (observed)	5	23	8	0
Winter (expected)	10.4	13.7	9.9	2.0

Chi-square = 23.05; test statistic ($p = 0.005$; 6 d.f.) = 18.55

Figure 3. Seasonal variation in habitat use (Gibbs 2000: 37).



Comparing the differences in habitat use recorded by Gibbs (2000), (who conducted the majority of her field work in summer and autumn), and Chan (1999), (who conducted the majority of his field work in winter and spring), also gave some indication of seasonal differences in habitat use by juvenile kiwi. In particular, Gibbs (2000: 32-35) found that the grazed pasture surrounding the park constituted a significant and favoured habitat type, especially during autumn. In contrast, Chan (1999: 67) recorded only one observation of a juvenile kiwi in grazed pasture.

5. Habitat use: nest location or selection?

Both Gibbs (2000: 38) and Chan (1999: 69) suggested that natal nest location might bias habitat use of juvenile kiwi. In an earlier study, Taborsky & Taborsky (1995) had also suggested that adult kiwi might choose their nest location based on the habitat requirements of juvenile kiwi.

The natal nest sites of juvenile kiwi studied by both Chan (1999) and Gibbs (2000) were located primarily around the edges of the park. Both studies also suggested that distribution and habitat use of kiwi two weeks of age or younger is influenced largely by nest location. However, the location of the natal nest was therefore discounted as being a major factor influencing distribution and habitat use of older chicks (Gibbs 2000: 39, 59, 93; Chan 1999: 69, 71).

Based on his observation that many young kiwi travelled large distances away from their natal areas, Chan (1999: 71) speculated that nest sites did not necessarily contain areas of preferred habitat for young chicks. This could imply that adult birds did not choose nest sites based on habitat requirements of young birds. Chan (1999: 46, 88, 91) speculated that habitat use by juvenile kiwi more than two weeks old was largely the result of active habitat selection rather than natal nest location.

Gibbs (2000: 122-126) showed that, in a park containing 450 h of forest, juvenile kiwi travelled up to 1.5 km from their natal nest site. She found that the relative proportion of times that kiwi were located in different habitat types was significantly different from availability of those habitats (Fig. 4). Gibbs (2000: 65-69) also found that young kiwi with access to both seral vegetation and pasture had a better survival rate than those that did not. Gibbs (2000: 45, 59, 79) concluded that, although juvenile kiwi actively selected areas based on habitat availability, there was no evidence that nest sites were selected by adult kiwi to ensure young chicks had ready access to preferred habitat.

Figure 4. Habitat use by juvenile kiwi and its relative availability within the park (Gibbs 2000: 32).

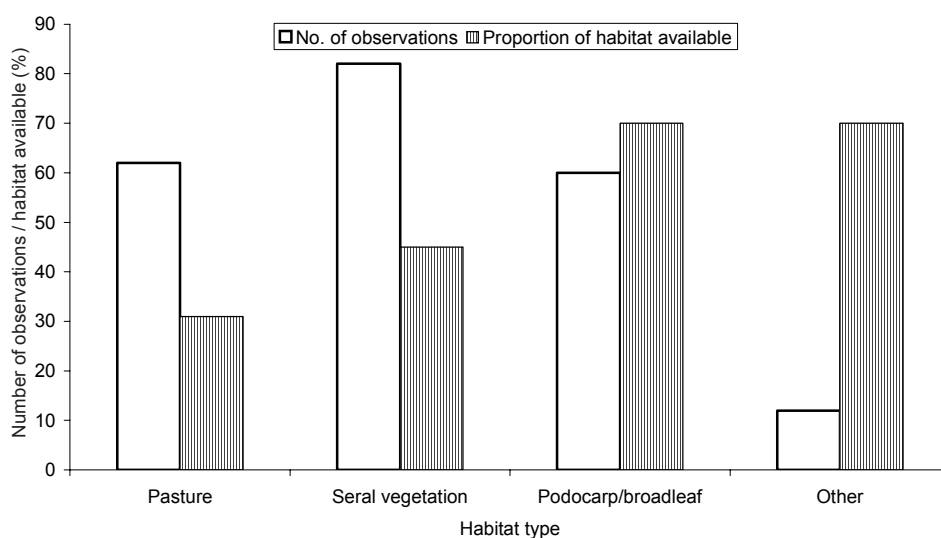


TABLE 2. CHI-SQUARE ANALYSIS OF HABITAT USE V. HABITAT AVAILABILITY (GIBBS 2000: 32).

	PASTURE	SERAL VEGETATION	PODOCARP/ BROADLEAF	OTHER
Number of observations	62	82	59	12
% availability	14.5	21.0	32.5	32.0
Proportion available	31.2	45.2	69.9	68.8

Chi-square = 109; test statistic ($p = 0.005$; 3 d.f) = 12.84

Small sample sizes and a short study period dictate that further study would be required to determine whether nest location or habitat selection had a statistically significant influence on habitat selection, particularly by chicks under two weeks of age.

6. Distribution and habitat use of juvenile kiwi and adult kiwi

It was suggested by Chan (1999: 67, 93-94) that further research into the distribution and habitat use of juvenile kiwi should concentrate, as far as possible, on reasons for habitat selection by this cohort. As adult kiwi are considered to be territorial (Heather & Robertson 1996; Butler & McLennan 1991), intra-specific interactions between adults and juvenile birds were identified as a possible factor that might influence the distribution and habitat use of juvenile kiwi, or vice versa (Gibbs 2000: 46-48; Chan 1999: 93).

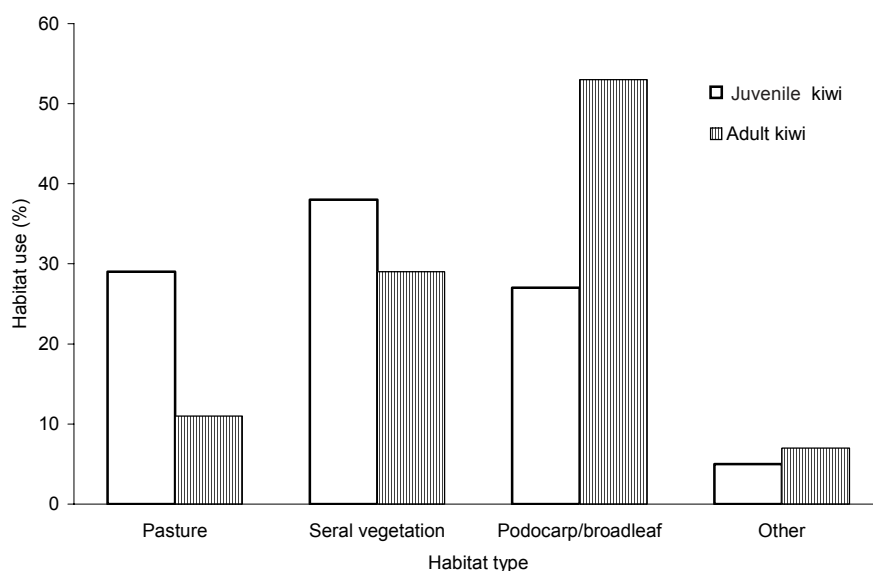
The distribution and habitat use of juvenile kiwi was compared with that of the adult male that had incubated them, with the aim of identifying major differences and similarities between them. (Gibbs 2000: 49-51).

Habitat use by juvenile kiwi was found to be significantly different from that of male parents. This difference appeared to be due to adult kiwi selecting for podocarp/broadleaf habitat more than juvenile kiwi and juvenile kiwi selecting for pasture more than adult kiwi (Fig. 5).

Gibbs (2000: 56, 59) speculated that the apparent difference between the habitat use of adult and juvenile kiwi could reflect the different beak lengths of adult and juvenile birds, resulting in different food availability for different cohorts in the same areas. Gibbs (2000: 56, 59) also suggested that habitat partitioning between adult and juvenile cohorts could therefore be vertical, rather than horizontal, with juveniles not feeding to such a depth in the leaf litter and soil as the adults.

Despite this, when the ranges of all birds were obtained by connecting the outermost location points, there was substantial overlap in the overall distribution of adult and juvenile kiwi. This could be partially due to the methods

Figure 5. Habitat use of juvenile and adult kiwi (Gibbs 2000: 53).



used to map and compare the distribution of adult and juvenile birds—which included outliers. However, it could also be interpreted as supporting the theory that, if it occurs, habitat partitioning between adult and juvenile kiwi occurs on a vertical, rather than horizontal, basis. (Gibbs 2000: 56).

7. Habitat value, as determined by survival and growth

Habitat studies have tended to assume that (1) a species will select and use areas that are best able to satisfy its life requirements; and (2) as a result, greater use will occur in higher quality habitat (Schamberger & O’Neil 1986). More recent work has pointed out that habitat use does not necessarily equate to habitat selection or habitat value. This is especially true for species that have a relatively low population density and detectability (Schamberger & O’Neil 1986) or that have difficulty in determining resource distribution, due to behavioural or morphological factors (Perrins & Birkhead 1993; Kolasa & Pickett 1991).

Flightless and nocturnal juvenile kiwi could be expected to have a poor knowledge of resource distribution. For this reason, habitat use compared with survival was analysed as one method of determining habitat value. Gibbs (2000: 65–69) observed that those birds that utilised all three main habitat types (pasture, seral vegetation and mature vegetation) had a higher survival rate than those that were only located in one or two habitat types (Table 3). While small sample sizes in this study and uneven sampling of chicks in terms of date from hatching means data obtained cannot be analysed statistically with any degree of confidence, the differences in survival related to habitat use were striking.

TABLE 3. HABITAT USE V. SURVIVAL OF JUVENILE KIWI.

MATURE FOREST	SERAL	PASTURE VEGETATION	NUMBER OF KIWI	SURVIVAL (> 18 MONTHS)
Yes	Yes	Yes	4	4/4 (100%)
Yes	No	Yes	2	0/2 (0%)
Yes	Yes	No	2	0/2 (0%)
Yes	No	No	2	0/2 (0%)

Gibbs (2000: 70–71, 76–77) also observed that:

- During the first nine months after hatching, the four birds observed in all three main habitat types grew faster than the one bird observed only in mature taraira-dominated forest.
- The median growth rate of juvenile kiwi at Trounson Kauri Park appeared to be substantially slower than the growth of juvenile kiwi measured (Miles 1998) at Lake Waikaremoana.

The apparent difference in growth rates between kiwi chicks observed in different habitat types at Trounson Kauri Park was interpreted as evidence of different levels of resource availability. It was suggested that more food was available in areas of pasture and seral vegetation during summer and autumn and that greater shelter from aerial predators was afforded in seral and mature vegetation. (Gibbs 2000: 79–80). It was suggested that apparent difference in growth rates between kiwi at Trounson and kiwi at Lake Waikaremoana could be due to regional differences in soil types and, therefore, food availability (Gibbs 2000: 77). Management implications of this were discussed (Gibbs 2000: 78–80), but subsequent re-examination of the Lake Waikaremoana growth data (J. Miles, pers. comm.) suggested that there may not, in fact, be major differences in growth rates. This possibility, nevertheless, merits further investigation.

8. Habitat overlap of juvenile kiwi with cats and stoats

The distribution of juvenile kiwi was mapped using locational data collected using methods described in Gibbs (2000). The distribution of stoats and cats at Trounson Park was also mapped, using locational data collected by methods described in Gillies (1998). The main difference in methodology for collecting data on kiwi and predator locations was the distance of the observer from the subject and the consequent scale of the potential error. The locations of juvenile kiwi found dead within or near Trounson Kauri Park between 1996–2000 were also mapped, using data supplied by DOC.

There was a strong tendency for both feral cats and stoats to be located in the vicinity of watercourses, roads, tracks, fence lines and boundaries between habitat types. Few predators were located within the park itself. Of those

predators that were located within the park, stoats tended to be found on the park boundary or near the edge of the bush whereas cats were found more frequently inside the park.

The juvenile kiwi that were monitored were distributed mostly around the boundary of the park in both forest and pasture.

The vastly different scale and error of data sets relating to juvenile kiwi and predators made it difficult to do more than superficially compare the distribution of juvenile kiwi and predators (Gibbs 2000: 89). However, the fact that most of the locations of juvenile kiwi found dead within Trounson Park were around the boundary and, especially, along the river, supported the hypothesis that predators have the most effect on juvenile kiwi around the forest boundaries.

The fact that predator control had begun within the park several years prior to this study needs to be taken into account when applying the results to other areas (Gibbs 2000: 88–89).

9. Conclusions

- It was found most appropriate to investigate the habitat use of juvenile kiwi on a ‘macro-habitat’ scale (Chan 1999).
- Radio telemetry was found to be an effective tool for investigating habitat use of juvenile kiwi (Chan 1999).
- Both Gibbs (2000) and Chan (1999) found that juvenile kiwi tended to select seral vegetation over more mature forest types more often than would be expected, based on the availability of these habitat types within Trounson Kauri Park.
- Gibbs (2000) observed a significant seasonal difference in habitat use by juvenile kiwi during the summer, autumn and winter. This difference appeared to be mostly due to juvenile kiwi spending more time than expected in pasture during the autumn and more time than expected in seral and mature vegetation types during the winter.
- Younger kiwi initially tended to remain close to their nest sites and were located most often in mature habitat types. As they grew older, some kiwi were observed to travel considerable distances from their natal areas and many used a greater range of habitat types. This was interpreted as indicating that, although natal nest location initially had the most influence over distribution and habitat use, juvenile kiwi increasingly selected habitats based on their own knowledge of the area (Gibbs 2000; Chan 1999).
- Chan (1999) suggested that ecological boundaries (such as rivers, fencelines and other linear features) had a strong influence on dispersal and habitat use of juvenile kiwi. In contrast, Gibbs (2000) found that juvenile kiwi used areas of grazed pasture within 133 m of the forest edge more often than would be expected based on availability. The difference between the two studies was attributed largely to seasonal differences (Gibbs, 2000).

- No evidence was obtained of adult kiwi excluding juvenile kiwi from their territory. However, juvenile and adult kiwi were observed to have significantly different habitat use (Gibbs 2000). Based on observations made by Chan (1999) and Gibbs (2000), it was suggested that the apparent difference in habitat use of adult and juvenile kiwi could be due to vertical, rather than horizontal, partitioning of food resources (Gibbs 2000).
- Gibbs (2000) found that juvenile kiwi that utilised all three main habitat types (pasture, seral and mature vegetation) had a higher survival rate and faster growth rate than those juvenile kiwi that utilised only one or two of the three main habitat types. This was interpreted as evidence that differences in vital resources, especially food and shelter from aerial predators, existed between habitat types.
- The habitat of juvenile kiwi appeared to overlap most with the habitat of feral cats and stoats around the forest edge. Rivers, roads, fences and tracks were identified as possible invasion routes used by predators (Gibbs 2000: 85–91).
- Predators operated over a large scale, both compared to juvenile kiwi and in relation to the small size of the park. This, along with the fact that dead juvenile kiwi were located within the park, demonstrate that predator control in a protected area of this size cannot be confined to the borders and must take place inside the park as well (Gibbs 2000: 91).

10. Management recommendations

That standard data collection and storage methods be agreed to make comparisons of data collected during the course of separate studies easier. This could have particular advantages in an intensively managed area or an experimental management area, such as Trounson. In this scenario, comparing two different data sets collected over different periods of time could be used to analyse the long-term effects of a management regime. Formulae that allow spatial data to be analysed using Excel™ are given in Appendix 2.1 of Gibbs (2000).

That further research be conducted into the possible differences in growth rates between kiwi in different regions. If regional differences in growth rates are detected, the selection of locations for future ‘mainland islands’ should take into account potential growth rates of juvenile kiwi in that region. With the current technologies and methods of predator control available for use over large areas, ‘mainland island’ management is prohibitively expensive in more than a few key areas. These areas therefore need to obtain the best benefits possible. If, for example, juvenile kiwi in Northland have a significantly slower growth rate than those in the East Coast region, it may be possible to protect a significantly larger area in a region of faster growth rates within a set budget. We note, however, that other issues (e.g. conservation of genetic diversity) may also dictate priorities for conservation action in particular regions.

That managers investigate adopting larger ‘mainland island’ areas than that managed presently at Trounson Kauri Park. The majority of predators at Trounson were located around the periphery of the park. If this phenomenon is repeated in other areas, a larger area:edge ratio should therefore make it more cost effective to protect a larger than a smaller area.

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