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MOVEMENT OF NORTH ISLAND BROWN KIWI *(APTERYX AUSTRALIS MANTELLI)* BETWEEN FOREST REMNANTS

Summary: Twenty-three kiwi were radio-tracked for 16-116 weeks in a Northland reserve. Eighty-three percent of the kiwi made use of the numerous forest remnants scattered over farmland outside the reserve. All remnants isolated by up to 80 m of pasture were used by kiwi. The maximum distance kiwi walked between forest remnants was 330 m. Longer migrations of up to 1.2 km from the reserve were made by kiwi using small forest remnants as 'stepping stones'. The planting and/or protection of small islands of forest adjacent to kiwi reserves is recommended as a method of linking forest remnants together and increasing the effective size of reserves. The possibility of managing several small populations of kiwi in concert to effect a larger population size is suggested.

Keywords: Brown kiwi; ratite; *Apteryx australis mantelli;* dispersal; corridors; bush remnants; reserve design; management.

Introduction

Large-scale forest clearance during the past century greatly reduced the distribution of many bush-dwelling New Zealand birds including the North Island brown kiwi *(Apteryx australis mantelli).* Only three enclaves of brown kiwi remain in the North Island. These are in Northland Taranaki-King Country and Urewera-Northern Hawkes Bay (Bull, Gaze and Robertson, 1985). Many of the birds are now restricted to small islands of forest and scrub separated by large tracts of pasture. McLennan, Rudge and Potter (1987) were concerned about the inadequacies in the physical size, and hence the carrying capacity, of the indigenous forest reserves in Hawkes Bay. Although brown kiwi in Northland can reach population densities 10 times those reported in Hawkes Bay (Potter, 1989), the small size of many of the remaining North Island forests containing kiwi should be of general concern.

Habitat fragmentation has two components, both of which can cause extinctions: first, absolute reduction in habitat area, which primarily affects population sizes and hence extinction rates; and second, dissection of the remaining area into separated fragments, which primarily affects dispersal and hence the probability of recolonisation after local extinction (Wilcove, McLellan and Dobson, 1986). Many of New Zealand's endemic species, including brown kiwi, need large areas (East and Williams, 1984). Unfortunately, the opportunity to create large new reserves has all but passed, and we need now to develop ways of enhancing and managing what is has left.

If management of the fragmented populations of brown kiwi is to be effective, we need to know more about how the pattern of vegetation affects the movements of kiwi between forest remnants. In particular, we require data on how far kiwi will travel over open pasture between patches of kiwi habitat. We also need information on land use practices that will allow kiwi to live, at least marginally, in land surrounding reserves. This will help provide buffer zones and enhance the carrying capacities of existing reserves.

Home range data obtained from radio-tagged kiwi in a Northland reserve are, used here to investigate management strategies and reserve design for North Island brown kiwi.

Study site

The study was undertaken at Paerata Wildlife Management Reserve (Paerata), Tangiteroria, Northland (35 °47'S, 174°02'E) between September 1985 and April 1988. Paerata (210 ha) is one of only two reserves specifically created for kiwi; the other is the Ecological Reserve (40 ha) in Waitangi State Forest. The study was concentrated in the southern third of Paerata (Fig. 1).

Paerata consists of low rolling hills up to 122 m a.s.l. The climate is subtropical, with warm humid summers and mild winters. Annual rainfall ranges between 1500-2400 mm (Tomlinson, 1976).

The reserve comprises a complex mosaic of grassland, manuka *(Leptospermum scoparium)* and kanuka *(Kunzea ericoides)* scrub, and regenerating podocarp/broadleaf forest. Hall's totara *(Podocarpus cunninghamii)* is the dominant tree species, with scattered patches of kohekohe *(Dysoxylum spectabile),* tanekaha *(Phyllocladus trichomanoides)* and putaputaweta *(Carpodetus serratus).* Some areas within the reserve contain dense understorey vegetation, and the two main valleys in the reserve are swampy and remain damp for all but brief periods in late summer. Several stands of raupo *(Typha orientalis)* occur in these valleys.

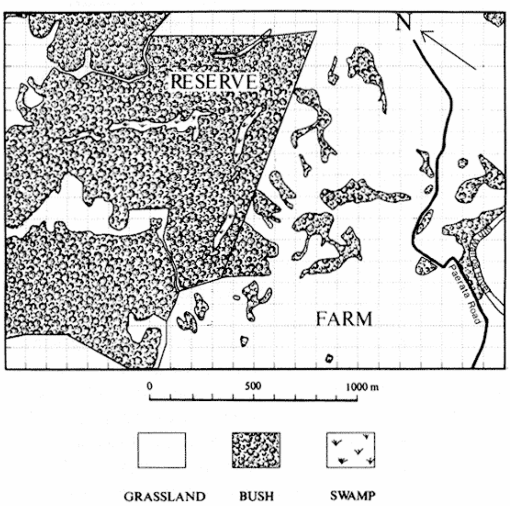

Figure 1: *Map of the study site at Paerata Wildlife Management Reserve, Tangiteroria, Northland (35 º47'S, 174 º02 'E). The southern boundary of the reserve runs obliquely down the centre of the map. Each grid cell is 1 ha.*

The original forest in the area was dominated by kauri *(Agathis australis),* but only a few scattered kauri remain in Paerata following milling during the mid-1800's, gum digging in the late 1800's, and farm development during the 1920's and 1930's. Large tracts of land adjacent to the reserve were cleared again between 1960 and 1980. Despite this clearance, the private land surrounding the reserve still has numerous small areas of forest and scrub, especially in the gullies (see results).

Paerata has been grazed continually by cattle *(Bos taurus)* since about the 1940's and harbours brush-tailed possums *(Trichosurus vulpecula)* and feral goats *(Capra hircus).* Predators present include feral cats *(Felis catus),* ferrets *(Mustela putorius),* and ship rats *(Rattus norvegicus).*

Methods

Between September 1985 and August 1987 thirty-two kiwi (11 males, 20 females and 1 juvenile) were caught and banded. Five chicks too small to band were also caught. Most kiwi were caught using a trained, muzzled Labrador bitch. The dog was used to locate birds in their daytime roosts and to catch them at night. Some kiwi were caught at night without the aid of a dog by spotlighting and running them down.

Twenty-three kiwi (10 males and 13 females) were fitted with radio transmitters of a design similar to those described by McLennan *et al.* (1987). The transmitters, each weighing 30-35 g and measuring 40 x 35 x 20 mm, were attached to the kiwis' upper leg (tibio-tarsus) with two soft, pliable plastic straps that broke naturally after 10-30 weeks. Battery life varied from 10 to about 25 weeks and kiwi were recaptured every 4-10 weeks to change straps and batteries if needed. Signals could be detected, using a CE12 receiver (Custom Electronics of Urbana Inc.) and a three element hand-held Yagi aerial, at distances of 10-2000 m when kiwi were in their daytime roosts, and from 200-2000 m when they were active at night. Radio-tagged kiwi were located, usually to within 20 m, on 375 days between September 1985 and April 1988. Individuals were located between 27 and 299 times over periods of 16 to 116 weeks. Kiwi were located on 2096 occasions during daytime, and 1447 occasions at night. The maximum number of radio fixes for an individual in one night was eight.

The distance kiwi moved between forest remnants was estimated in one of three ways. If the bird's route was known, the maximum distance travelled was measured. If the actual route to a forest remnant was not observed, the minimum distance between the remnant and the nearest forest within Paerata was used. Similarly, if the exact route to a forest remnant was not known and a series of forest 'stepping stones' were available to travel between a visited remnant and the reserve, I assumed the kiwi took the shortest route between these.

Results

Population size and dispersion

The whole of Paerata contained about 80-90 kiwi, i.e., a density of about one bird per 2.5 ha (Potter, 1989). Most of the birds I captured came from the southern third of the reserve, and here they were fairly evenly distributed along the 1200 m boundary.

Table 1: *The size, isolation, vegetation type and use by kiwi of the 23 forest remnants at the southern end of Paerata Reserve, Tangiteroria, Northland. Major vegetation types: 1 = totara; 2 = tree ferns; 3 = manuka/kanuka scrub; 4 = bracken fern; 5 = raupo; 6 = toetoe; 7 = radiata pine; 8 = blackberry; 9 = long rank grass; 10 = totara slash/cut scrub; 11 = kahikatea (*Dacrycarpus dacrydioides*); A = open bush; B = mixture of thick undergrowth and open bush; C = thick undergrowth. * Remnant only used at night.*

Remnant	Size (ha)	Distance from Paerata (m)	Distance from neighbour (m)	No. birds using remnant (% tagged birds)	Vegetation
1	0.77	0	0	7 (30)	1,2,3,10,B
2	3.84	0	0	5 (22)	1,2,3,10,B
3	1.45	0.8	10	6 (26)	1,2,3,5,6,B
4	0.83	15	15	4 (17)	1,A
5	0.33	25	25	5 (22)	1,3,10,A
6	0.43	25	25	7 (30)	1,2,3,10,B
7	0.36	54	25	5 (22)	1,2,3,B
8	0.10	58	40	2* (9)	1,A
9	0.11	130	48	1 (4)	1,2,3,B
10	0.17	255	60	2 (9)	1,11,A
11	3.90	200	70	4 (17)	1,2,3,4,5,6,8,10,B
12	1.80	285	70	2 (9)	1,2,3,10,B
13	0.25	105	80	1* (4)	1,3,A
14	1.73	178	80	1 (4)	1,2,3,6,7,10,B
15	0.52	675	135	0 (0)	1,2,3,6,B
16	0.13	738	135	0 (0)	1,2,3,4,C
17	0.17	768	290	2 (9)	3,4,6,7,8,9,10,C
18	0.11	845	290	0 (0)	1,A
19	3.69	888	290	2 (9)	1,2,3,4,6,7,9,B
20	2.50	900	290	2 (9)	1,2,3,6,9,10,B
21	0.46	850	300	0 (0)	7,A
22	0.20	640	400	0 (0)	1,A
23	2.70	750	550	0 (0)	1,2,3,B

Forest remnants

Twenty-three forest remnants of at least 0.1 ha and that were accessible to kiwi were situated on farmland within 1 km of the southern fence line of Paerata Reserve (Fig. 1; Table 1). The Northern Wairoa River was an effective barrier to kiwi.

The forest remnants were dominated by manuka and kanuka scrub, Hall's totara of various ages, and tree ferns (Table 1). Two remnants contained small raupo swamps. The remnants were not fenced but most contained some dense scrub cover despite moderate to heavy grazing by stock. In Northland, totara seems to be particularly resilient to grazing, and can often regenerate under the combined onslaught of cattle, sheep and goats. Some of the remnants used by kiwi consisted of little more than large patches of toetoe *(Cortaderia* sp.) and bracken *(Pteridium esculentum).* A lot of totara slash lay on the ground near many of the forest remnants, and this dead vegetation was used by kiwi for daytime shelter (Potter, 1989).

Use of forest remnants

Kiwi from Paerata made extensive use of forest remnants on farmland adjacent to the reserve --both for daytime shelter and while foraging at night. The 23 radio-tagged kiwi spent, on average, 25% of their time outside the reserve. Only four were never recorded beyond the reserve boundary. One pair spent 83% of their time over two years in forest remnants outside the reserve. This pair occasionally travelled up to 1200 m from the reserve by moving through three intermediate forest remnants to reach a fourth (Fig. 2). Another pair regularly moved up to 350 m from the reserve in a similar way. The other 15 birds travelled between 50 - 280 m from the reserve.

Two of the 23 forest remnants near the southern boundary of Paerata were contiguous with the reserve. The other remnants were separated from the reserve, and each other, by up to 550 m of pasture (Table 1). Figure 3 shows the maximum width of pasture each kiwi crossed when moving between remnants. This route was not always the shortest available. Kiwi often covered quickly the open ground between remnants. For instance, the pair that walked the greatest distance between remnants often covered the 330 m in less than 10 minutes.

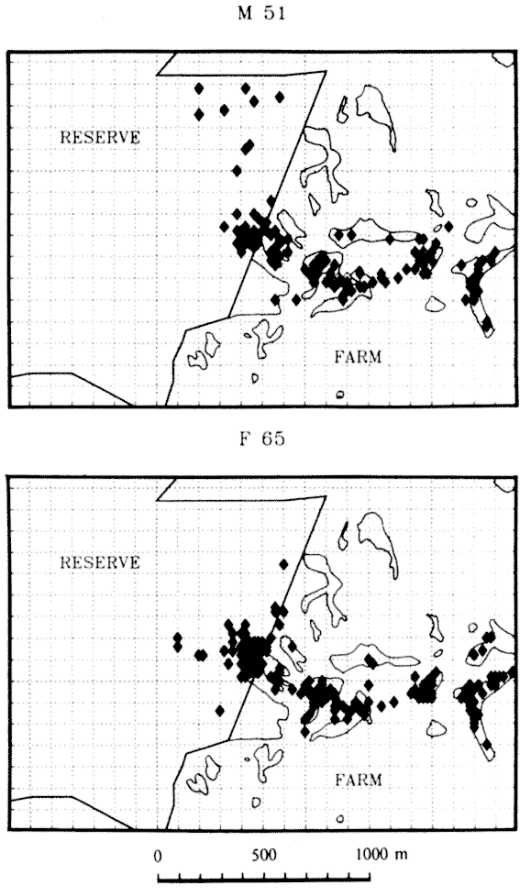

Figure 2: *Location records for Male* 51 *and Female* 65 *between September* 1985 *and April* 1988 *at Paerata Wildlife Management Reserve. Forest remnants are shown in outline. Each grid cell is* 1 *ha. See Fig.* 1 *for a more detailed habitat map.*

Although 19 of the 23 radio tagged kiwi (83%) occasionally used forest outside the reserve, only seven kiwi (30%) ever crossed more than 120 m of grassland. One pair regularly walked 330 m between two forest remnants but they may have been encouraged to do so by the local topography. When moving between these remnants this pair invariably walked down a steep-sided swampy gully. This gully was in the middle of an open paddock but there were several scattered patches of rush and blackberry which may have provided the kiwi with some cover. Another female was once observed 280 m from the nearest forest cover in completely open pasture. This observation is not included in Fig. 3 because the female walked out of, and back to, the same forest patch. Excursions of this type should be expected if kiwi actively seek out new areas of forest.

Remnant size and vegetation
The area of each of the forest remnants and their separation from other forest areas that could serve as 'stepping stones' are shown in Fig. 4. All remnants isolated by up to 80 m of pasture, regardless of size, were used by kiwi, but only three of the nine remnants separated by more than 80 m of pasture were used, and then only by a single pair. Two remnants isolated by 80 m or less were used only at night (Table I). In both cases the vegetation lacked diversity and was open underneath. Three other forest remnants of similar vegetation type and isolation were used by roosting

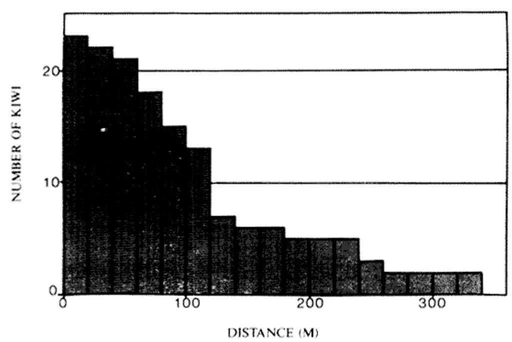

Figure 3: *The maximum distance (m) between forest remnants travelled by 23 kiwi at Paerata Wildlife Management Reserve, between September 1985 and April 1988.*

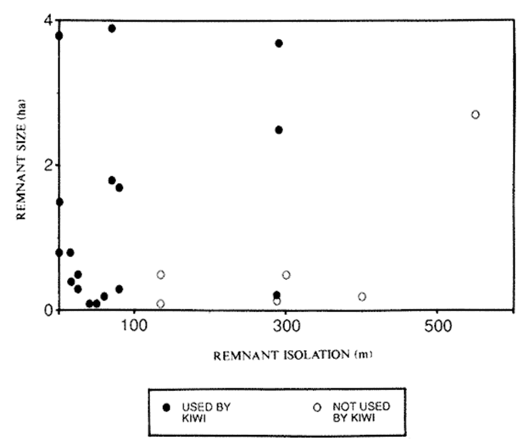

Figure 4: *The size and separation of forest remnants from other forest remnants that could serve as 'stepping stones' at the southern end of Paerata Wildlife Management Reserve, and their use by kiwi.*

kiwi, but these contained potential roost sites in the form of natural cavities and washouts, and/or piles of cut totara and scrub. The three remnants isolated by more than 80 m of pasture that were used by kiwi were those with the greater plant diversity and areas of dense undercover (Table 1).

Discussion

Historical and comparative densities

In the 1970's local farmers reported kiwi to be present in large numbers in the Paerata/Mangakahia area, and resulting surveys by the New Zealand Wildlife Service in 1976 and 1978 (reported in Reid, 1983) confirmed this. The density of about one kiwi per 2.5 ha that I found in Paerata is comparable with the density of kiwi in Waitangi State Forest (approximately 5 ha per pair (Colbourne and Kleinpaste, 1983)) before a feral dog reduced this by about one half in 1987 (Taborsky, 1988), but about 10 times greater than the density of one pair per 55 ha reported for Hawkes Bay (McLennan *et al.,* 1987). Historical data on pre-European/early European kiwi densities are virtually non-existent. The only information we have are anecdotal accounts of early naturalists, e.g., Buller (1988) describing kiwi hunts last century in which "a hundred or more" kiwi were caught with the aid of a dog in a single night, indicating that kiwi must have been abundant, if only locally.

All three brown kiwi populations for which reliable density data are available have been subject to habitat disturbance and land clearance. For some forest-dwelling species land clearance can result temporarily in artificially high densities as individuals are forced to crowd into forest remnants (Lovejoy *et al.,* 1986). This does not appear to have happened to kiwi in Hawkes Bay where a large tract of forest adjacent to the study area was cleared recently for conversion to pine forest (McLennan *et al.,* 1987). While the density of kiwi in Paerata must have been affected by the local history of land clearance and habitat modification, it seems unlikely that the high density of kiwi is solely an artifact of this disturbance. The most recent large-scale clearance of land around Paerata occurred between 1975 and 1980, when 120 ha of scrub/forest near the Mangakahia River was converted to farmland. Before this clearance a series of recovery operations removed over 80 kiwi from the block (M.B. Tapp, pers. comm.). Also, relatively undisturbed forests in Northland (eg. Waipoua) appear to contain kiwi in densities comparable with those in Paerata and Waitangi (R. Colbourne, pers. comm.). It is doubtful whether any extant populations of kiwi have escaped fully the effects of habitat modification - if not from forest clearance, then at least that caused by introduced herbivores and predators. Whatever the proximate cause of the high density of kiwi in Paerata, this reserve offered an excellent opportunity to investigate habitat use by kiwi in an environment fragmented by land clearance and farm development - an environment now typical of much of the remaining North Island kiwi habitat.

Comparative movements

Observations of how far kiwi will move away from forest cover in other areas are provided by the study of brown kiwi in Hawkes Bay (McLennan *et al.,* 1987). There two kiwi were observed at least 200 m from the nearest forest cover. These kiwi had moved onto land that had recently been cleared, burnt, and planted in pines. Although this land was not as clear and open as developed pasture, it was considerably more open than the forest and scrub with which kiwi are generally associated. These movements are consistent with those reported here, suggesting that many kiwi (perhaps >500/0) will travel up to 100 m across open pasture between remnants, but few (perhaps >10%) will cross distances of 300 m or more. These findings should be treated as guidelines only. How far kiwi would ultimately walk in open pasture could be influenced by their need to do so, which in turn could depend on the quality and quantity of resources available in their current habitat. The movements reported here are based on the day-to-day ranging of adult kiwi. Nothing is currently known about the pattern of chick dispersal or whether dispersal is sex-biased. Until these deficiencies in our knowledge are addressed we must design reserves based on the known ranging patterns of adult kiwi.

Remnant size versus isolation

The theory of island biogeography (MacArthur and Wilson, 1967) predicts that large islands have a greater chance of being found by migrating species than small islands. The same principles can apply to bush birds migrating between habitat remnants in a sea of cleared land (Frankel and Soulé, 1981). Although few remnants at Paerata were separated by more than 100 m of pasture, with one exception the more remote remnants used by kiwi were relatively large. The relationship between remnant size and the likelihood of kiwi using them requires further investigation.

Effect of vegetation type

The remnants used by kiwi in Paerata comprised several vegetation types, including *Pinus radiata* where this was associated with a dense understorey.

Kiwi are abundant in several *P. radiata* forests in Northland (Colbourne and Kleinpaste, 1983; Reid, 1983) but they are much less common in pine forests further south. In some locations kiwi live entirely within regenerating scrub (e.g. Waitere (McLennan *et al.,* 1987)). The actual vegetation may be of minimal importance to kiwi so long as two requirements are met: (i) the area has a rich surface and soil invertebrate fauna; (ii) the area provides dense cover for shelter and roost sites. These requirements are most likely to be met in environments with diverse floras. Certainly here the more isolated forest remnants used by kiwi were those with the greater plant diversity. This must be an important consideration when planting buffer zones around reserves, or 'stepping stones' between reserves.

Reserve design and enhancement

In designing a reserve for a target species the aim is to reduce the risk of local extinction of that species. Reduced populations are more susceptible to random demographic, environmental, genetic, and catastrophic events than large ones (Shaffer, 1987). A considerable body of theory has been developed to determine the "minimum viable population" (MVP) size for a species (Franklin, 1980; Soulé, 1980, 1987; Shaffer, 1981, 1983; Gilpin and Soulé, 1986; Soulé and Simberloff, 1986). How large a reserve should ideally be depends on the specific habitat requirements and MVP size of the target species. While there is no 'magic number', Frankel and Soulé (1981) calculated that most populations need to contain 500-1000 breeding individuals to have long-term viability. McLennan *et al.* (1987) believed this range to be a realistic one for kiwi, and used it as a guideline for determining the size requirements for brown kiwi reserves in Hawkes Bay. They estimated that reserves in that part of the North Island need to be between 7500 to 15000 ha each to meet this requirement. Although some kiwi populations may reach densities nearly 10 times higher than those found in Hawkes Bay, the predicted minimum reserve size requirements of these populations are still considerable (750 to 1500 ha). In many areas the creation of such large reserves is no longer possible because of land clearance, and many kiwi are left stranded in forest remnants of less than optimum size - including those in Paerata. Insufficient large populations of brown kiwi remain to ignore the conservation value of smaller populations. If we are to take seriously the conservation and preservation of kiwi, we must accept that active management of relatively small populations of kiwi is necessary.

How should we manage kiwi populations of less than optimum size? Good reserve design does not remove the need for ongoing monitoring and management, but it can reduce the intensity of management required (Gilbert, 1980). Consequently the management requirements of reserves of less than optimum size are likely to be greater, on an effort per kiwi basis, than for large reserves. The first requirement in developing a management plan for kiwi must be to locate the remaining populations of kiwi and determine their relative population sizes. This is currently being addressed through the Department of Conservation's 'kiwi call-card scheme'. Second, wherever possible we must supplement and enhance the available habitat, and the effective population sizes of these remnant populations, by linking islands of habitat together. We have seen that some kiwi will travel up to 1200 m from a reserve using forest remnants as 'stepping stones' or corridors. Forest remnants within 1-2 km of each other, therefore, could be linked by enhancing existing bush 'stepping stones', or by creating new ones. If new bush 'stepping stones' or corridors for kiwi are to be planted they should be as close as possible to maximise their use - ideally no more than 100-300 m apart, and contain a range of plant species. Preferably new plantings should comprise local flora, but the effectiveness of other species, including exotics, is worth investigating. Third, ongoing population monitoring and predator control is vital (see Taborsky, 1988; Diamond, 1989).

The forest remnants around the southern end of Paerata Reserve contribute over 20 ha of useful kiwi habitat to the main 210 ha reserve. The effective size of other reserves could similarly be enhanced by planting shelter belts, or by protecting existing remnants. Fencing of forest remnants may not be necessary in all locations, but must be a prime consideration where regrowth is restricted or unlikely; for instance, where stock have access to the reserve. Fencing may be minimally effective in discouraging dogs from roaming through these areas. The standard seven-wire fence is not a major obstacle to kiwi.

After linking islands of kiwi habitat with forest 'stepping stones', and enhancing the land surrounding reserves by creating and/or protecting adjacent forested areas, the combined area and kiwi population may remain inadequately small. How should we cope with this? By enhancing and linking islands of kiwi habitat we have addressed the first major component of habitat fragmentation identified by Wilcove *et al.* (1986) as causing extinction. Next we must redress the second major consequence of habitat fragmentation: a reduction in dispersal, and hence the probability of recolonisation after local extinction. This could be done by instigating a programme of artificial migration between reserves within a region. Groups of small populations could be managed in concert to effect a larger population spread across several reserves. This would increase gene flow within the small populations, and/or replace losses. Regular population monitoring would be useful to determine trends within each sub-population. Handled correctly, brown kiwi are tolerant of relocation, and quickly settle down to normal ranging patterns (M.A. Potter, unpublished data). Where our knowledge is currently deficient is in exactly how many kiwi should be caught and relocated at a time, and how frequently this should be done. Genetic studies will be beneficial here.

Many management questions are not yet answered. These include the effects on kiwi of grazing by stock; effects of predation on kiwi survival and recruitment; regional genetic variation between kiwi populations; and dispersal patterns of kiwi chicks. While these questions need attention, it is important not to let ignorance of these matters prevent us from acting now on the information we have (see Diamond, 1986). I have shown that kiwi will use forest 'stepping stones', and that kiwi habitat can be enhanced if land owners are encouraged to retain and protect forest remnants near kiwi reserves. We need to apply these principles elsewhere and, as Janzen (1986) urged, learn to be as concerned about the composition of the surrounding habitat as we are about reserves themselves. Remaining inactive may send many of our remaining kiwi populations to extinction.

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