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SEX RATIO OF NORTH ISLAND KAKA (*NESTOR MERIDIONALIS SEPTENTRIONALIS*), WAIHAHA ECOLOGICAL AREA, PUREORA FOREST PARK

Summary: The sex ratio of the kaka population inhabiting the Waihaha Ecological Area, Pureora Forest Park was estimated between late October 1994 and January 1995. The observed sex ratio estimate was three males to one female compared to a capture rate (using mist nets) of six to one in the same area between January and June 1994. Females appeared to be less susceptible to capture than males. The skewed sex ratio toward male kaka was significant and suggests that female kaka suffer higher mortality (probably due to predation at the nest) than males. The slow breeding rate of kaka combined with a high loss of breeding females is a serious threat to the long term survival of the kaka population within the Waihaha Ecological Area.

Keywords: kaka; parrot; *Nestor meridionalis septentrionalis*; sex ratio; radio-tracking; predators; stoat.

Introduction

Although once widespread and common throughout New Zealand, kaka (*Nestor meridionalis*) are now uncommon and continuing to decline throughout their historical range largely because of predation and competition from introduced animals, habitat destruction and hunting pressure (Oliver, 1955; Beggs and Wilson, 1991). North Island kaka (*N. m. septentrionalis*) are now rare in most districts, with population strongholds restricted to the few larger remnant tracts of virgin podocarp/hardwood forest (Pureora and Whirinaki) in the central North Island and a few pest-free offshore islands (Oliver, 1955; Moorhouse, 1991).

During 1994, 21 kaka were caught using mist nets and broadcast calls within the Waihaha Ecological Area (WEA) as part of a programme investigating the impacts of aerial applications of 1080 poison on threatened non-target species during pest control operations (Greene, 1998). Of these, only three were female, giving a sex ratio of one female to six males (Greene, *unpubl. data*; Department of Conservation, Auckland, N.Z.). Given the perceived quality of the forest habitat (Leigh and Clegg, 1989), the high number of kaka found within the WEA compared to other areas in the North Island (O'Donnell and Rasch, 1991) and the "threatened" status of the species (Tisdall, 1994), this disparity was considered worthy of further investigation.

The apparent imbalance in the sex ratio may have been a reflection of methods used to capture birds, but if it is real, it suggests that female kaka might suffer much higher mortality, possibly associated with nesting behaviours, than do males. The long-term effects on this population will be serious. Disproportionate losses of breeding females (or males) from any population over a prolonged period of time will inevitably lead to a decline in overall numbers. Assessment of a population's sex ratio is a fundamental element in the conservation of any threatened species (Elliott, 1996; Elliott, Dilks and O'Donnell, 1996). The detection of such an imbalance, however, can be problematic particularly if, like kaka, the sexes are difficult to distinguish in the field (Murray, 1994; Moorhouse *et al*., *in press*).

To test whether the sex ratio of captured kaka reflected the true sex ratio, an independent sampling method was required. Field observations of physical and behavioural characteristics were chosen as the only practical means of comparison. This paper presents results from field observations of kaka in the Waihaha Ecological Area, Pureora Forest Park during mid October 1994 to December 1994.

Study area and methods

Pureora Forest Park is dominated by the Rangitoto and Hauhungaroa Ranges forming an ecologically distinctive and extensive tract of native forest

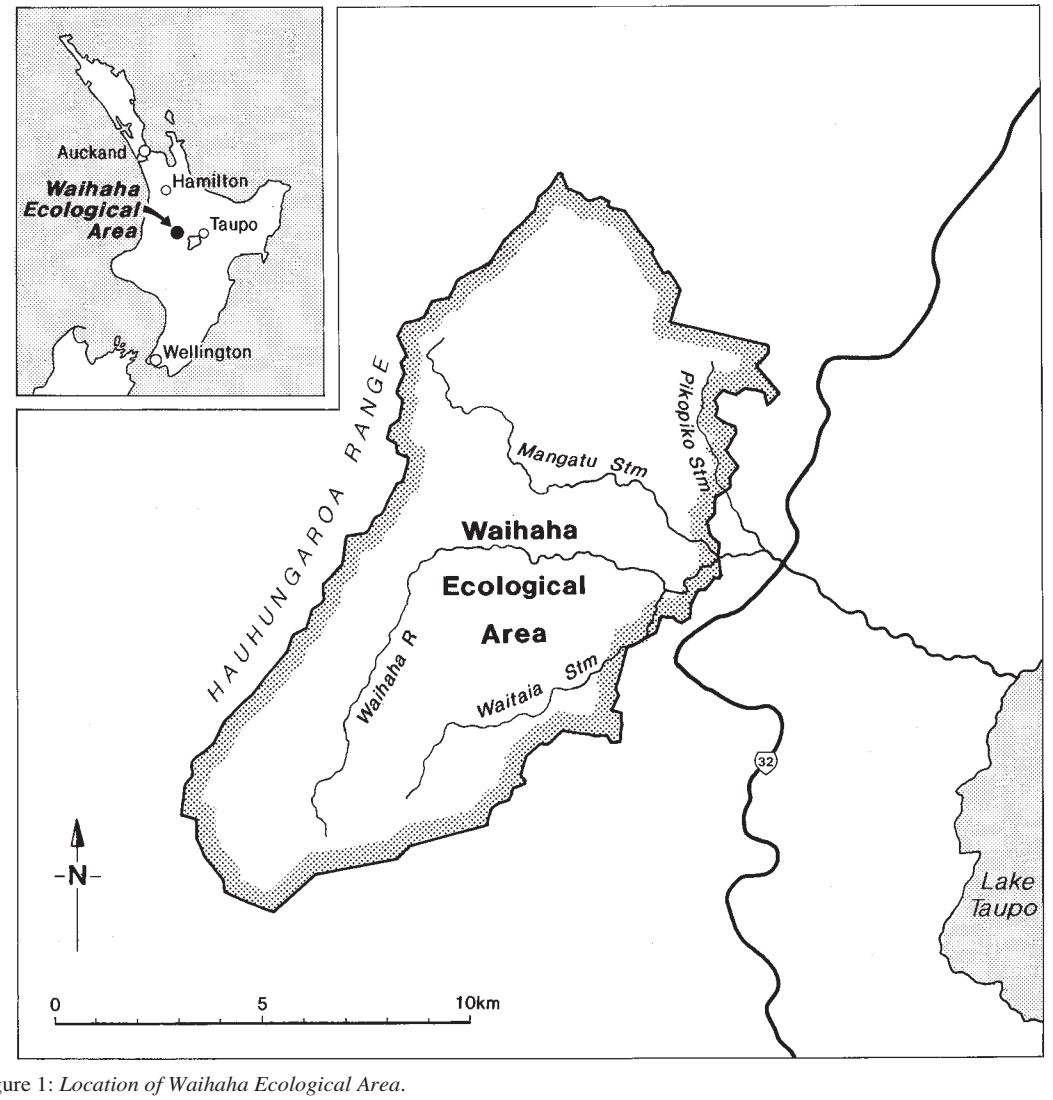

Figure 1: *Location of Waihaha Ecological Area.*

dividing the Maniapoto District from the Taupo Basin (Fig. 1.). The Waihaha Ecological Area covers a significant portion (11,000 hectares) of the forested area east of the main range and has been identified as one of the finest areas of dense virgin podocarp forest with significant wildlife values remaining in the North Island (Imboden, 1978; Leigh and Clegg, 1989).

Any reliable assessment of a species' sex ratio is reliant on the ability of observers to identify males and females accurately. Cues such as overall size, plumage colour, song, behaviours, or combinations of these may be used. Kaka are sexually dimorphic in size throughout their range but these differences are often not obvious when viewed in the wild. Although standardised measurements of weight (cube root), culmen length and depth are significantly greater (4.2%, 13.6% and 12.4% respectively, $P<0.0001$) in male North Island kaka (Moorhouse, *et al.*, *in press*), there is no significant variation in plumage colouration between the sexes and no readily detectable sexual differences in calls.

Kaka are monogamous, like virtually all other parrots (Murray, 1984; Forshaw, 1989). However, kaka within the Waihaha Ecological Area appear to

move about independently of each other for much of the year (March - August) and female kaka can rarely be distinguished accurately (T.C. Greene, *unpubl. data*; Department of Conservation, Auckland, N.Z.). The peak laying period for North Island kaka appears to occur (at least on Kapiti Island) during December (R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.). Prior to laying, however, males and females are often seen consorting in pairs. Behaviours exhibited during this 1-2 month period are often related to pair formation (allo-preening, allo-feeding and copulation) and nest site prospecting (R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.). During this time breeding displays and copulations can be readily observed and the birds sexed behaviourally, providing that it is a year in which kaka breed (kaka do not usually breed every year; Moorhouse, 1991). This pair bond usually remains stable throughout the duration of the breeding season until March (6-7 months) when any fledglings become independent.

To ensure accurate representation of both sexes, assessment of the sex ratio of kaka in the study area was attempted between October (when mated pairs and breeding behaviours become obvious) and December (when females begin incubation).

To allow a direct comparison of bill size and a means of interpreting behaviours, only birds observed in groups of two or more were sexed. This significantly reduced the chances of incorrectly assigning sex to each bird. If there was some doubt about the sex of birds seen in these groups (sex-specific behaviour not seen or the birds could simply not be seen clearly enough) sex was categorised as undetermined. It was also assumed (given the strength of the pair bond) that a female seen with a banded male was a different individual to a female seen with another banded or unbanded male.

Observations of kaka in the WEA and elsewhere during the period prior to egg laying suggest that they exhibit very strong pair bonds and consort closely even when socialising with other kaka of either sex. Any males without mates showing an interest in paired females are routinely chased away by either the male or the female of the pair. The strength and duration of this pair bond and the ability to identify pairs during the period prior to egg laying therefore minimised the possibility of significantly underestimating (or overestimating) the number of female kaka and producing a biased estimate of the population sex ratio.

Assessment of the sex ratio was further assisted by following radio-tagged males (the low female capture rate meant that only one radio-tagged female could be followed) during spring and summer. As both male and female kaka are particularly gregarious during this period (R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.), radio-tagged males often led observers to other groups/pairs of birds, the sex of which could then be determined.

A total of 28 days was spent following 14 (one female and 13 males) of the 21 kaka fitted with transmitters within the WEA. Kaka with transmitters were located and observed for as long as possible. As the tolerance of kaka in close proximity to one another prior to egg laying appears to be indicative of mated pairs, the presence of another kaka within an arbitrary (and highly conservative) distance of 5 metres were recorded as pairs. Any sexual behaviours that may have confirmed sex were also recorded.

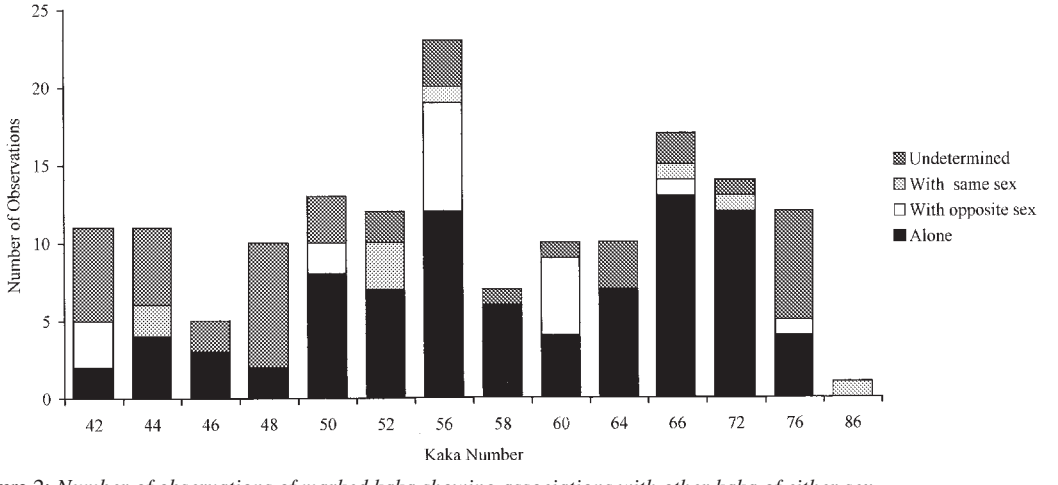

Figure 2: *Number of observations of marked kaka showing associations with other kaka of either sex.*

Results

A total of 161 observations were made of 14 radio-tagged kaka (Figure 2.). Twelve kaka were located and observed on more than five occasions. Eight of the twelve kaka were encountered more frequently by themselves than with other birds. Six of the twelve kaka were seen with another bird of the opposite sex. The number of observations required to find a bird for the first time with one of the opposite sex varied between one and eleven observations.

One kaka (No. 60), a female that attempted to nest, was encountered on six occasions before it was determined that she had a mate. She was the kaka most often found with a bird of the opposite sex (50 % of encounters).

On several occasions a female was found in the company of more than one male. Two males were often seen in close proximity to a nest tree when the female (No. 60) was inside the hole. At another nest, at least three males were often seen close by; and radio-tagged males were often seen as part of a two male to one female group.

Of the 13 male kaka monitored, 5 males had female mates, and one male was found associating with a female who already had a mate. The sex ratio by observation was therefore estimated to be one female to three males. The single radio-tagged female kaka monitored also had a mate.

Discussion

The observed sex ratio of kaka within the WEA was one female to three males compared to a capture ratio using mist nets of one female to 6 males. The population sex ratio derived from mist net captures appears significantly to underestimate the number of female kaka within mainland forests.

Kaka captured on Kapiti Island using mist nets between 1988-91 gave an estimated sex ratio of one female to 1.25 males (n=25, R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.; Table 1). Similarly, kaka captured in cage traps on Little Barrier Island between 1989-93 gave a ratio of one female to 1.3 males (n=70, Department of Conservation, *unpubl. data*). Although it is possible that the capture methods used on Kapiti Island and Little Barrier Island may also underestimate numbers of females, such an underestimate is less extreme compared to that found in the WEA if the "normal" population sex ratio for a monogamous species is assumed to be close to 1:1 (Murray, 1984). This assumption is supported by the 1:1 secondary sex ratio (Murray, 1994) recorded for captive kaka at hatching (M.J. Sibley, *pers. comm.*; Auckland Zoological Park, Auckland, N.Z.).

If it is assumed that the sex ratio derived from mist netting on Kapiti Island (and/or cage traps on Little Barrier Island) accurately reflects the true sex ratio, then mist netting on the mainland should also accurately reflect numbers of females. This is obviously not the case and, given the secondary sex ratio of 1:1 at hatching (M.J. Sibley, *pers. comm.*; Auckland Zoological Park, Auckland, N.Z.) and probably fledging, observations on the mainland suggest that female kaka suffer much greater losses before or during adulthood.

Timing can significantly affect the sex of birds available for capture during mist netting operations. For example, if females are all incubating eggs it is likely that predominantly males will be captured.

Table 1: *Sex ratio estimates for kaka populations.*

Location	Period	Estimation method	Sex ratio (female : male)	n	Reference
Kapiti Is.	1988-91	Mist net	1:1.27	25	R.J. Moorhouse *pers. comm.*
Little Barrier Is.	1989-93	Cage-trap	1:1.3	70	D.O.C. *unpubl. data*
South Westland	1992	Observation	1:3.2	46[1]	C.F.J. O'Donnell *pers. comm.*
Nelson Lakes	1984-89	Mist net	1:2	30	P.R. Wilson *pers. comm.*
	1989-91	Mist net	1:2.8	23	P.R. Wilson *pers. comm.*
Waihaha	1994	Mist net	1:6	21	T.C. Greene *unpubl. data*
Ecological Area	1995	Observation	1:3	14[2]	T.C. Greene *unpubl. data*

[1]Number of confirmed sex sitings from a total of 325 observations
[2]Number of confirmed sex sitings from a total of 161 observations

Assuming that the timing of the breeding season was similar to that experienced during 1994, kaka females at Waihaha should have already raised their chicks to fledging and been ranging throughout the forest during the capture period. Unless mist netting operations take place during a breeding season, timing of capture is not considered to cause a major bias in the sex ratios recorded for kaka.

Overall, females appear to be less susceptible to capture within mainland forests than males although the reasons for this remain unclear. Males may exhibit a stronger response to broadcast calls, particularly alarm calls (the latter were not used on Kapiti Island, R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.), than females, or females may simply be more cautious and/or less common within mainland forests.

The best estimate of the sex ratio for kaka in the Waihaha Ecological Area is one female to three males. This is very similar to that estimated in a pilot study conducted in South Westland during 1992 (C.F.J. O'Donnell *pers. comm.*; Department of Conservation, Christchurch, N.Z.), where 35 male and 11 female kaka were "positively" identified through observations; a sex ratio of one female to 3.2 males (Table 1). An ongoing study of a kaka population in Big Bush, Nelson Lakes also identified a skewed sex ratio in favour of males (Table 1). Prior to 1989 the sex ratio of this population was estimated as two males for every female (n=30). Between 1989 and 1991, however, this ratio increased to 2.8 males for every female (n=23) (P.R. Wilson, *pers. comm.*; Landcare, Nelson, N.Z.).

It is interesting to speculate why a male biased sex ratio of 1:3 appears to be common on the mainland for both North Island and South Island kaka subspecies, and in different forest types, compared to the approximate 1:1 sex ratio found on the relatively unmodified island habitats of Kapiti Island and Little Barrier Island.

In contrast to the mainland, Kapiti Island and Little Barrier Island have no significant arboreal predators, such as mustelids, ship rats (*Rattus rattus*) or possums (*Trichosurus vulpecula*). There has been much speculation as to whether predation has caused the apparent skew in sex ratio on the mainland. Stoats (*Mustela erminea*) have been strongly implicated in the predation of female kaka at the nest as only females incubate eggs and brood chicks (Beggs and Wilson, 1991; O'Donnell and Rasch, 1991). Although only two observations of stoats entering kaka nests have been recorded in the last 10 years (P.R. Wilson, *pers. comm.*; Landcare, Nelson, N.Z. and R. van Mierlo, *pers. comm.*; Department of Conservation, Hokitika, N.Z.), six females known to breed successfully at Big Bush, one incubating female within Whirinaki Forest and several chicks are assumed to have been killed by stoats (P.R. Wilson, *pers. comm.*; Landcare, Nelson, N.Z.; T.C. Greene, *unpubl. data*; Department of Conservation, Auckland, N.Z.).

Stoats are thought to have similar effects on the sex ratio of a number of other bird species. They are known to be an important predator of both yellowheads (*Mohoua ochrocephala*) and yellow-crowned parakeets (*Cyanoramphus auriceps),* both of which are hole nesting species where only females incubate eggs and raise chicks (Elliott, 1992 and 1996; Elliott, Dilks and O'Donnell, 1996).

Possums are also thought to have had adverse effects on the productivity of mainland kaka populations (Beggs and Wilson, 1991; O'Donnell and Rasch, 1991). Considerable overlap has been found in the preferred foods of both kaka and possums, particularly the high energy food sources kaka may require for breeding. Research in South Westland also indicated that kaka numbers declined significantly as a result of increasing possum density and history of occupation (O'Donnell and Rasch, 1991). Although competition with browsers such as possums is likely to affect overall productivity of kaka populations (Beggs and Wilson, 1991), direct impacts on population sex ratio are unlikely.

Recent studies of kokako (*Callaeas cinerea wilsoni*) also suggest that predators are capable of significantly influencing the population sex ratio (I. Flux, *pers. comm.*; Department of Conservation, Wellington, N.Z.). Prior to intensive predator and browser control, the sex ratio of kokako within a remnant King Country population at Mapara was strongly biased toward male birds (90% male in 1989) with numerous single males and male-male pairings. Female kokako were thought to have been particularly vulnerable to predation while nesting. Following intensive pest control, the population sex ratio (60% male in 1996) and overall productivity had both improved significantly (I. Flux, *pers. comm.*; Department of Conservation, Wellington, N.Z.).

Behavioural observations in the Waihaha area support a skewed sex ratio for kaka. All females observed were seen with males, but only relatively few males were seen with females (see Fig. 2). Males without mates were often seen in the vicinity of the females (and their mates), and this was particularly marked when females nested. Up to three unpaired males were often seen in the vicinity of the two nests located. Unpaired males associated with nesting females may have been sub-adults curious about females. However, it is much more likely that they were adult males actively competing

for scarce females. Recent observations (1996-97) from Nelson Lakes where the sex ratio has deteriorated rapidly (seven males to every female using mist netting data, R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.) have revealed two males copulating with the same female. This is thought to be an artefact of increased inter-male competition resulting from the heavily male biased sex ratio now occurring in the area (R.J. Moorhouse, *pers. comm.*; Department of Conservation, Nelson, N.Z.). Although male-male pairings, as in kokako, cannot be discounted for kaka within the WEA, there is as yet no evidence of this occurring anywhere in New Zealand despite many hours of observations.

Whether the sex ratio of one female to three males indicates a threat to the long-term survival of the kaka population in the Waihaha area cannot be determined without further investigation of kaka population demographics. However, the breeding rate of kaka both on the mainland and in relatively undisturbed island populations has been shown to be low and highly variable, with no breeding occurring in some years (often consecutive) and considerable variation in the number of females attempting to breed in a given season. These variations in productivity have been strongly linked to the abundance of food (Beggs and Wilson, 1991; Moorhouse, 1991). Consequently, the presence of introduced predators (particularly stoats) and the current evidence of a highly skewed sex ratio for kaka within the Waihaha Ecological Area, should be regarded as a serious threat to the long-term survival of the Waihaha kaka population.

A greater loss of breeding females than males, combined with related poor breeding success, will inevitably result in an increasingly skewed sex ratio. Eventually the proportion of old males will increase, and long-term, unless the factors causing the skewed sex ratio can be rectified, the kaka population within this nationally significant stronghold will decline to extinction.

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References

Beggs, J.R.; Wilson, P.R. 1991. The kaka *Nestor meridionalis*, a New Zealand parrot, threatened by introduced wasps and mammals. *Biological Conservation 56:* 23-28.

Elliott, G.P. 1992. Habitat relationships and the conservation of the yellowhead. *New Zealand Journal of Ecology 16*: 83-90.

Elliott, G.P. 1996. Mohua and stoats: a population viability analysis. *New Zealand Journal of Zoology 23*: 239-247.

Elliott, G.P.; Dilks, P.J.; O'Donnell, C.F.J. 1996. The ecology of yellow-crowned parakeets (*Cyanoramphus auriceps*) in *Nothofagus* forest in Fiordland, New Zealand. *New Zealand Journal of Zoology 23*: 249-265.

Greene, T.C. 1998. The effect of compound 1080 on populations of specific non-target species, Waihaha Ecological Area, Pureora Forest Park, winter 1994. Science for Conservation 69, Department of Conservation, Wellington, N.Z. 54 pp.

Imboden, C. 1978 (unpublished). *Wildlife values and wildlife conservation in the Hauhungaroa and Rangitoto Ranges*. New Zealand Wildlife Service Fauna Survey Unit Report No. 10. Department of Internal Affairs, Wellington.

Leigh, A.H.; Clegg, S.E. 1989 (unpublished). *Maniapoto district wild animal management plan 1989 to 1999*. Department of Conservation, Hamilton, N.Z. 180 pp.

Moorhouse, R.J. 1991. Annual variation in productivity of North Island kaka on Kapiti Island, New Zealand. *Acta XX Congressus Internationalis Ornithologici*: 690-696.

Moorhouse, R.J.; Sibley, M.J.; Lloyd, B.D.; Greene, T.C. in press. Sexual dimorphism in the North Island kaka (*Nestor meridionalis septentrionalis*). *Ibis*.

Murray, B. G. Jr. 1984. *A demographic theory on the evolution of mating systems as exemplified by birds*. In: Hecht, G.; Wallace, B. and Prance, G. (eds). Evolutionary Biology Vol. 18. Plenum Press, New York, pp. 71-140.

O'Donnell, C.F.J.; Rasch, G. 1991 (unpublished). *Conservation of kaka in New Zealand. A review of status, threats, priorities for research and implications for management*. Science and Research Internal Report No. 101, Department of Conservation, Wellington, N.Z. 13 pp.

Oliver, W.R.B. 1955. *New Zealand birds* (2nd ed.). Reed, Wellington, N.Z. 661 pp.

Tisdall, C. 1994. *Setting the priorities for the conservation of New Zealand's threatened plants and animals*. Second edition, Department of Conservation, Wellington, N.Z. 64pp.