A THEORETICAL ASSESSMENT OF THE ABILITY OF BIRD SPECIES TO RECOVER FROM AN IMPOSED REDUCTION IN NUMBERS, WITH PARTICULAR REFERENCE TO 1080 POISONING

E. B. SPURR

Protection Forestry Division, Forest Research Institute, N.Z. Forest Service, P.O. Box 31-011, Christchurch

SUMMARY: A consideration of the composition of bird diets, and the list of bird species found deadl indicates that most New Zealand land bird species risk being killed by feeding directly on baits poisoned with Compound 1080 or by eating poisoned prey. Theoretically, if a population of a species is heavily reduced, its ability, or inability, to recover can be predicted from a consideration of its reproductive and dispersal capacities. Species with poor reproductive potential and poor dispersal have a high risk of non-recovery, e.g., the three species of kiwi, the takahe, kakapo, laughing owl, bush wren, rock wren, fernbird, yellowhead, stitchbird, saddleback, kokako, and New Zealand thrush. Species with either poor reproduction or poor dispersal are medium risk species, e.g., the New Zealand falcon, weka, New Zealand pigeon, kaka, kea, the three species of parakeets, the morepork, rifleman, brown creeper, whitehead, and robin. Species with good reproductive and good dispersal capacities are low risk species, e.g., the Australasian harrier, pukeko, kingfisher, welcome swallow, New Zealand pipit, grey warbler, fantail, tit, silvereye, bellbird, and tui. The implications of this classification are discussed in relation to forest management practice.

INTRODUCTION

Bird populations may be reduced by, among other things, pesticides (e.g., see Mills, 1973), predators (e.g., see Merton, 1975; Flack and Lloyd, 1978), disease (e.g., see bellbirds* in Falla, Sibson and Turbott, 1975), weather (e.g., see Bull and Dawson, 1969), and destruction of habitat (e.g., land clearance for farming, logging for timber). Except for the latter, the above causes of reduction usually do not prevent recovery.

One potential cause of reduction (the use of pesticides) has recently been highlighted by reports (summarised by Harrison, 1978) of bird deaths after possum *(Trichosurus vulpecula)* poisoning operations using sodium monofluoroacetate (Compound 1080). Compound 1080 is used mainly for control of possums and other wild animals in forests and on agricultural land (Batcheler, 1978). The 1080 is incorporated into baits, usually diced carrot, but also other baits such as pollard pellets and oats, and is commonly distributed from the air. The toxicity of baits ranges from 0.02 % by weight in some rabbit *(Oryctolagus cuniculus)* operations, to about 0.09% in some possum operations. The area treated ranges from a few hectares for ground operations to about 10000 ha for aerial operations.

Several species of native birds are known or suspected to have been poisoned by 1080 (Table 1). In some (e.g., the weka, kaka, kea, whitehead, robin) 1080 has been identified in the carcasses, but in others the cause of death has only been inferred, since dead birds were not found in unpoisoned areas of forest. The southern black-backed gull (Douglas, 1967) and several introduced species, for example, the chukor, Californian quail, skylark, hedge sparrow, song thrush, blackbird, yellow hammer, chaffinch, goldfinch, redpoll, house sparrow, and the white-backed magpie have also been found dead in areas poisoned with 1080 (Harris, 1977; Batcheler, 1978; Harrison, 1978; personal observation).

Field trials are currently under way to assess the proportion of any population killed and the long-term impact on bird numbers of any losses caused by poisoning. However, the results of the trials may not be known for some time, and existing trials are assessing only a selection of the species found in the areas being poisoned. Some species, for example rare or endangered birds such as the kokako, and nocturnal birds such as the kiwi, weka and morepork, require special monitoring which has not

*Latin names of all birds mentioned in the text and tables are included in Appendix 1.

TABLE 1. *Susceptibility of native land birds to 1080 poisoning from a consideration of the composition of their diets and of the species found dead in areas poisoned with Compound 1080.*

Bird species considered	Vegetable component of diet[1]			Species found dead
	important	minor	none[2]	
Brown kiwi	+			
Little spotted kiwi	+			
Great spotted kiwi	+			
Australasian harrier			+	+[3,4]
N.Z. falcon			+	
Weka	+			+[3,4,5]
Pukeko	+			+[3,4]
Takahe	+			
N.Z. pigeon	+			
Kakapo	+			
Kaka	+			+[6]
Kea	+			+[7]
Red-crowned parakeet	+			
Yellow-crowned parakeet	+			
Orange-fronted parakeet	+			
Morepork			+	+[8]
Laughing owl			+	
Kingfisher			+	
Rifleman		+		+[8,9]
Bush wren			+	
Rock wren	+			
Welcome swallow			+	
N.Z. pipit		+		+[3]
Fembird			+	
Brown creeper			+	+[8]
Whitehead		+		+[8,9]
Yellowhead		+		
Grey warbler		+		+[8,9]
Fantail			+	+[8]
Tit		+		+[8,9]
Robin		+		+[8,9]
Silvereye	+			+[8,9]
Stitchbird	+			
Bellbird	+			
Tui	+			
Saddleback	+			
Kokako	+			
N.Z. thrush	+			

Notes:
1. Data from Falla *et al*. (1975) unless otherwise stated in text.
2. So far as is known.
3. Batcheler (1978).
4. Harris (1977).
5. McIntosh *et al*. (1966).
6. Anon (1978).
7. Douglas (1976).
8. Personal observation.
9. Harrison (1978).

yet been attempted. Thus, I believe it appropriate to use data available now to attempt to predict the ability of species to recover from an imposed reduction in numbers, such as might occur from 1080 poisoning for control of possums in forests.

I have restricted the assessment .to 38 species of native land (forest and forest margin) birds. Freshwater birds and the two migrants, the shining cuckoo and the long-tailed cuckoo, have been excluded.

SUSCEPTIBILITY TO 1080 POISONING

Before assessing species' ability to recover from a reduction in numbers, I have attempted to identify the land birds likely to be reduced by 1080 poisoning.

Consideration of feeding habits

The first step is to determine which species might obtain poison by feeding on poisoned baits or on other animals that have eaten baits. Those which feed on vegetable matter (particularly fruits, shoots, etc.) may be in danger of feeding on baits (particularly carrot, but also grain-based baits) used for possum control. For example, Bull (1959) warned that the presence of vegetable matter in the diet of kiwis should be taken into account by anyone planning to use poisoned baits for control of noxious (or wild) animals. According to Fleming (1974), the little spotted kiwi may feed on fruit more than do the other kiwi species. It may therefore be more likely to eat poisoned baits. Reid (1978) reported recently that the little spotted kiwi has drastically declined in numbers.

Vegetable matter is eaten by all of our land birds except the birds of prey and some insectivorous birds (Table I). The Australasian harrier, New Zealand falcon, laughing owl, morepork, and kingfisher would be unlikely to ingest poisoned baits directly, but might eat dead or sub-lethally poisoned rodents or small birds. Dead mice *(Mus musculus)* have been found on the forest floor after appl:cation of 1080 poison. Sub-lethally poisoned rodents and birds would be prime targets for predators. This is possibly how the morepork listed in Table 1 was killed.

Several so-called insectivorous species have been found dead after poison operations (Table 1), so they must have eaten either poisoned insects or baits. In support of the former, many insects and slugs have been found on both carrot and pollard-based baits (Batcheler, 1978) and it is known that insects generally are very sensitive to 1080 (Chenoweth, 1949). However, some predominantly insectivorous birds e.g., the rifleman (Gibb, in Harrison, 1978), whitehead (Falla *et al.,* 1975; St Paul, 1976), yellowhead (Child, 1978), grey warbler (Gibb, in Harrison, 1978), tit (Riney *et al.,* 1959), and robin *(St* Paul, 1976), do feed on vegetable matter (and sometimes from the ground) and other insectivorous species might do the same. For example, the fantail has been seen to take insects and grit from the ground (St Paul, 1975) and might also take vegetable matter. Thus, the predominantly insectivorous species might feed on poisoned baits, particularly the small fragments or "chaff", from either the ground or, more probably, up in the leaves and branches. The propensity to take baits is probably increased by poisoning in winter when food, particularly insect life, is likely to be in short supply.

To discover how birds obtain 1080 poison, it will be necessary either to observe birds feeding, or to perform autopsies on the recovered carcasses. The former approach has so far provided little information, e.g., Pracy (1958) found that "Definite interest was shown by robins and wekas, but baits were given only incidental attention by other birds. . . pigeons, parakeets, tuis, bellbirds, fantails, kakas, tomtits, and whiteheads showed little interest irrespective of whether baits were placed in trees or on the ground". However, keas (Douglas, 1967), whiteheads and silvereyes have been seen feeding directly on carrot baits on the ground. Carrot has been identified from the gizzards of introduced blackbirds and chaffinches (Spurr, unpubl.), but the gizzards of poisoned insectivorous birds have usually been empty at autopsy.

Estimation of lethal dose

The second step in identifying species at risk from 1080 poisoning is to establish whether the amount

TABLE 2. *Quantity of carrot bait. containing 0.09% 1080, required to kill various bird species assuming an LD_{50} of 3.0 mg 1080 / kg bird's body weight.*

Name of species	Weight[1] (g)	mg 1080 for LD_{50}	g carrot for LD_{50}
Rifleman	7	.02	.02
Grey warbler	7	.02	.02
Tit	11	.03	.03
Silvereye	12	.04	.04
Whitehead	17	.05	.06
Chaffinch	21	.06	.06
Robin	30	.09	.10
Blackbird	90	.27	.30

Note: 1. Weights from B. M. Fitzgerald *(pers. comm.)* and personal observation.

of poisoned bait likely to be eaten is sufficient for a lethal dose. So far, the lethal dose has been calculated for only one native bird, the weka, the LD_{50} (i.e., the dosage lethal to 50 per cent of a population) of which is 8.1 mg 1080/kg of body weight (McIntosh *et al.,* 1966). This means that, on average, a 1000 g weka will be killed by eating 9 g of carrot containing 0.09% 1080. The introduced house sparrow has an LD_{50} of 3.0 mg/kg (Tucker and Crabtree, 1970). Although acute toxicity is species-spedic, I have used the figure of 3.0 mg/kg to estimate the amount of poisoned carrot bait required to kill some of the small native and introduced passerines recovered from 1080 poisoned areas (Table 2). It is likely that small insectivorous species which possess a high metabolic rate will be more sensitive to 1080 poisoning than are house sparrows, so the amount of bait required to kill some species may be less than that shown in Table 2. Even this is a conservative estimate because the calculations assume an even gradient of toxin uptake, although it is known that relatively small pieces of carrot absorb a higher concentration of 1080 than larger pieces (Staples, 1969). Thus, most of the small insectivorous birds probably require only a tiny fragment of a bait (less than 0.1 g; perhaps one mouthful) to receive a lethal dose of 1080.

The available evidence (i.e., a consideration of the diets, the species of birds killed, and the amount of bait probably required for a lethal dose) indicates that most of our land bird species should be regarded as being at risk of being killed by feeding directly on poisoned baits or secondarily on poisoned prey.

Extent of reduction

The likely extent of any reduction in numbers is difficult to predict. There is some evidence (e.g., Tinbergen, 1960; Pyke, Pulliam and Chamov, 1977) that the selection of food items by birds is affected by the abundance of the items in the environment. With as many as 100 000 carrot baits or bait fragments per hectare (Batcheler, 1978) birds should have sufficient opportunity to find them.

For the purposes of the next two sections of this paper, it is assumed that each bird population has been heavily reduced.

REPRODUCTIVE CAPACITY

Having established that populations of most land bird species may be reduced by poisoning, the next step is to estimate the ability of the populations to recover from a reduction in numbers, either by the reproductive effort of the survivors or by immigration.

A model for the rate of growth (by reproduction) of a population incorporates multiplication of the existing number by an exponential factor known as the "rate of increase" (e^{rt}) thus:

$$N_t=N_{t-1}\, e^{rt} \qquad (1)$$

where Nt represents the number of birds at time t, which for the present purposes is immediately prior to breeding, so that all birds will be adults. The rate of increase of a population is a function of reproduction and survival. Following Knipling and McGuire (1972) expression (1) may be expanded as follows:

$$N_t=N_{t-}1\, e^{st}+0.5\, N_{t-1}\, e^{It} \qquad (2)$$

where e^{St} represents the rate of adult survival and e^{It} represents the rate of recruitment into the adult population in terms of birds recruited per adult female. The essential data required on adult survival and recruitment are not available for most New Zealand species even for stable population densities. The few data that are available indicate that endemic New Zealand species are comparatively long-lived, and therefore probably have correspondingly low reproductive rates. For example, it has been recorded that kiwis are "probably long-lived" (Reid and Williams, 1975), takahe have 85% annual adult survival (Reid, 1967), keas have 63% adult survival (Jackson, 1969), grey warblers have "low" adult mortality (Gill, 1978), robins have 70 to 85%* adult survival (Flack, 1976), saddlebacks have "exceptional longevity" (Jenkins, 1978), and the kokako is "probably a long-lived species" (Crook and Imboden, 1978). By comparison the introduced blackbird has been recorded with 54% adult survival in an urban area (Bull, 1953), and the starling with 51 % adult survival in a rural area (Coleman, 1972), both values being within the range of 40 to 60% recorded for various passerine species in Europe (Lack, 1954).

A stable population (having a zero rate of increase) with 50% adult survival requires to recruit annually 1.0 young per female to the adult population (assuming an equal adult sex ratio), whereas a population with 80% adult survival requires to recruit 0.4 young per female. Most females lay several eggs annually, so that adult recruitment in a stable population is much less than the reproductive output.

The excess reproductive output can increase the population, especially when numbers are below the,

* Flack (1976) recorded an adult survival of 70% fof robins at Kaikoura and 80 to 85% for robins introduced to offshore islands, although the age structure of the different populations was not stated.

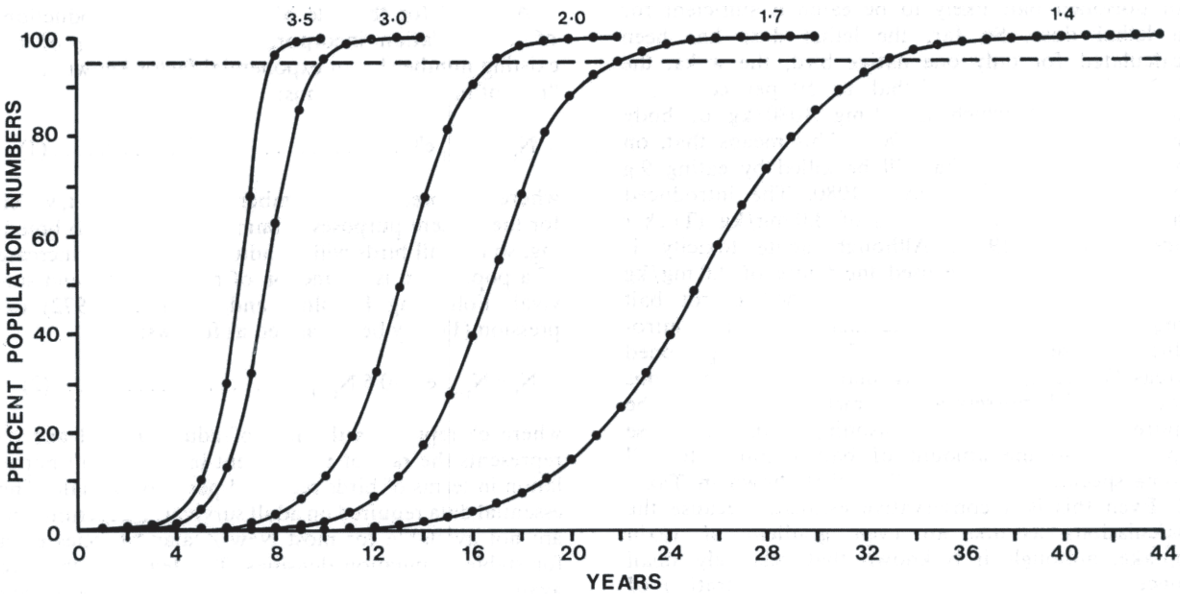

FIGURE 1. *Theoretical population growth curves of birds (calculated from equations* 1 *and* 2). *with the maximum rate of increase indicated beside each curve. The* 95% *population level is indicated by the broken line. A population with a maximum rate of increase of* 3.5, *suffering a* 90% *reduction in numbers, will theoretically take* 3 *years to recover to* 95% *of its former level by its own reproductive effort. If the maximum rate of increase was* 1.7, *the time taken would be* 9 *years.*

carrying capacity of the habitat. However, the rate of increase of birds colonising new areas or recovering from a reduction in numbers has seldom been recorded.

Robins introduced on to islands in the Marlborough Sounds showed as much as 5-fold increase in three years (Flack, 1975; 1976), which translates to a maximum rate of increase of about 1.7 per annum. If annual adult survival was 80% (see above) this rate of increase would be achieved by 1.8 young per female being recruited to the adult population annually. If not all adults bred, adult recruitment would have to be higher than 1.8 per breeding pair.

A rate of increase of 3.5 (or greater) has been recorded for starlings introduced into North America (see Davis, 1950), pheasants introduced on to an island off the west coast of the USA (see Lack, 1954), and the hooded crow in Israel (see Mendelssohn, 1972). This latter species was reduced by a poison campaign against the jackal *(Canis au reus)* to less than 10% of its former level (i.e., a 90% reduction) but responded, through increased breeding success, to have almost reached its former density within 3 years (Mendelssohn, op. cit.). A rate of increase of 3.5 may be achieved by 60% annual survival of adults and about 6 young per pair being recruited to the adult population annually. This is quite within the range of some New Zealand birds (see below).

If the maximum rate of increase is known, it is possible to estimate theoretically the effect of any reduction on bird numbers (Fig. 1). The calculations are only theoretical because, for example, reduced populations risk suffering further reductions from additional causes, such as bad weather (e.g., see Bull and Dawson, 1969), increased predator pressure (e.g., see Flack and Lloyd, 1978) or another poison operation. Nevertheless, the slower the rate of increase the longer is the period for which numbers are reduced, and the longer is the period for which the population is at risk (Fig. 1).

It is not possible, because of a lack of data, to estimate accurately the potential rates of increase of the different species of New Zealand land birds. However, the rate of increase of a population is markedly affected by the reproductive rate, for which data are available. While a low reproductive rate does not necessarily mean an equally low rate of recruitment (e.g., parental care may compensate

TABLE 3. *A classification of the reproductive capacity of New Zealand land bird species based on maximum annual egg production*[1].

Ranges of clutch sizes			
Single-brooded species[2]			
Australasian harrier[3]	2-7		
N.Z. falcon	2-3		
Takahe	1-2		
Kakapo	2-4		
Kaka	4-5		
Kea	2-4		
Morepork	2-3		
Laughing owl	2		
Bush wren	2-3		
Rock wren	2-3		
Yellowhead	3-4		
Stitch bird	3-5		
Kokako	2-3		
Double-brooded species[2]			
3 or fewer eggs/clutch		more than 3 eggs/clutch	
Brown kiwi	1-2	Weka[4]	3-6
Little spotted kiwi	1	Pukeko[4]	4-7
Great spotted kiwi	1-2	Red-crowned parakeet	5-9
N.Z. pigeon	1	Yellow-crowned parakeet	5-9
Fembird	2-3	Orange-fronted parakeet	5-9
Saddleback	2-3	Kingfisher	4-5
N .Z. thrush	2	Rifleman	4-5
		Welcome swallow[4]	3-5
		N.Z. pipit	3-4
		Brown creeper	3-4
		Whitehead	2-4
		Grey warbler	3-6
		Fantail[4]	3-4
		Tit	3-5
		Robin[4,5]	2-4
		Silvereye	3-4
		Bellbird	3-4
		Tui	2-4

Notes:
1. Data from Falla *et al*. (1975), unless otherwise stated.
2. Probably.
3. Commonly 4 eggs.
4. Multiple-brooded.
5. Range 2-4, but mean less than 3 (Flack, 1973).

for low numbers of eggs produced, or susceptibility to introduced predators may reduce an apparently high reproductive rate), birds with a low reproductive rate can never increase their population as quickly as those with a high one. Thus, given that egg production limits the capacity of a species to respond to a reduction in numbers, I have made a comparative classification of each species' reproductive capacity according to its probable maximum egg production (Table 3). The classifycation is divided into three categories: firstly, sing!e-brooded species which (except for the Australasian harrier) produce fewer than 6 eggs annually (most fewer than 4); secondly, double-brooded species which also produce fewer1'Than 6 'eggs annually (again, most fewer than 4); and finally, double- or multiple-brooded species which produce more than 6 eggs annually. 'Species which produce more than 6 eggs annually could theoretically recruit at least 6 young per female to the adult population annually, and could have a quite high rate of increase. However, species that do not produce 6 eggs annually are more limited in their response to any reduction in numbers breeding.

DISPERSAL CAPACTIY

The ability to recover from a population reduction in an area is influenced not only by the reproductive capacity of the survivors but also by the rate of immigration into the area.

Published records of movements of banded birds are insufficient to form a basis for a classification of the dispersal capacity of New Zealand birds. It is, therefore, necessary to assess dispersal capacity from other sources of information, viz.

1. Adaptive physical and ecological features of the birds;
2. Sub-speciation, indicating poor dispersal, between different populations on the mainland (North, South and Stewart Islands);
3. Presence on offshore and outlying islands; and
4 Abundance and distribution of the species on the mainland.

I have looked at each in turn before making a final classification of dispersal capacity.

1. *Adaptive physical and ecological features of New Zealand birds*

The New Zealand land bird fauna is derived mainly from the Australian fauna (Falla, 1953; Bull and Whitaker, 1975). Possible dates of colonisation by their ancestors are shown in Table 4. These ancestors, except perhaps for the ratites (including the kiwis), were presumably good dispersers which arrived by flying (and wind assistance). They have since speciated and sub-speciated to differing degrees on the mainland and on offshore and outlying islands (see sub-sections 2 and 3 below), and in so doing have lost some dispersal ability. Two not unrelated characteristics of the present fauna, both indicating poor dispersal capacity, are the evolutionary trends, in the absence of mammalian predators, towards large size and flightlessness (Williams, 1973; Bull and Whitaker, 1975). These trends are most evident among the more endemic elements of the fauna (Tables 4 and 5). Post-colonisation loss of dispersal ability is often correlated with degree of endemism (MacArthur and Wilson, 1967). Thus, with the exception of the rifleman (but see below), species in endemic orders and families, and several species in endemic genera, are either poor flyers or flightless.

Poor dispersal capacity, however, is not necessarily restricted to poor flyers. Ecological adaptation (or specialisation) to the more stable parts of the environment is another means by which dispersal ability is reduced following colonisation (MacArthur and Wilson, 1967). Thus, it is recognised that species wh:ch inhabit the forest interior are generally poorer dispersers than those of second-growth forest and scrub (e.g., see Diamond, 1970, 1973; MacArthur, Diamond and Karr, 1972). Similarly, ground and forest understorey species are recognised as poorer dispersers than canopy species (Terborgh and Weske, 1969; Terborgh, 1974). This is not because of a physical inability to fly, but may be the result of selection for competitiveness as opposed to dispersal ability (MacArthur and Wilson, 1967; Diamond, 1974). The rifleman, for example, is ecologically restricted to the forest interior, feeding mainly in the understorey and searching especially on .the trunk, rather than the twigs and branches, of trees (Gravatt, 1971). The yellowhead, likewise, is restricted to the interior of unmodified forests, and might be expected to be a poorer disperser than either the closely related whitehead or the brown creeper, both of which enter second-growth forest. Stitchbirds are more reliant on plants for food (fruit and nectar) and occupy a lower forest stratum than bellbirds (Gravatt, 1971). Robins feed more on the ground (Gravatt, 1971) and show a greater avoidance of open spaces than tits (Flack, 1976).

2. *Sub-speciation on the North. South and Stewart Islands*

Sub-speciation on the three main islands of New Zealand is evidence of the inability of a species to disperse across the intervening sea gaps. Foveaux Strait, between Stewart Island and the South Island, is slightly younger (9500 vs 10000 years), shallower, and has more "stepping-stone" islands than Cook Strait (Fleming, 1975a), and may therefore be regarded as less of a barrier to dispersal. The maximum sea gap in Foveaux Strait is about 14 km compared to about 22 km for Cook Strait.

Some species occurring on the South Island have either developed sub-species on Stewart Island or have failed to reach Stewart Island since it was last separated from the South Island (Table 6). Six of these species are flightless. Of the remainder, the bush wren, fern bird and robin have sub-speciated, while the kea, oranged-fronted parakeet, rock wren, yellowhead and New Zealand thrush do not occur on Stewart Island. The bush wren, yellowhead, robin, and New Zealand thrush have, furthermore, not re-colonised Banks Peninsula since they became

TABLE 4. *Possible dates of colonisation by ancestors of some New Zealand land birds*[1].

Upper Cretaceous (over 70 million years ago)	Early Tertiary (up to 70 million years ago)	Late Tertiary (up to 25 million years ago)	Early Pleistocene (up to 2 million years ago)	Recent (up to 20000 years ago)
Species in endemic orders	Species in endemic families	Species in endemic genera	Endemic species	Australian species
Brown kiwi	Rifleman	Weka	N.Z. falcon	A. harrier[4]
L. spotted kiwi	Bush wren	Takahe	Grey warbler	Pukeko[4]
G. spotted kiwi	Rock wren	N.Z. pigeon	Tit	Morepork[3]
	Saddleback	Kakapo	Robin[2]	Kingfisher[3]
	Kokako	Kaka		Welcome swallow[4]
	N.Z. thrush	Kea		N.Z. pipit[3]
		R-c parakeet		Fantail[3]
		Y -c parakeet		Silvereye[4]
		O-f parakeet		
		Laughing owl		
		Fernbird		
		Brown ,Creeper		
		Whitehead		
		Yellowhead		
		Stitchbird		
		Bellbird		
		Tui		

Notes :
1. Data from Fleming (1962a) based on systematic differences which distinguish New Zealand birds from their relatives overseas.
2. Sub-genus *Miro,* of earlier origin than others in this group, possibly late Tertiary (Bull and Whitaker, 1975).
3. Endemic sub-species.
4. Not distinguishable from Australian sub-species.

extinct there about the turn of the century (Turbott, 1969). This whole group may be regarded as the poorest dispersers. The whitehead and stitchbird have been excluded from this group because they do not occur on the South Island and therefore have not had the opportunity to reach Stewart Island, but both occur on Little Barrier Island, which is about 16 km from the nearest land source.

A second group of species have either developed sub-species on both sides of Cook Strait, or have failed to cross the Strait (Table 6). The kaka, saddleback, and kokako have, furthermore, not re-colonised the forest remnants on Banks Peninsula since they became extinct there about the turn of the century (Turbott, 1969). With the exception of the whitehead and stitchbird, all species in this group occur on Stewart Island as the South Island sub-species. This whole group may"be-classified as medium dispersers.

Finally, there is a third group of species which may be regarded as good dispersers, which have not developed sub-species on the North, South, or Stewart Islands. Some of these species, for example the welcome swallow and silvereye, have not been in New Zealand long enough to have sub-speciated, but the very recency of their arrival from Australia (and subsequent dispersal to offshore and outlying islands) indicates that they are still good dispersers. There have been some notable band recoveries for species in this group. The Australasian harrier, for example, has been recorded at localities 966 km apart, on either side of'Cook Strait (Kinsky, 1960). The pukeko (100 km) and silvereye (98 km) are two other species with long-distance band recoveries (Robertson, 1972).

This classification has some limitations because some species may not have dispersed across a sea (or other) gap, not because they are unable to, but because there is no suitable habitat on the other side and! or there is insufficient area to maintain a viable population. This may be one reason why the kaka, saddleback, and kokako have not re-colonised Banks Peninsula. However, other examples are difficult to identify. It is more likely that dispersal

TABLE 5. *A classification of dispersal ability as indicated from physital and ecological adaptations. of New Zealand land birds.*

Poor flight or flightless	Occupy forest interior or understorey	Occupy forest canopy or margins
Brown kiwi	Rifleman	Australasian harrier
Little spotted kiwi	Yellowhead	N.Z. falcon
Great spotted kiwi	Robin	Pukeko
Weka	Stitchbird	N.Z. pigeon
Takahe		Kaka
Kakapo		Kea
Bush wren		Red-crowned parakeet
Rock wren		Yellow-crowned parakeet
Fembird		Orange-fronted parakeet
Saddleback		Morepork
Kokako		Laughing owl
N.Z. thrush		Kingfisher
		Welcome swallow
		N.Z. pipit
		Brown creeper
		Whitehead
		Grey warbler
		Fantail
		Tit
		Silvereye
		Bellbird
		Tui

TABLE 6. *A classification of dispersal capacity of New Zealand land birds judged by the development of separate sub-species on the North Island. South Island. and Stewart Island*[1]

Separate sub-species or not occur on Stewart Island	N. and S. Island sub-species or occur on one island only	No sub-species N. or S. Island or Stewart Island
Brown kiwi[2]	Kakapo[2,3]	Australasian harrier
Little spotted kiwi	Kaka[2]	N.Z. falcon
Great spotted kiwi	Laughing owl[2]	Pukeko
Weka2	Rifleman[2]	N.Z. pigeon
Takahe	Brown creeper	Red-crowned parakeet
Kea	Whitehead[4]	Yellow-crowned parakeet
Orange-fronted parakeet	Fantail[2]	Kingfisher
Bush wren[2]	Tit[2]	Morepork
Rock wren	Stitchbird[4]	Welcome swallow
Fernbird2	Saddleback[2]	N.Z. pipit
Yellowhead	Kokako[2]	Grey warbler
Robin[2]		Silvereye
N.Z. thrush		Bellbird
		Tui

Notes:
1. Data from the Annotated Checklist of the Birds of New Zealand (Kinsky, 1970), unless otherwise stated.
2. Separate sub-species.
3. Sub-species not in Checklist (above) but in Mathews and Iredale (1913).
4. North Island only.

TABLE 7. *Dispersal of land birds from the mainland of New Zealand (North. South. and Stewart Islands) to offshore and outlying islands*[1].

Not offshore islands	Offshore but not outlying	Outlying islands
Brown kiwi[2]	Rifleman	Australasian harrier
Little spotted kiwi[2]	Bush wren[4]	N .Z. falcon
Great spotted kiwi	Brown creeper	Pukeko
Weka[2]	Whitehead	N.Z. pigeon[5]
Takahe	Stitchbird	Kaka[6]
Kakapo[2,3]	Saddleback	Red-crowned parakeet[5]
Kea	Kokako	Yellow-crowned parakeet[5]
Orange-fronted parakeet		Morepork
Rock wren		Laughing owl[6]
Yellowhead		Kingfisher
N.Z. thrush		Welcome swallow
		N.Z. pipit[5]
		Fernbird[5]
		Grey warbler[7]
		Fantail[5]
		Tit[4]
		Robin[7]
		Silvereye
		Bellbird[5]
		Tui[5]

Notes: 1. Offshore islands are within 50 km (Atkinson and Bell. 1973). Reference to birds on offshore islands. too numerous to list individually, are mainly from New Zealand Bird Notes, Notornis, and Tane. Records from outlying islands are mainly from Falla (1965), Falla *et al.* (1975), Kinsky (1970), Lindsay *et al.* (1959), Merton (1970), and Warham (1967).
2. Introduced to offshore islands by Man.
3. Former occurrence on the Chatham Island doubtful (Williams, 1956).
4. Sub-species only.
5. Including sub-species.
6. Fossils only (Chatham Islands).
7. Separate species (Chatham Island warbler and black robin respectively).

is limited by the present abundance and distribution of a species (see sub-section 4, below).

3. *Presence on offshore and outlying islands*

The islands around New Zealand may be divided into those that have had geologically Recent land-bridge connections with the mainland and those that have been isolated at least since the Pliocene. This distinction corresponds with the classification by Atkinson and Bell (1973) into offshore (within 50 km) and outlying islands (more than 50 km away).

The presence (or absence) of birds on these islands gives a measure of dispersal capacity independent of sub-speciation. Caution is required, however, because presence, on offshore islands particularly, may reflect relict populations from land-bridge times rather than dispersal. Also, absence from islands may reflect a lack of survival there rather than a lack of dispersal. Nevertheless, current absence from islands may be taken as indicative of present inability to disperse there.

Of the good dispersers in Table 6 (i.e., those that have not sub-speciated) none has failed to reach at least one outlying island (Table 7). The most distant island group (the Antipodes, at about 700 km from the New Zealand mainland) has been colonised by two species (parakeets, which are assumed to have invaded twice, resulting in a separate species and a sub-species of the red-crowned parakeet, and the New Zealand pipit). Parakeets are regarded as excellent trans-oceanic colonists (Mayr, 1972). The Bounty Islands (about 600 km distance) are devoid of forest and are not occupied by land birds (Falla, 1965; Atkinson and Bell, 1973). On Campbell Island (nearly 550 km away) the Australasian harrier, silvereye, and tui as well as the N.Z. pipit have been

TABLE 8. *A classification of the abundance and distribution of New Zealand land birds on the mainland (North. South. and Stewart Islands)*[1].

Rare	Patchy	Common[2]
Little spotted kiwi	Brown kiwi	Australasian harrier
Takahe	Great spotted kiwi[3]	Pukeko
Kakapo	N.Z. falcon'	N.Z. pigeon
Orange-fronted parakeet	Weka	Morepork
Laughing owl	Kaka	Kingfisher
Bush wren	Kea	Rifleman
Rock wren	Red-crowned parakeetS	Welcome swallow
Stitchbird	Yellow-crowned parakeet	N.Z. pipit
Saddleback	Fembird	Grey warbler
Kokako	Brown creeper	Fantail
N.Z. thrush	Whitehead	Tit
	Yellowhead	Silvereye
	Robin	Bellbird
		Tui

Notes :
1. Data from "Bird Distribution in New Zealand" (Bull *et al*. 1978).
2. Presence on 10000 yard squares; rare, fewer than 50 squares; patchy, 50-500 squares; common, over 500 squares.
3. Assuming unidentified South Island kiwis are either Great Spotted or Brown depending on known distribution.
4. More common than generally known (Fox, 978).
5. Assuming unidentified observations are in the same proportion as positive identifications of red-crowned and yellow-crowned parakeets.

recorded. The Auckland Islands (at about 300 km) have, in addition to all the above, the N.Z. falcon, yellow-crowned parakeet, welcome swallow, tit, and bellbird. These species all have good dispersal capacity.

Some species (e.g., the fembird and robin) which have either speciated or sub-speciated several times, indicating poor dispersal, nevertheless occur on outlying islands. Perhaps their dispersal capacity in the past (in their colonisation phase) was better than now; certainly conditions for dispersal were formerly better than now (Heming, 1962b; p. 105). Alternatively, dispersal may have been assisted by wind, independently of flying ability, as suggested by Williams (1953) for the dispersal of introduced passerines, including some distinctly sedentary ones, from the New Zealand mainland to its outlying islands.

4. *A bundance and distribution of birds on the mainland*

Despite the evidence from sub- speciation and island distribution, the present dispersal capacity of a species (or its ability to re-colonise an area) is probably most affected by its present distribution and abundance on .the mainland (North, South and Stewart Islands). This particularly affects re-colonisation of isolated tracts of forest that are now a feature of our landscape (see also Diamond, 1975; Fleming, 1975b). A small isolated population (e.g., of robins at Kaikoura), if lost, may not be replaced because there are no others of the species within dispersal range.

The data for this section come from the provisional atlas of "Bird Distribution in New Zealand" (Bull, Gaze and Robertson, 1978) which gives the distribution and number of 10 000 yard (9144 metre) squares occupied by each species. For con. venience, I have divided species (in Table 8) into rare (occupying fewer than 50 squares), patchy (occupying 50-500 squares), and common (occupying more than 500 squares). Of the rare species, only the kokako is sufficiently common to be presented in the map section of the atlas. Rare species all have a very local distribution, occurring in only one or a few widely separated localities. Some species (e.g., the laughing owl and N.Z. thrush) are so rare as to be possibly extinct. Species with a patchy distribution generally have areas of apparently suitable habitat unoccupied.

This classification is not without problems. For example, the kea and brown creeper could be classified as common if their distribution is limited to the South Island. Furthermore, the atlas is only provisional and relative abundance may change as more records become available. Thus, the N.Z. falcon is classified from the provisional atlas as patchy, but according to Fox (1978) it is more common than generally known. It might well appear as a common species in the final distribution atlas.

TABLE 9. *A classification of dispersal capacity of New Zealand land birds based on evidence in Tables* 4-8.

Poor dispersal	Good dispersal
Brown kiwi	Australasian harrier
Little spotted kiwi	N.Z. falcon
Great spotted kiwi	Pukeko
Weka	N .Z. pigeon
Takahe	Kingfisher
Kakapo	Morepork
Kaka	Welcome swallow
Kea	N.Z. pipit
Red-crowned parakeet	Grey warbler
Yellow-crowned parakeet	Fantail
Orange-fronted parakeet	Tit
Laughing owl	Silvereyo
Rifleman	Bellbird
Bush wren	Tui
Rock wren	
Fernbird	
Brown creeper	
Whitehead	
Yellowhead	
Robin	
Stitchbird	
Saddleback	
Kokako	
N.Z. thrush	

5. *A classification of dispersal capacity*

From the evidence in the previous sections, some species are clearly poor dispersers, some good dispersers (Table 9). However, there are some borderline species.

Red-crowned and yellow-crowned parakeets, for example, seem well adapted for dispersal, and have a wide distribution on outlying islands. Although they have speciated and sub-speciated on these islands, they have not done so on the mainland (North, South, and Stewart Islands). They are reported to have spread over parts of the country in large flocks in the 1800s (Harrison, 1970; Falla *et al.*, 1975). This, however, was when their habitat was more extensive. Their dispersal ability since seems to have decreased, as their numbers have been reduced. For example, .they have not re-colonised the forest remnants on Banks Peninsula since they were exterminated there about the turn of the century (Turbott, 1969). Their patchy distribution means that the prospect of their re--colonising an area is not good, and they have been classified in Table 9 as having a poor dispersal capacity.

The rifleman is restricted ecologically to .the forest interior, has sub-speciated on the North and South Islands, and has not reached outlying islands. It must be classified as having a poor dispersal capacity

TABLE 10. *A classification of the species at risk of non-recovery if reduced in numbers. for example by 1080 poisoning for possum control.*

High risk	Medium risk	Low risk
Brown kiwi	N .Z. falcon[1]	Australasian harrier
Little spotted kiwi	Weka[2]	Pukeko
Great spotted kiwi	N.Z. pigeon[1]	Kingfisher
Takahe	Red-crowned parakeet[2]	Welcome swallow
Kakapo	Yellow-crowned parakeet[2]	N.Z. pipit
Kaka	Orange-fronted parakeet[2]	Grey warbler
Kea	Morepork[1]	Fantail
Laughing owl	Rifleman[2]	Tit
Bush wren	Brown creeper[2]	Silvereye
Rock wren	Whitehead[2]	Bellbird
Fernbird	Robin[2]	Tui
Yellowhead		
Stitch bird		
Saddleback		
Kokako		
N .Z. thrush		

Notes: 1. Poor reproductive capacity.
2. Poor dispersal capacity.

(although not as poor as the bush wren or rock wren), despite its relatively common abundance.

The brown creeper and whitehead do not appear to be restricted from dispersing, either physically or ecologically. However, they have not crossed Cook Strait, nor have they dispersed to outlying islands. They have a patchy distribution, and must be classified as poor dispersers (although not as poor as the yellowhead).

RISK OF NON-RECOVERY FROM A REDUCTION IN NUMBERS

In this section the information on reproductive and dispersal capacities is brought together in an attempt to classify species according to their ability, or more correctly, their inability to recover from a heavy reduction in numbers.

I have recognised three arbitrary categories of the risk of non-recovery (Table 10). Species in the high risk category have both poor reproductive capacity and poor dispersal capacity. Eight of the species in this category, the takahe, kakapo, laughing owl, bush wren, stitchbird, saddleback, kokako, and N.Z. thrush, appear in the Red Data Book of the International Union for Conservation of Nature and Natural Resources (Vincent, 1971), and also in Fisher, Simon and Vincent (1969), where they are classified either as rare or endangered species. If populations of these species were reduced their chances of recovery would be very low. To these I have added the three kiwi species, the kaka, kea, rock wren, fernbird and yellowhead.

Species in the medium risk category have either poor reproductive capacity or poor dispersal capacity. One species, the orange-fronted parakeet, is included in the Red Data Book (Vincent, 1971) as a rare species, although its exact status is inadequately known (see also Harrison, 1970). All three parakeet species have been classified as having a good reproductive capacity, although nothing is really known about their reproduction. Although the parakeets may produce an abundance of eggs, their reproductive capacity may be reduced by some aspect of their behaviour or ecology which makes them, for example, particularly susceptible to predation by introduced mammals. Thus, the red-crowned parakeet, which feeds more on the ground, is now rarer than the yellow-crowned parakeet. It is possible, in terms of recruitment to the adult population, that all three parakeets have a poor reproductive capacity, added to their poor dispersal capacity, and therefore should all be classified in the high risk category.

The weka, flightless like the three species of kiwi, has poor dispersal but unlike the kiwis has a good reproductive capacity (having multiple broods of 3-6 eggs). The rifleman, brown creeper, whitehead and robin also have a poor dispersal but a good reproductive capacity. The N .Z. falcon, N .Z. pigeon, and morepork, although good dispersers, have a poor reproductive capacity.

The susceptibility of birds in the medium risk category may be illustrated by the recent history of the N .Z. pigeon. This species decreased during the period of early European settlement (as did many other species); probably the most important factor contributing to restoration of numbers has been a total protection from shooting since 1921 (Falla *et al.,* 1975). The inability of the N.Z. pigeon to withstand shooting pressure would seem to be, at least partly, a result of its poor reproductive capacity. I predict, for the same reason, that it would be slow to recover from any reductions caused by 1080 poisoning.

Species in the low risk category have both good reproductive and good dispersal capacities.

It should be stressed that this classification is still provisional. I have not yet devised a system of weighting different factors. For example, the orange-fronted parakeet is classified in the medium risk category, although it appears in the Red Data Book of Vincent (1971). Perhaps the rarity of the species should out-weigh other factors (such as its potentially good reproductive capacity) so that it should be classified as a high risk species.

RELEVANCE TO MANAGEMENT

Having identified species at risk, the next step is to use this information in management practice, particularly in view of recent (although in some cases abandoned) proposals to control wild animals in areas containing some of these species; e.g., the proposed possum control operations in kokako habitats in Rotoehu and Horohoro State Forests and in the little spotted kiwi habitats in the Arahura River valley in Westland (S. E. Fokerd, N.Z. Forest Service, *pers. comm.),* and the proposed red deer *(Cervus elaphus)* control in takahe habitats in Fiordland National Park (Cuddihy and Stanley, 1978; Miers, 1978; Parkes, Tustin and Staniey, 1978). It is not argued that a pest species should not be controlled if it is directly or indirectly affecting the species at risk (see also Anon, 1969; Nelson, 1958; Kean and Pracy, 1949), but rather that control must be applied with caution.

It is wise management, before an area is poisoned, to check for the presence of high risk species. If such species are present (and this will be only in certain areas) then special management is necessary; e.g., special care should be taken in the placement of baits, which may need to be applied by hand rather than indiscriminately from the air. For deer control in takahe habitats, it is proposed to use cut-vegetation poisoning on species inaccessible to takahe. In other operations, it may be necessary to use bait stations and I or pest-specific lures. In some situations, baits could be laid after dark and removed before dawn, as was done recently in the Wainuiomata River valley (A. H. Leigh, N.Z. Forest Service, *pers. comm.).* Finally, control may have to be postponed or abandoned (as was the proposed poisoning in kokako habitats) until the risks have been fully evaluated and methods of overcoming them have been found.

This proposed system of management is being increasingly used in resource management overseas. In the southern USA, for example, the Forest Service uses what is known as the featured species system (Gould, 1977) in which a wildlife species (or a group of species) is selected as the prime objective of management: e.g., if an endangered bird species occurs in an area, it should be the featured species, and in most instances should be the only objective of management (see also Webb, 1977). Management practice, whether it be logging or pest controi, should aim to enhance the survival of featured species.

CONCLUDING REMARKS

The accuracy of the theoretical predictions in this paper will be determined only when field assessments have been completed. For some species, e.g., the parakeets, the information available in the literature is unclear. They have potentially good reproductive and dispersal capacities but they are not common, and their ability to recover from a reduction in numbers is not easily predicted. More data are needed on their behaviour and breeding biology under present environmental conditions.

Other species in the medium risk category might also be re-classified when more evidence is available. For example, the robin might be re-classified as a high risk species if it proves to be highly susceptible to feeding on baits. Because of its patchy distribution and poor dispersal, any population eliminated may not be replaced. On the other hand, the N.Z. falcon might be re-classified as a low risk species.

It is clear from the available evidence that species with good reproductive and good dispersal capacities have the ability to recover from even a large reduction in numbers. It is equally clear that species with both poor reproductive and poor dispersal capacities have only a limited ability to recover. Such species may be re-classified if field evidence shows, for example, that they do not eat baits, or that the numbers killed are an insignificant proportion of the population. However, many of these species are vegetarian, and might be expected to feed on baits intended for control of wild animals. Many are also rare or have a very restricted distribution, and should certainly be a featured species in any system of management.

ACKNOWLEDGEMENTS

I wish to thank Dr B. M. Fitzgerald, Ecology Division, DSIR, for making available to me unpublished figures on body weights of birds, and Dr C. N. Challies and Dr J. D. Coleman for commenting on the manuscript. Bird carcasses were analysed for 1080 content at the Animal Health Reference Laboratory, Ministry of Agriculture and Fisheries, Wallaceville.

REFERENCES

ANON, 1969. Opossum damage to bush and birds is appalling. *Forest and Bird* 173: 3-5.

ANON, 1978. Tests find 1080 killed kaka. *The Press, Christchurch,* 16 *February* 1978, p. 20.

ATKINSON, I. A. E.; BELL, B. D. 1973. Offshore and outlying islands. *In:* Williams, G. R. (Editor) *The Natural History of New Zealand*. pp. 372-92. A. H. and A. W. Reed, Wellington. 434 pp.

BATCHELER, C. L. 1978. Compound 1080, its properties, effectiveness, dangers, and use. *Report to Minister of Forests and Minister of Agriculture and Fisheries. New Zealand Forest Service and Ministry of Agriculture and Fisheries, Wellington.* 68 pp.

BULL, P. C. 1953. Observations on a marked population of blackbirds at Lower Hutt. *Notornis* 5: 149-56.

BULL, P. C. 1959. Stomach contents of a North Island Kiwi *(Apteryx australis mantelli)* from the Raetihi district. *Notornis* 8: 143-5.

BULL, P. C.; DAWSON, D. G. 1969. Mortality and survival of birds during an unseasonable snowstorm in South Canterbury, November 1967. *Notornis* 16: 172-9.

BULL, P. C.; WHITAKER, A. H. 1975. The amphibians, reptiles, birds and mammals. *In:* Kuschel, G. (Editor) *Biogeography and Ecology* in *New Zealand*. pp. 231-76. Junk, The Hague.

BULL, P. C.; GAZE, P. D.; ROBERTSON, C. J. R. 1978. *Bird Distribution in New Zealand. A provisional atlas* 1969-1976. Ornithological Society of New Zealand Inc. Wellington. 254 pp.

CHENOWETH, M. B. 1949. Monofluoroacetate acid and related compounds. *Pharmacological Reviews* 1: 383-424.

CHILD, P. 1978. Yellowhead not entirely insectivorous. *Notornis* 25: 352-3.

COLEMAN, J. D. 1972 (Unpublished). *The Feeding Ecology, Productivity and Management of Starlings in Canterbury, New Zealand.* Ph.D. Thesis, University of Canterbury.

CROOK, I.; IMBODEN, C. 1978. The Kokako. *Forest and Bird* 208: 13-16.

CUDDIHY, M. J.; STANLEY, L. M. 1978. The role and effectiveness of ground shooting and the impact of helicopter hunting in the Murchison Mountains. *In: Proceedings of the Seminar on the Takahe and its Habitat 1978*. pp. 174-86. FiordIand National Park Board, Invercargill.

AVIS, D. E. 1950. The growth of starling, *Sturnus vulgaris,* populations. *Auk* 67: 460-5.

DIAMOND, J. M. 1970. Ecological consequences of island colonisation by southwest Pacific birds, I. Types of niche shifts. *Proceedings of the National Academy of Sciences* 67: 529-36.

DIAMOND, J. M. 1973. Distributional ecology of New Guinea birds. *Science* 179: 759-69.

DIAMOND, J. M. 1974. Colonisation of exploded volcanic islands by birds: the supertramp strategy *Science* 184: 803-6.

DIAMOND, J. M. 1975. The island dilemma: lessons of modem biogeographic studies for the design of natural reserves. *Biological Conservation* 7: 129-46.

DOUGLAS, M. H. 1967. Control of thar *(Hemitragus jemlahicus):* evaluation of a poisoning technique. *New Zealand Journal of Science* 10: 511-26.

FALLA, R. A. 1953. The Australian element in the avifauna of New Zealand. *Emu* 53: 36-46.

FALLA, R. A. 1965. Birds and mammals of the subantarctic islands. *Proceedings of the New Zealand Ecological Society* 12: 63-8.

FALLA, R. A.; SIBSON, R. B.; TURBOTT, E. G. 1975. *A Field Guide to the Birds of New Zealand and Outlying Islands*. Collins, London. 256 pp

FISHER, J.; SIMON, N.; VINCENT, J. 1969. *The Red Book.Wildlife in Danger*. Collins, London. 368 pp.

FLACK, J. A. D. 1973. Robin research-a progress report. *Wildlife-a Review* 4: 28-36.

FLACK, J. A. D. 1975. The Chatham Island Black Robin, extinction or survival? *Bulletin of the International Council for Bird Preservation* 12: 146-50.

FLACK, J. A. D. 1976. New Zealand robins. *Wildlife-a Review* 7: 15-19.

FLACK, J. A. D.; LLOYD, B. D. 1978. The effect of rodents on the breeding success of the South Island robin. *In:* Dingwall, P. R.; Atkinson, I. A. E.; Hay, C. (Editors). *The Ecology and Control of Rodents in New Zealand Nature Reserves*. pp. 59-66. Department of Lands and Survey Information Series No.4. 237 pp.

FLEMING, C. A. 1962a. History of the New Zealand land bird fauna. *Notornis* 9: 270-4.

FLEMING, C. A. 1962b. New Zealand biogeography. A paleontologist's approach. *Tuatara* 10: 53-108.

FLEMING, C. A. 1974. The coming of the birds. *New Zealand Nature Heritage* 1: 61-8.

FLEMING, C. A. 1975a. Geological history of New Zealand and its biota. *In:* Kuschel, G. (Editor) *Biogeography and Ecology in New Zealand*. pp. 1-86. Junk, The Hague.

FLEMING, C. A. 1975b. Scientific planning of reserves. *Forest and Bird* 196: 15-18.

FOX, N. C. 1978. The distribution and numbers of New Zealand falcons. *Notornis* 25: 317-31.

GILL, B. J. 1978. Breeding of the Grey Warbler. *Notornis* 25: 244-5.

GOULD, N. E. 1977. Featured species planning for wildlife on southern national forests. *Transactions of the North American Wildlife and Natural Resources Conference*. 42: 435-7.

GRAVATT, D. J. 1971. Aspects of habitat use by New Zealand Honeyeaters, with reference to other forest species. *Emu* 71: 65-72.

HARRIS, G. 1977. Report on the use of sodium ftuoroacetate (1080). *Report for the Minister of Lands. Nature Conservation Council. Wellington*. 24 pp.

HARRISON, M. 1970. The Orange-fronted Parakeet *(Cyanoramphus malherbi)*. *Notornis* 17: 115-25.

HARRISON, M. 1978. The use of poisons and their effect on bird-life. *In: Proceedings of the Seminar on the Takahe and its Habitat 1978*. pp. 103-21. Fiordland National Park Board, Invercargill.

JACKSON, J. R. 1969. What do keas die of? *Notornis* 16: 33-44.

JENKINS, P. F. 1978. Cultural transmission of song patterns and dialect development in a free-living bird population. *A nimal Behaviour* 26: 50-78.

KEAN, R. I.; PRACY, L. 1949. Effects of the Australian opossum *(Trichosurus vulpecula* Kerr) on indigenous vegetation in New Zealand. *Proceedings of the Seventh Pacific Science Congress, Vol*. 4 *(Zoology),* 7(4): 696-705.

KINSKY, F. C. (Compiler) 1960. *10th Annual Report of the Banding Committee, Ornithological Society of New Zealand, Inc. for the Year Ending 31 March 1960*. Dominion Museum, Wellington. 42 pp.

KINSKY, F. C. 1970. *Annotated Checklist of the Birds of New Zealand including the Birds of the Ross Dependency*. A. H. and A. W. Reed, Wellington. 96 pp.

KNIPLING, E. F.; McGUIRE, J. U. 1972. Potential role of sterilisation for suppressing rat populations. A theoretical appraisal. *United States Department of Agriculture. Agricultural Research Service, Technical Bulletin* No. 1455. 27 pp.

LACK, D. 1954. *The Natural Regulation of Animal Numbers*. Clarendon Press, Oxford. 343 pp.

LINDSAY, C. J.; PHILLIPPS, W. J.; WATTERS, W. A 1959.Birds of Chatham Island and Pitt Island. *Notornis* 8: 99-106.

MAcARTHUR, R. H.; WILSON, E. O. 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, N.J. 203 pp.

MACARTHUR, R. H.; DIAMOND, J. M.; KARR, J. R. 1972. Density compensation in island faunas. *Ecology* 53: 330-42.

McINTOSH, I. G.; BELL, J.; POOLE, W. G. H.; STAPLES, E. L. J. 1966. The toxicity of monoftuoroacetate (1080) to the North Island web *(Gallirallus* *australis greyi). New Zealand Journal of Science* 9: 125-8.

MATHEWS, G. M.; IREDALE, T. 1913. A reference list of the birds of New Zealand. *Ibis* 55: 201-63, 402-52.

MAYR, E. 1972. Continental drift and the history of the Australian bird fauna. *Emu* 71: 26-8.

MENDELSSOHN, H. 1972. The impact of pesticides on bird life in Israel. *Bulletin of the International Council for Bird Preservation* 11: 75-104.

MERTON, D. V. 1970. Kermadec Islands expedition reports: a general account of birdlife. *Notornis* 17: 147-99.

MERTON, D. V. 1975. Success in re-establishing a threatened species: The Saddleback-its status and conservation. *Bulletin of the International Council for Bird Preservation* 12: 150-8.

MIERs, K. H. 1978. The possible role of 1080. *In: Proceedings of the Seminar on the Takahe and its Habitat 1978*. pp. 200-02. Fiordland National Park Board, Invercargill.

MILLS, J. A. 1973. Some observations on the effects of field applications of fdnsulfothion and parathion on bird and mammal populations. *Proceedings of the New Zealand Ecological Society* 20: 65-71.

NELSON, R. C. 1958. The deer problem. *In: Proceedings of the meeting to discuss the noxious animal problem in New Zealand*. pp. 23-7. New Zealand Forest Service, Wellington.

PARKES, J.; TuSTIN, K.; STANLEY, L. 1978. The history and control of red deer in the takahe area, Murchison Mountains, Fiordland National Park. *New Zealand Journal of Ecology* I: 145-52.

PRACY, L. T. 1958 (Unpublished). Baiting trials in relation to birds. *New Zealand Forest Service Internal Report*.

PYKE, G. H.; PULLiAM, H. R.; CHARNOV, E. L. 1977. Optimal foraging: a selective review of theory and tests. *Quarterly Review of Biology* 52: 137-54.

REID, B. 1967. Some features of recent research on the Takahe *(Notornis mantelli)*. *Proceedings of the New Zealand Ecological Society* 14: 79-87.

REID, B. E. 1978. The little spotted kiwi-a hunted and destroyed species. *Forest and Bird* 210: 29-32.

REID, B.; WILLIAMS, G. R. 1975. The Kiwi. *In:* Kuschel, G. (Editor) *Biogeography and Ecology in New Zealand*. pp. 301-30. Junk, The Hague.

RINEY, T.; WATSON, J. S.; 'BASSEIT, C.; TURBOIT, E. G.; HOWARD, W. E. 1959. Lake Monk expedition. An ecological study in southern Fiordland. *NewZealand Department of Scientific and Industrial Research Bulletin* 135. 75 pp.

ROBERTSON, C. J. R. 1972. Preliminary report of bird banding in New Zealand 1964-1971. *Notornis* 19: 61-73.

ST PAUL, R. 1975. A bushman's seventeen years of noting birds. Part B-New Zealand Pipit, Grey Warbler, North Island Fantail, and Silvereye. *Notornis* 22: 273-82.

ST PAUL, R. 1976. A bushman's seventeen years of noting birds. Part C-North Island Rifleman, Whitehead, Pied Tit and North Island Robin. *Notornis* 23: 220-32.

STAPLES, E. J. L. 1969. Absorption of sodium monofluoroacetate ("1080") solution by carrot baits. *New Zealand Journal of Agricultural Research* 12: 783-8.

TERBORGH, J. 1974. Preservation of natural diversity: the problem of extinction of prone species. *Bio Science* 24: 715-22.

TERBORGH, J.; WESKE, J. S. 1969. Colonisation of secondary habitats by Peruvian birds. *Ecology* 50: 765-82.

TINBERGEN, L. 1960. The natural control of insects in pine woods. I. Factors influencing the intensity of predation by songbirds. *Archives Neerlandaises de Zoologie* 13: 265-336.

TUCKER, R. K.; CRABTREE, D. G. 1970. Handbook of Toxicity of Pesticides to Wildlife. *United States Department of the Interior, Bureau of Sport Fisheries and Wildlife, Resource Publication* No. 84. 131 pp.

TURBOIT, E. G. 1969. Native birds. *In:* Knox, G. A. (Editor). *The Natural History of Canterbury*. pp. 426-34. A. H. and A. W. Reed, Wellington, 620 pp.

VINCENT, J. (Compiler) 1971. *Red Data Book. Volume 2-Aves*. International Union for Conservation of Nature and Natural Resources.

WARHAM, J. 1967. Snares Island birds. *Notornis* 14: 122-39.

WEBB, W. L. 1977. Songbird management in a northern hardwood forest. *Transactions of the North American Wildlife and Natural Resources Conference* 42: 438-48.

WILLIAMS, G. R. 1953. The dispersal from New Zealand and Australia of some introduced European passerines. *Ibis* 95: 676-92.

WILLIAMS, G. R. 1956. The Kakapo *(Strigops habroptilus,* Gray). A review and reappraisal of a near-extinct species. *Notornis* 7: 29-56.

WILLIAMS, G. R. 1973. Birds. *In:* Williams, G. R. (Editor) *The Natural History of New Zealand*. pp. 304-33. A. H. and A. W. Reed, Wellington, 434 pp.

APPENDIX 1

SCIENTIFIC NAMES OF BIRDS MENTIONED IN TEXT

(a) *Endemic species*

Common name	Scientific name
Brown kiwi	*Apteryx australis,*
Little spotted kiwi	*Apteryx oweni*
Great spotted kiwi	*Apteryx haasti.*
Australasian harrier	*Circus approximans gouldi*
N .Z. .falcon	*Falco novaeseelandiae*
Weka	*Gallirallus australis*
Pukeko	*Porphyrio porphyio melanotus*
Takahe	*Notornis mantelli*
Southern black-backed gull	*Larus dominicanus*
N.Z. pigeon	*Hemjphaga novaeseelandiae*
Kakapo	*Strigops habroptilus*
Kaka	*Nestor meridionalis*
Kea	*Nestor notabilis*
Red.crowned parakeet	*Cyanoramphus novaezelandiae*
Yellow-crowned, parakeet	*Cyanoramphus auriceps*
Orange-fronted parakeet	*Cyanoramphus malherbi*
Shining cuckoo	*Chalcites lucidus*
Long-tailed cuckoo	*Eudynamis taitensis*
Morepork	*Ninox novaeseelandiae*
Laughing owl	*Sceloglaux albifacies*
King fisher	*Halcyon sancta vagans*
Rifleman.	*Acanthisita chloris*
Bush wren	*Xenicus longipes*
Rock wren	*Xenicus gilviventris*
Welcome swallow	*Hirundo tahitica neoxena*
N .Z. pipit	*Anthus novaeseelandiae*
Fernbird	*Bowdleria punctata*
Brown, creeper.	*Finschia novadeelandiae*
Whitehead ..	*Mohoua albicilla*
Yellowhead	*Mohoua ochrocephala*
Grey warbler	*Gerygone igata igata*
Fantail	*Rhipidura fuliginosa .*
Tit	*Petroica macrocephala*
Robin	*Petraica (Miro) australis*
Silvereye	*Zosterops lateralis lateralis*
Stitch bird	*Notiomystis cincta*
Bellbird	*Anthornis melanura*
Tui ..	*Prosthemadera novaeseelandiae*
Saddleback	*Phifesiurnus carunculatus*
Kokako	*Callaeas cinera*
N .Z. thrush	*Turnagra capensis*

APPENDIX 1 *(continued)*

(b) *Other species*

Chukor	*Alectoris chukar*
Californian quail	*Lophortyx californica*
Pheasant	*Phasianus colchicus*
Hedge sparrow	*Prunella modularis*
Song thrush	*Turdus philomelos*
Blackbird	*Turdus merula*
Yellow hammer	*Emberiza citrinella*
Chaffinch	*Fringilla coelebs*
Goldfinch	*Carduelis carduelis*
Redpoll	*Acanthis flammea*
House sparrow	*Passer domesticus*
Starling	*Sturnus vulgaris*
White-backed magpie	*Gymnorhina tibicen hypoleuca*
Hooded crow	*Corvus corone*