The Value of New Zealand Islands as Biological Reservoirs

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Abstract

New Zealand's islands function as biological reservoirs for native plants, animals, communities and habitats. They also contain parts of larger marine ecosystems in which ecological and evolutionary processes can be studied or monitored. About 6% of New Zealand's native vascular plant species are confined to islands. Some groups of invertebrates, for example flightless weevils and giant wetas (wingless crickets), have become partly or wholly confined to islands. About 25% of the country's native frogs and reptiles are also confined to islands as are about 50% of the species and subspecies of breeding birds. Most types of mainland communities and habitats are under-represented or absent on islands. Communities restricted to islands include those strongly influenced by seabirds or seals or by salt, those on oceanic islands that are dominated by endemic plants and animals, and some in a pristine condition. Management to maintain or increase the biological values of islands is discussed. In situ management of endemic plants and animals, limiting factors that restrict the suitability of islands for endangered species, and the problem of genetic bottlenecks that arise when founder populations of endangered species are translocated to an island are considered. In addition to continuing effort to prevent alien mammals, particularly rats, from reaching further islands, there is need for the biological restoration of large islands, including some that are inhabited, to increase opportunities for conserving species as evolving populations.

INTRODUCTION

As man continues to modify or destroy an ever-increasing area of the world's natural vegetation and the wildlife it supports, greater attention is being focused on islands as places where at least a fraction of the world's biota and natural communities can be more effectively protected than elsewhere. From this viewpoint the value of New Zealand's islands does not differ from those of Australia or many other parts of the world. This contribution reviews the extent to which the New Zealand islands (excluding the North and South Islands) have functioned as biological reservoirs and considers some of the management problems encountered in trying to maintain or increase their biological value.

New Zealand's islands are dispersed over 22° of latitude and more than 2 500 km of distance. They range in size from tiny stacks of less than a hectare up to the 172 000 ha of Stewart Island; they are frequently rugged and several hundred metres high. It is necessary to distinguish the outlying or oceanic islands (>50 km from mainland coast), which have never been connected to the New Zealand mainland, from the offshore or continental-shelf islands.

The oceanic islands occur in eight separate groups (Fig. 1). Those with subtropical or warm temperate climates are the recent and active volcanoes of the Kermadec group 1 000 km north-east of Auckland, the volcanic remnants of the Three Kings group 56 km north-west of North Cape, and the Chatham group 700 km south-east of the North Island. The remaining five island groups experience a cool temperate to subantarctic climate and are mainly volcanic in origin. With distances and directions from Stewart Island, they are: the Snares Islands (100 km °SW), Auckland Islands (300 km °S), Campbell Islands (530 km °SE), Antipodes Islands (790 km °E) and the Bounty Islands (790 km °ESE).

The continental-shelf islands are concentrated in four main regions. The northern group extends along the north-east coastline of the North Island from North Cape to East Cape (Figs. 1, 2). The majority are volcanic with one, White Island, still active. This group of islands was heavily modified during Maori occupation between 1 000 and 1 800 A.D.

The Cook Strait-Marlborough Sounds islands (Fig. 3) in the central part of New Zealand, largely of sedimentary rocks, have been separated from the mainland by rises in sea level. Many of these islands were also modified during Maori occupation.

The islands of Fiordland in the south-west of the South Island (Fig. 1) are composed mainly of metamorphic rocks. Modification by the Maori is

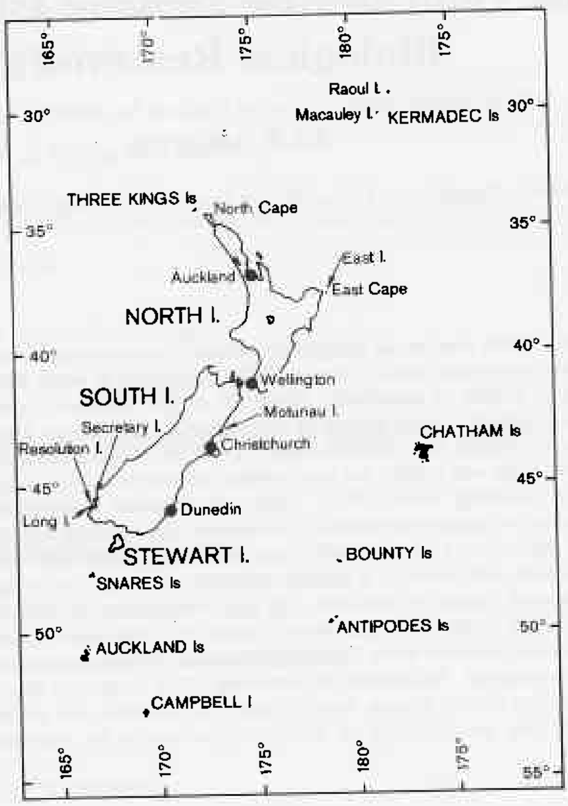

Figure 1
New Zealand and its oceanic islands (islands of Fiordland in lower case lettering)

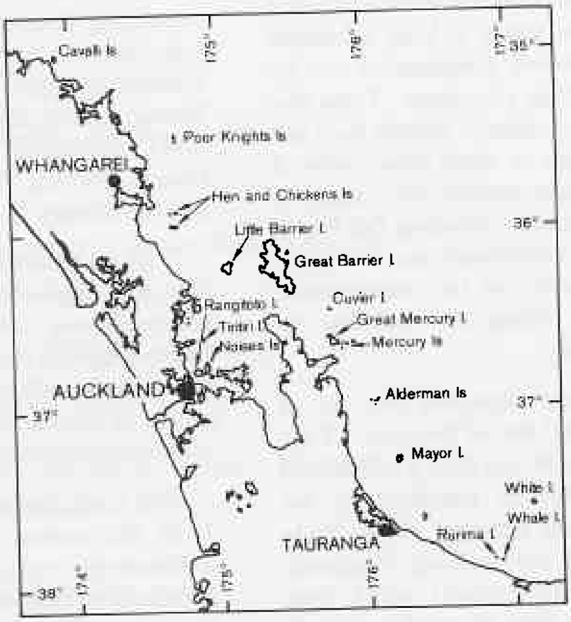

Figure 2
The northern islands

Figure 3
The Cook Strait-Marlborough Sounds islands.

Figure 4
The southern islands surrounding Stewart Island.

seldom evident. Biologically this island group is less well known than others.

The southern or Stewart Island group include islands of Foveaux Strait and Stewart Island (Fig. 4). Gneisses and granites predominate, both rocks that are very resistant to marine erosion. Although frequently visited by the Maori for birding and other food gathering, few of these islands were permanently occupied and hence modification of their vegetation was much less than in the islands further north.

Maori occupation of islands had largely ceased by 1840 but some islands were then occupied and farmed by Europeans (Table 1). The earliest island reserves in New Zealand were established in the 1890s as bird sanctuaries and this established a tradition of Crown ownership for biologically valuable islands.

Statistics for islands quoted in Tables 1, 6 and 7 are based on islands ≥5 ha in area. Many very small islands, however, are important refuges for invertebrates and lizards, and some are important breeding grounds for burrow-nesting or surface-nesting seabirds.

BIOLOGICAL VALUES OF ISLANDS

Isolation has allowed many islands to function as refuges for native plants and animals as well as certain kinds of biotic communities and habitats. On a few islands the presence of strains of feral mammals may be of commercial or scientific interest. Islands provide opportunities for scientific and educational studies in which islands can be compared with each other and with the mainland.

Native Plants

Only a small percentage of the native vascular plants of the New Zealand region are confined to islands (Table 2) and most of these are endemic to the oceanic islands. Examples are the small tree *Homolanthus polyandrus* from the Kermadec Islands, the tree *Elingamita johnsonii* from the Three Kings Islands, the megaherb *Myosotidium hortensia* from the Chatham Islands, and the megaherb *Pleurophyllum speciosum* which occurs on both the Auckland and Campbell Islands.

Although more than 25% of the vascular plants occurring on the New Zealand subantarctic islands (and on Macquarie Island) are endemic to these islands as a whole (Cheeseman 1909), few species are endemic to individual island groups, e.g. Auckland Islands. However, many endemic species are associated with the oceanic island groups further north, viz. the Kermadec, Three Kings and Chatham Island groups. The latter group has about 11% of its native vascular flora endemic (Given and Williams 1984).

Native Invertebrates

New Zealand's invertebrates are far from completely known. There is, however, a tendency for larger flightless forms to be confined to islands (Table 3). This is partly related to the presence of endemic species on oceanic islands, but it also reflects the degree to which larger flightless insects have been eliminated from the mainland by introduced predators, particularly rats.

Native Vertebrates

New Zealand's herpetofauna includes 3 species of primitive frogs belonging to the endemic genus *Leiopelma*; one of these species is now confined to islands.

New Zealand's best known reptile is the tuatara *Sphenodon punctatus*, the only surviving rhynchocephalian. Now confined to a number of islands (Crook 1973) it was formerly widespread on the mainland.

The taxonomy of New Zealand's lizards is still under review so that the percentage of the herpetofauna confined to islands (Table 4) is approximate. This percentage is high, apparently a result of predators, particularly rats, that have eliminated vulnerable lizards from the mainland (e.g. Whitaker 1973).

New Zealand has 3 species of seal and sealion: the New Zealand fur seal *Arctocephalus forsteri* which ranges to Western Australia, the New Zealand sea lion *Phocarctos hookeri*, and the elephant seal *Mirounga leonina*. The latter two species breed only on islands.

The country had three species of bat at the time of European colonisation, but one species, the greater short-tailed bat (*Mystacina* sp.) had become confined to Big South Cape and Solomon Islands, off Stewart Island, prior to European settlement (Daniel and Williams 1984). This species was lost as a result of an invasion of these two islands by *Rattus rattus* in 1962 (Atkinson and Bell 1973).

The number of species and subspecies of landbirds whose breeding is now confined to islands (34% of the resident landbird fauna, Table 4) includes such species as the flightless night parrot or kakapo *Strigops habroptilus*, the black robin *Petroica traversi* of the Chatham Islands and the stitchbird *Notiomystis cincta*. Six of the landbird species now confined to islands formerly occurred on the mainland.

Table 1

Numbers, size and occupancy of New Zealand Oceanic and Continental-shelf Islands ≥5ha

Island size (ha)	Formerly occupied by Polynesians		Currently farmed		Total number of islands	
	Oceanic	Shelf*	Oceanic	Shelf	Oceanic	Shelf
5-10	2	9	-	-	14	50
11-100	1	26	-	15	17	110
101-1000	2	21	-	11	7	48
>1000	3	10	2	6	7	20
Totals	8	66	2	32	45	228

* Minimum numbers only because many islands have not been properly surveyed for former Maori occupation.

Table 2

Native vascular plants confined to islands

	No. of species confined to islands	Approximate % of N.Z. Flora*
Woody plants	43	8
Ferns and fern allies	8	4
Herbaceous monocots	24	4
Herbaceous dicots	56	6
Total confined to islands	131	6

* Data on flora totals for each plant group derived from Druce 1984a and b.

Table 3
Some flightless invertebrates confined to islands. Data from M.J. Meads (personal communication 1985)

	No. of species	% of Faunal group
Stag beetles (Dorcus spp.)	2	33
Large weevils (Anagotis spp.) > 20 mm	4	44
Giant wetas (Deinacrida spp.) (wingless crickets)	4	57
Click beetles (Amychus spp.)	2	100

Table 4
Some native vertebrates confined to islands

	No.	% of Fauna
Frogs, reptiles (all endemic species)	10	25
Seals, sealions	2	67
Breeding landbirds (spp. + subspp.)	38	34*
Breeding seabirds (spp. + subspp.)	60	71*
Total breeding birds (sp. + subsp.)	98	50*
Total breeding birds (species only)	61	42

* Data from Robertson 1985

The high percentage of breeding seabirds confined to islands (71%) reflects the positions of some islands within or close to the oceanic feeding areas of these birds. Furthermore, the breeding of some of the smaller petrels may always have been confined to islands because of the presence on the mainland of natural predators such as the weka *Gallirallus australis*. The introduction of alien predators to the mainland has subsequently confined a greater percentage of seabirds to islands for breeding (Moors and Atkinson 1984).

The proportion of the New Zealand avifauna confined to islands is very high (Table 4). This has been appreciated for a long time, and has been an important reason for giving New Zealand islands protected status.

Mainland Communities on Islands

Without a national classification of biotic communities or habitats in New Zealand, quantitative assessment of the representation of mainland communities/habitats on islands is not possible. However, some qualitative assessment is possible.

Most types of northern coastal forest and scrub are well represented on islands, particularly those dominated by *Metrosideros excelsa, Dysoxylum spectabile* and *Corynocarpus laevigatus*. This is true also of southern coastal forest and scrub where tree composites in the genus *Olearia* and *Brachyglottis* are important.

Excepting the dunes at Mason Bay, Stewart Island, only small areas of sand dune and salt marsh are present on islands. Large estuaries are present at Whangapoua, Great Barrier Island, and at Patterson Inlet in Stewart Island but most islands lack large estuaries.

Lowland podocarp/hardwood forest occurs on some islands >1 000 ha where rimu *Dacrydium cupressinum* is the principal podocarp and kamahi *Weinmannia racemosa* the main hardwood. Other islands of this size carry tall hardwood forests of *Metrosideros robusta, M. umbellata* or *Beilschmiedia tawa*. However, tall forests (>25 m) of *Nothofagus* spp, *Agathis australis* and podocarps are under-represented.

Wetlands are usually absent and lakes are present on a very few islands.

Montane communities are under-represented, although the southward lowering of altitudinal zones results in somewhat similar kinds of communities near sea level on the islands of Fiordland and Stewart Island and on the subantarctic islands.

With the exception of Secretary Island, subalpine and alpine communities are not represented on the continental-shelf islands. However, structural analogues of mainland alpine communities occur on the subantarctic islands even though these are floristically distinct.

Special Communities on Islands

The vegetation of most of the oceanic islands is dominated by plants that are either endemic to one of these islands or, in the case of the subantarctic islands, endemic to the whole group. This trend is most marked in the Chatham group where of the 12 species of tree that are forest dominants, only one is not endemic at the specific or infraspecific level.

A second class of communities especially associated with islands are those inhabited and produced by seabirds, seals or sealions. The seabirds may be surface-nesting or burrow-nesting. Surface nesters include the albatrosses and mollymawks, penguins, gannets, shags, terns and gulls, some of which form very large colonies. Burrow nesters include petrels, shearwaters and storm petrels and are commonly found on both shelf and oceanic islands. The local effect of the seabird activity is to retard or inhibit the regeneration of many plants, particularly woody species, through burrowing and trampling. The mineral additions from bird excreta enhance soil fertility and enable plants that do survive to grow rapidly. In some cases, particular species of herb have adapted to the chemical conditions of seabird excreta to the extent that they can form distinctive communities at seabird colonies, e.g., the subwoody herb *Cotula featherstonii* on small islands inhabited by albatrosses in the Chatham group. The outstanding example of a seabird-dominated island in the New Zealand region is the Snares Islands. Warham and Wilson (1982) estimated the size of the sooty shearwater *Puffinus griseus* population there to be 2.75 million burrow-holding pairs, equivalent to a biomass of 13.4 tonnes of shearwater/ha.

Fur seal colonies are normally located on rocky shores and little modification of the plant cover is apparent. Sealions at their breeding grounds in the Auckland Islands penetrate much further inland and at all times of the year, but Taylor (1971) considered their impact relatively slight at that time. The wallowing of elephant seals can have pronounced local effects on the plant cover (Falla *et al.* 1979).

A third class of communities that are often better developed on islands than elsewhere are those whose structure and composition are greatly influenced by salt. These include the halophytic and megaherb-tussock communities of the splash zone, and the woody communities of seaward slopes whose canopies are channelled and sheared by wind-carried salt, particularly in regions where gale-force winds with humidities less than 50% are frequent.

A fourth class of communities associated specifically with islands are those that for reasons of various combinations of precipitous slopes, isolation, small size and chance have largely escaped the major influences of either man or introduced animals and plants. Among the shelf islands, these pristine communities occur only on a few small islands. Among the oceanic islands, however, several much larger islands can be fairly described as still in a pristine state, e.g., Adams Island (9 896 ha) and Disappointment Island (375 ha) of the Auckland group and the Snares Islands (328 ha).

Feral Farm Mammals on Islands

There are a few populations of feral farm mammals, isolated on islands since last century, that may be worthy of protection for their genetic characteristics such as fecundity, fibre quality or disease resistance. The case for conserving such populations has been argued by Rudge (1986) who points out that, whether or not they are rare breeds, they (a) may represent a more primitive stage of domestic selection and (b) are free to continue varying and adapting unconstrained by man's selection or management (Table 5).

As recognised by Rudge, the indigenous values of an island should take precedence over the value of a particular population of feral mammals and there should therefore be no unmanageable conflict. On Campbell Island this was achieved by fencing to restrict the sheep to less than a fifth of the island's total area.

There is now more recognition of the importance of maintaining the genetic diversity of livestock breeds. If, however, livestock breeders do not evaluate the genetic qualities and possible commercial significance of these populations, they cannot expect island managers to maintain these feral mammals indefinitely.

Table 5

Examples of feral farm mammals of possible genetic value on New Zealand islands

Feral mammal	Island	Status of land and animals
Merino sheep	Pitt Island, Chatham group	Scientific Reserve; managed flock (Rudge 1983)
Merino cross longwood sheep	Campbell Island	Sheep fenced within Nature Reserve (Meurk 1982)
Merino sheep	Arapawa Island, Marlborough Sounds	Scenic Reserve; sheep to be removed to another part of the island
Goats	Auckland Island	Nature Reserve; goats may be removed to the mainland
Pigs	Auckland Island	Nature Reserve; future of pigs not decided

Islands as Systems for Scientific and Educational Study

The value of islands as simplified systems for the scientific study of ecological and evolutionary processes has often been noted (e.g., Mayr 1967). Their apparently self-contained boundaries become less well defined when account is taken of inputs from the sea by marine mammals, seabirds, wave action and wind, and outputs from the island of nutrients and eroded material. Nevertheless, the frequent absence on islands of major factors operating on the adjacent mainland, and the various combinations of factors found among islands within a group, provide many opportunities for examining and comparing islands as large-scale experiments. With improved understanding of population genetics and techniques for measuring rates of molecular and chromosomal evolution, the effects of geographical isolation on the origin of species can be studied more precisely.

Islands as Monitoring Stations for Changes in the Marine Environment

Different species of seabird are dependent on marine food chains in different ways according to their food preferences, e.g., plankton, squid, fish, etc. Major changes in the numbers of these marine organisms must affect breeding success and ultimately population numbers of the seabirds they support. Many seabird censuses are already carried out on islands. If greater effort is made to identify the areas where different seabird species feed, then systematic seabird censuses could become a practical means of monitoring changes, caused both by man and other factors, in the marine ecosystem.

ISLAND MANAGEMENT PROBLEMS

A number of problems arise when trying to maintain or increase the biological values of islands. Four of current concern in New Zealand are the *in situ* management of endangered species on islands, the limited number of island options for translocating endangered animals, genetic bottlenecks, and priorities for island restoration.

In Situ Management of Endangered Species on Islands

(a) Endangered Plants. Some endemic plants of the oceanic islands have been reduced to very low numbers. No agreement has been reached about the most appropriate action for safeguarding these species. An example is the shrub *Hebe breviracemosa* (Scrophulariaceae) endemic to the Kermadec Islands. This had not been seen since early this century and was thought extinct until 1983 when, following the eradication of goats on Raoul Island, a single plant was found. Management on the island has involved 'weeding' around the plant to increase the chances of seedlings establishing and a so far unsuccessful attempt to raise seedlings at the Meteorological Station on the island. Both cuttings and seedlings have been raised on the mainland (W.R. Sykes, personal communication). If either cuttings or seedlings are transferred from the mainland to the island, special precautions will be needed to ensure that no disease is introduced.

A second example is that of the woody climber *Tecomanthe speciosa* (Bignoniaceae) which is endemic to the Three Kings Islands. This also survives only as a single plant on one island in the group, a probable result of the former presence of goats. The species is self-fertile but no seedlings have established in the wild during the 40 years since its discovery. However, seedlings have been raised from seed set by flowering plants on the mainland. This has been known since 1956 but no attempt has been made to increase the population of *Tecomanthe speciosa* on the Three Kings Islands.

Propagation of endangered plants in nurseries and gardens can secure the survival of a species as a collection of live plants. Such action by itself, however, does not ensure the survival of the species as a continuously evolving population able to respond to the selective forces operating in its original habitat. Establishing further individuals in suitable sites on the island in question, either from those propagated on the island or, with safeguards against disease, from those propagated on the mainland, appears essential. Only with this kind of action can effects of genetic bottlenecks, discussed below, be avoided and the survival of these endemic plants as evolving species be made possible.

(b) Endangered Animals. *In situ* management of endangered animals has been attempted on several New Zealand islands.

Maud Island (Fig. 3) in the Cook Strait-Marlborough Sounds region, supports a dwindling population of the large carnivorous land snail *Powelliphanta hochstetteri obscura* which is vulnerable to human trampling and predation by wekas. In June 1980 a 250 x 100 m fenced exclosure was erected to protect the snails from further disturbance but recovery of their numbers is expected to be slow (Meads *et al.* 1984 and M.J. Meads personal communication).

Most management of endangered animals on islands has centred on birds. The rearing of broods of the black robin *Petroica traversi* in the Chatham

Islands by using Chatham Island tits *P. macrocephala chathamensis* as foster parents (Merton 1983) has rescued the black robin from the brink of extinction. The use of roost boxes specially designed and placed to reduce the chances of rat predation is now being tested with the aim of assisting a population of North Island saddlebacks *Philesturnus carunculatus rufusater* to coexist with two rat species (*Rattus norvegicus* and *R. exulans*) on Kapiti Island (Lovegrove 1985).

Translocation of endangered species to islands

(a) Endangered Plants. No systematic translocation of endangered plant species to islands has been attempted in New Zealand although there are several endangered coastal and lowland species that could be established on particular islands.

(b) Endangered Animals. Translocations to additional islands of two potentially endangered invertebrates, the flax snail *Placostylis hongii* and the Cook Strait giant weta *Deinacrida rugosa*, have both been effected successfully. Translocation of some endangered lizards is now underway (Towns *et al*, in press). Translocation of endangered birds began in the 1890s but has intensified since 1960 (see Bell, this volume). A major problem with translocation is the limited number of islands that are suitable for endangered species.

Limited Availability of Islands for Translocation of Endangered Species

Some factors that limit options for translocating endangered species to islands are

(i) small size of island and the area of suitable habitat taking into account successional changes,

(ii) presence of introduced browsing mammals and introduced predators, both mammals and birds,

(iii) risk of fire and further introductions of alien mammals, particularly on islands that are settled, and

(iv) possibility of the translocated species disrupting intrinsic values of the island.

(a) Oceanic Islands. Five of the eight oceanic island groups contain one or more islands greater than 1 000 ha in size and these provide a greater diversity of habitats and presumably greater long-term security for at least some of the species present than do smaller islands.

The percentages of these islands occupied by various introduced predatory and browsing mammals are shown in Table 6.

The oceanic islands have suffered fewer introductions than have the shelf islands, but the continuing interest in rock lobster, squid and fin fisheries in southern waters by overseas and New Zealand fishermen, has put at least 8 important islands at risk from rat invasions : Auckland, Adams, Disappointment, Enderby, Ewing and Rose of the Auckland group, and North East and Broughton Islands of the Snares group. Pitt Island in the Chatham group is also continuously at risk from rat invasion by reason of its permanent settlement and transit of stores from Chatham Island which is rat-inhabited.

Introducing a mainland species could change the distinctive biological character of an oceanic island. Each supports a unique combination of plants and animals, and these intrinsic qualities should not be modified without very good reason.

(b) Continental-shelf Islands. Of the 20 shelf islands greater than 1 000 ha, 10 have permanent settlements. Nearly half of the 228 shelf islands considered have browsing mammals of one kind or another and more than a third have introduced predators (Table 7). Only 13% of these islands are completely free of all introduced mammals as well as wekas, and most of them are small. Seven important island reserves require particular vigilance against invasions by *Rattus rattus* or *R. norvegicus* because these islands are frequently visited by people: Little Barrier, Tiritiri, Kapiti, Mana, Stephens, Maud and Codfish Islands.

The limited options for translocating endangered species to islands can be seen more clearly when island size as well as farming modification and the presence of introduced mammals and wekas are all considered together (Fig. 5). The largest islands (>1 000 ha) with the greatest potential as biological reservoirs drop from a total of 20 down to one island (Little Barrier) when those settled and farmed and those with browsing mammals are excluded from the list of options. No shelf island larger than 1 000 ha is without any introduced mammals. Nevertheless it is important to note that apparently no island of the 228 considered has **all** the introduced mammals that are widespread in lowland native vegetation on the mainland : pigs, goats, possums, stoats, cats, ship rats *R. rattus* and Norway rats *R. norvegicus*. For example, Stewart Island, the largest considered, has deer, possums, cats and three species of rat. But the absence of stoats has probably been of critical significance in allowing the survival on the island of a breeding population of kakapo. Thus, although the widespread modification of islands by introduced mammals has greatly reduced the options for translocating and protecting endangered species, the absence of some mammals determines that no island

Table 6
Percentages of New Zealand Oceanic Islands (≥ 5ha) currently affected by introduced mammals and other modification

Modifying Factor	No. of Islands affected	% of Total
Settled and farmed	2	4
With browsing mammals	6	13
With cats	5	11
With rats or rats and mice	9	20
With mice but no rats	4	9
Free of all introduced mammals	35	78
Currently at risk from rat invasion	9	20
Total islands > 5 ha	45	

Table 7
Percentages of New Zealand Continental-shelf islands (≥ 5ha) currently affected by introduced mammals and other modification

Modifying Factor	No. of Islands affected	% of Total
Settled or farmed	31	14
With browsing mammals (or within swimming distance of deer)	108	47
With cats or stoats or within swimming distance of stoats	84	37
With wekas *Gallirallus australis*	32	14
With either *Rattus rattus* or *R. norvegicus*	65	29
With *Rattus exulans*	41	18
Free of rodents	50	22
Free of all introduced mammals and wekas	30	13
Currently at risk from rat invasion	7	3
Total islands ≥ 5 ha	228	

can be regarded as simply another part of the mainland.

(c) Swimming distances for certain introduced mammals and wekas. Effort in eliminating alien vertebrates on some islands (see Bell, this volume) can be wasted if an island is subsequently reached by the vertebrate simply swimming from the mainland or a nearby island. Available information about the distances these animals can swim in New Zealand seas is summarised in Table 8, but much more investigation is needed of circumstances such as sea conditions, food availability at the place of departure, and attractive cues, (e.g., plant smells, bird calls) on the island in question, before we can predict the frequency with which such swimming activity is likely to occur.

Genetic Bottlenecks

These occur whenever there is a sudden collapse of population numbers within a single generation. The immediate effects can be some loss of genetic heterozygosity and losses of specific alleles, particularly those at low frequencies in the original population. The impact of a genetic bottleneck is directly related to the effective population size, i.e., the number of breeding individuals. The total amount of genetic variation lost during a bottleneck depends on how quickly the population can return to moderate (several hundred or more) size (Frankel and Soule' 1981).

Genetic variation is correlated with short-term fitness, i.e., factors which affect reproductive output, fertility, developmental rate, etc. Inbreeding in small populations can result in loss of genetic variation and thus reduced fitness. Franklin (1980) has noted that an inbreeding rate (rate at which genes become fixed as identical alleles) as high as one per cent increase per generation is accepted by breeders of domestic animals. From this he considers that an effective population size of 50 may be regarded as a minimal size to maintain fitness.

Retention of genetic variation is also seen as essential for a population to retain the capacity to adapt to new conditions. Franklin (1980) and Frankel and Soule' (1981) suggest an effective population size of 500 individuals as a 'rule of thumb' criterion if the

Table 8

Swimming distances in sea of certain introduced mammals and Wekas in New Zealand

Introduced Animal	Sea-distances Swum	Source of Information
Red deer	At least 1.1 km	Deer swam to Secretary Island from mainland
Goats	Not known to cross sea gaps	
Possums	Incapable of crossing sea gaps	
Cats	Incapable of crossing sea gaps	
Stoats	Up to 1.1 km	Taylor and Tilley (1984)
Wekas	At least 860 m in special circumstances	Wekas swam to Maud Island, Pelorus Sound from mainland
Rattus rattus and R. norvegicus	< 300 m in cool southern waters.	R.H. Taylor, pers. comm.
Rattus exulans	< 200 m, possibly < 50 m	Atkinson (1986)

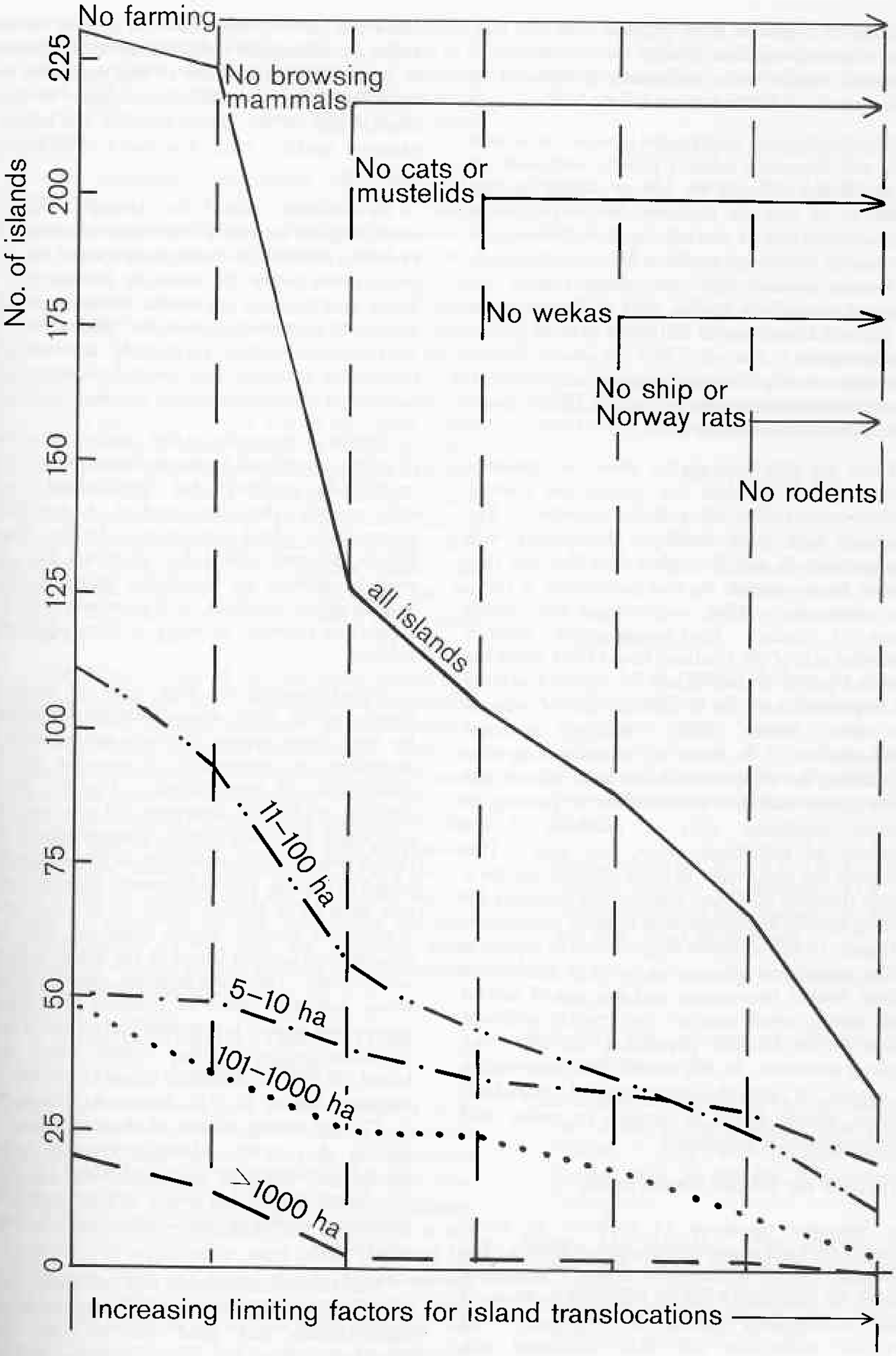

Figure 5
Limiting factors for translocating species to islands.

evolution of a species is to continue. At this size, losses of genetic variation through random fixation of genes are thought to be approximately balanced by gain in genetic variation from mutation.

Translocating an endangered species to a new island will frequently inflict a genetic bottleneck on the population although the source population may already be at very low numbers. If the population increases quickly in its new habitat, man's intervention has done no more than replicate the many thousands of founder events that occur when islands are colonised naturally by species. Not all translocations are successful however, so that if the risks of genetic impoverishment are to be avoided, further intervention during the initial stages of establishment, to boost numbers as rapidly as possible, should always be included in the recovery plan.

There are still uncertainties about the minimum effective population sizes that species can tolerate without serious loss of genetic variation. The guidelines have been developed from work with domestic animals and *Drosophila* fruit flies and they may not be appropriate for wild populations of birds, some mammals, reptiles, invertebrates and various groups of plants. For example, the effective population size of the Chatham Island black robin has remained below 25 individuals for nearly a century and at present there are no obvious signs of reduced short-term fitness (D.V. Merton, personal communication). In terms of retaining long-term adaptability, the available evidence from animals and higher plants that have been studied is pointing to effective population sizes of hundreds if not thousands of individuals rather than tens. This underlines the importance of large effective size for a reserve (Frankel 1984) and suggests two strategies for avoiding genetic impoverishment in small populations on islands: (i) use of islands large enough to support a species population of several hundred individuals without further intervention and (ii) use of several small islands which together can provide sufficient habitat for an effective population size above the required minimum. In this second case, intervention by means of periodic exchanges of individuals between islands would be needed to ensure that genetic variation is maintained.

Priorities for Island Restoration

The foregoing discussion of problems of island management has focused on endangered species. The irreversible finality of extinction makes it imperative to focus on endangered species but other problems of island management cannot be forgotten. Of particular importance are those associated with restoring an island depleted by man of its native flora, fauna and biotic communities. In pursing restorative action the assumption is that a state of the system can be reached which is closer to that operating before depletion or other modification began. In fact the original state of the system is often not known and whatever model is used, it is based often largely on inference.

Nevertheless, there are strong reasons for attempting the biological restoration of some islands. Providing habitats for endangered species has been a primary motivation for restoring islands, but such action also increases the habitat for other plants and animals of restricted distribution. With certain kinds of restorative action, particularly the removal of introduced browsing and predatory mammals, the recovery of whole communities becomes possible.

Details of restorative action involving the removal of various introduced mammals from islands are given by Bell (this workshop), but New Zealand is not the only country that has applied a multiple-step approach to island restoration. In the Bermuda Islands, Wingate (1985) has described his pioneer work is restoring the tiny (6 ha) island of Nonsuch from a desert condition to a point where it is now supporting examples of many of Bermuda's original habitats.

Notwithstanding the high value of many small island reserves, larger areas of habitat will be needed for many larger species of plants and animals. This underlines the importance of restoring the biotic communities of large islands. Four of the most intensive eradication campaigns, all now successfully completed in New Zealand, concern islands larger than 1 000 ha : the eradication of goats from Raoul Island (2 938 ha), Kermadec group; the eradication of cats from Little Barrier Island (2 917 ha), and the eradications ridding Kapiti Island (1 970 ha) of possums and Codfish Island (1 396 ha) of both wekas and possums. There are, however, other large islands whose biological values or potential for supporting endangered species is very high and all are in need of restorative action. These include Great Barrier Island (28 510 ha), Rangitoto Island (2 333 ha), Great Mercury Island (1 718 ha) and Mayor Island (1 277 ha) among islands of the continental shelf. Among the oceanic islands restorative action is needed particularly for Auckland Island (45 975 ha). Pitt Island (6 203 ha) has a greater potential for protecting wildlife in the Chatham Islands than any other island.

The future conservation role of islands such as Great Barrier and Pitt depends very much on the understanding and good will of their human inhabitants. Here lies a great challenge because, in protecting nature, society often tends to exclude rather than involve the local people. It remains to be proved to what extend the cultural and economic needs and expectations of a farming community can be accommodated with conservation in an island context.

The imaginative conservation plan proposed for Pitt Island by B.D. Bell in 1984 is a unique opportunity to test this idea. Pitt Island lies some 20 km south-east of the main Chatham Island and has a population of about 50 people, most of whom are farmers and fishermen. It is a close-knit, self-reliant community with a considerable interest in its natural heritage. Most of the endangered birds (but not the endangered plants) of the Chatham group are now dependent for their future on two small islands (219 and 113 ha), together with several very small islands none of which is larger than 20 ha. If birds such as the Chatham Island snipe *Coenocorypha aucklandica pusilla*, black robin, Chatham Island pigeon *Hemiphaga novaeseelandiae chathamensis*, Chatham Island oystercatcher *Haematopus chathamensis*, New Zealand shore plover and Chatham Island taiko *Pterodroma magentae* can be established on Pitt Island, their future will be very much more secure than it is at present.

Pitt Island is free of rats and could remain so if adequate steps are taken to prevent them establishing. The presence of three introduced predators restricts the value of the island for native fauna. These are cats, wekas and pigs. The conservation plan proposes that feral cats (but not neutered house cats) and wekas are removed. It may prove necessary to either confine pigs to parts of the island using conventional and electric fencing or alternatively control them at low numbers. Success with the Pitt Island plan will depend on a close working relationship and good communication between the Pitt Islanders, island managers, and researchers studying the requirements of particular endangered species.

CONCLUSION : THE FUTURE CHALLENGE

Our most immediate task in New Zealand is to maintain the biological values of what we have in our islands. A high priority must be to implement practical precautions that will prevent rats from establishing on any of our valuable islands (Atkinson 1985, 1986) But maintaining the *status quo* is not going to be sufficient to meet either the need for conserving plant and animal species as continuously evolving populations or the need to protect a wider range of habitats on islands than so far achieved. We must, therefore, give more attention to improving techniques for restoring the biological values of islands, using greater scientific and technical input where appropriate, and giving preference to larger islands, sometimes including those inhabited, whenever it is practical to do so.

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