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ECOLOGY OF KOWHAI BUSH, KAIKOURA

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(Editors)

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Sections 4 to 6 and 8 to 15 of this booklet are abstracts of research. They do not include results in full, which authors may publish elsewhere.

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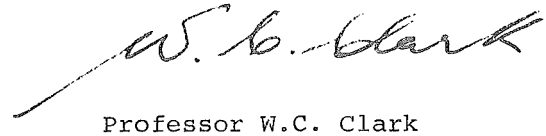
FRONTISPIECE - Dr. Flack examining the tracking paper from a tree tunnel in the depths of Kowhai Bush. To reach the robin nest (not visible) a predator must pass through the tunnel (see Section 15. Photo: Wildlife Service).

FOREWORD

The studies outlined here strongly emphasize the great and increasing value of isolated, and other small, patches of semi-native vegetation now remaining in many parts of New Zealand. The work reviewed here is in accord with the best traditions of biological field science. These studies have increased understanding and awareness not only of the plant and animal inhabitants of the bush, but also of subtleties of their interrelationships. These studies remind us of the often slight differences that determine success and failure, and thus survival or extinction.

It is remarkable that so much has been learned in so short a time, by a small band of observers. That this work will continue is evidenced by Jim Cunningham's newly started study of the brown creeper. It is to be hoped, however, that publications such as this will encourage other interested people to continue the Kowhai Bush work, to study other habitats and their inhabitants, and to make public the record of their endeavours. It is time that we in New Zealand tried to nurture one of the most endangered species, the skilled and devoted local amateur, naturalist or ecologist. There are many knowledgeable observers of nature in New Zealand, but few record what they have seen. That the value of Kowhai Bush has been recognised must be a feather in the cap of the Royal Forest and Bird Protection Society for they protested in 1970 when the robin habitat was first threatened. It is to be hoped that what was initiated by an essentially amateur group will be continued by more amateurs at Kowhai Bush and elsewhere. Many of us in the University of Canterbury sit on the borderline as an institution whose role is to convert amateurs into professionals. We will, however, continue to be involved in unravelling the intricacies of Kowhai Bush, a task so well started by the contributors to this volume.



Professor W.C. Clark

Professor of Zoology
and Head of Department,
University of Canterbury.

CONTENTS

1. INTRODUCTION

by B.J. Gill and D.M. Hunt

Kowhai Bush (42°23'S, 173°37'E; NZMS1 S49 895 953) in Marlborough, takes its name from the Kowhai River which rises in the Seaward Kaikoura Ranges of the South Island of New Zealand and reaches the east coast just south of the Kaikoura Peninsula (Fig. 1). The Bush is a narrow strip of kanuka/broad-leaf forest covering 240 ha of river-gravels on the north-eastern side of the Kowhai River. Kowhai Bush is 8 km north-west of Kaikoura (1,680 people), which in turn is 190 km north of Christchurch on State Highway 1, and 130 km south of Blenheim.

Debris from erosion of the upper catchment has raised the shingle bed of the lower Kowhai River above the level of surrounding land, and brought the threat of floods. As early as 1866, steps were taken to reserve Kowhai Bush for its value in holding gravel and stemming flood-waters. The "Kowhai River Protection Reserve" is currently administered by the Marlborough Catchment Board, and the removal of trees and dumping of rubbish is prohibited in the Reserve. The Board sees the main function of Kowhai Bush as river control, and there have been conflicts, still not finally resolved, between this and management objectives that others have identified.

The forest which makes up Kowhai Bush is interesting because flooding has produced a mosaic of successional stages once common on river-flats of the eastern South Island but now rare. Native birds in Kowhai Bush are numerous and varied, and the area is particularly well known for its population of South Island robins. A thriving population of these birds in lowland forest and so close to a town is unusual. The forest is also important ornithologically for its dense population of riflemen and brown creepers.

Kowhai Bush is easily reached by road. Both Postman's Road and Schoolhouse Road terminate in the forest at their western ends (Fig. 1). The Bush is large, yet has clear boundaries and can be regarded as an ecological "island" within a "sea" of farmland. Successional stages are easily distinguished. The forest grows on flat land below 150 m a.s.l.; it has a low canopy and an open interior in places. Survey lines and tracks give access within the forest, though visiting members of the public seldom penetrate beyond its edges.

Thus Kowhai Bush is highly suitable for some types of field research and has been the focus of attention of several scientists, with interests ranging from tardigrades to time-budgets. Research began at Kowhai Bush in 1971 when Dr Flack started work on the South Island robin. In seeking a mainland study area Dr Flack could find no other with even a few of the advantages of Kowhai Bush. The area is probably the best in New Zealand for a study that involves finding nests of song-birds. Kowhai Bush is also ideal for teaching practical ecology and principles such as succession to students, and is used for that purpose by Canterbury University and several secondary schools in the region. The Bush has recreational potential, as yet only partly realised.

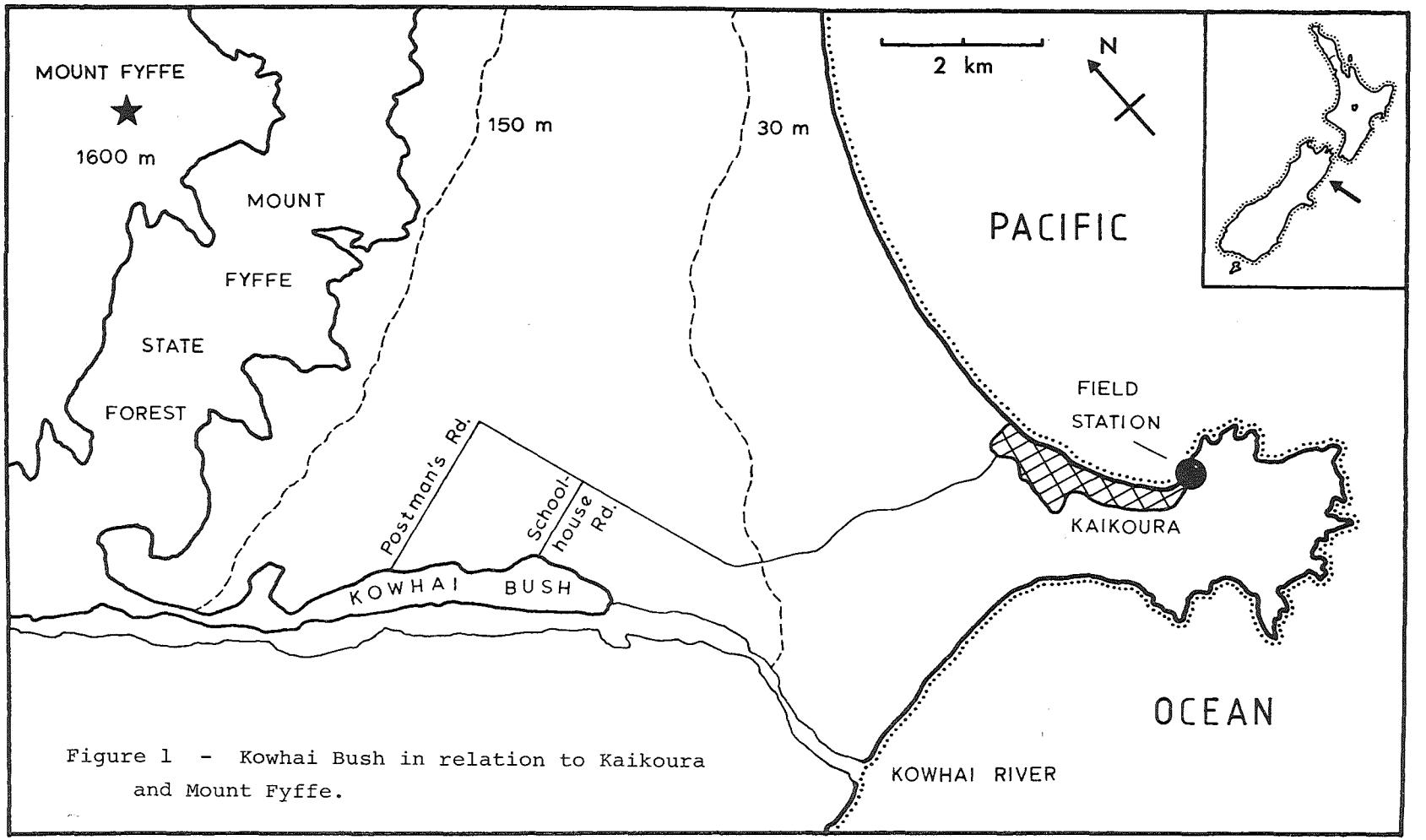


Figure 1 - Kowhai Bush in relation to Kaikoura and Mount Fyffe.

The Zoology Department of Canterbury University administers the Edward Percival Field Station (formerly the E.P. Marine Laboratory) at Kaikoura, the scientific and accommodational facilities of which greatly enhance the suitability of Kowhai Bush as a study area, especially for postgraduate students. The Station was officially opened in March 1963, and has bunk-rooms, a kitchen, living-space and laboratory facilities for 30 people.

Intensive multidisciplinary studies in one area are rare in New Zealand, and therefore especially valuable where they have occurred. Much research has been undertaken at Kowhai Bush, but little has been published. A consolidation of knowledge is therefore timely. This booklet has been compiled to describe the physical aspects of Kowhai Bush, and to summarise existing scientific information by a series of abstracts, solicited where possible from the investigators concerned. A bibliography, and checklists of the plants, birds and mammals are included as appendices. This booklet will be a valuable first reference for anyone contemplating research at Kowhai Bush, and, we hope, a stimulus for further work.

Where a reference is not cited in full in the text the complete citation is in the bibliography. We would like to acknowledge support received from the Zoology Department (University of Canterbury), the University of Canterbury Students' Association, the Wildlife Service and the Marlborough Catchment Board in preparing this booklet. Mr P.A. Thomson, the Catchment Board's Chief Engineer, supplied most of the data on hydrology. We also thank Graham Fenwick and the other officers of "Mauri Ora" for their assistance with publication. Special thanks are due to the contributors whose activities and endeavours made this booklet possible.

2. HISTORY
by D.M. Hunt

In the 1840's European settlers in the Kaikoura area found a plain with extensive areas of swamp, and a covering of fern, toi-toi, flax, niggerheads, raupo, tutu, and koromiko (Sherrard, J.M. 1966. Kaikoura - a History of the District. Kaikoura County Council, New Zealand). Areas of drier soil, such as the Kowhai River flats, supported forest and scrub. In 1864 sections of Kaikoura land were first offered for sale by the Government, and clearance of the native vegetation began. Swampland was drained and pasture grasses replaced bush. However, a strip of natural vegetation along the north bank of the Kowhai River was left to act as a buffer between the flood-prone Kowhai River and the farmlands. The Marlborough Gazette (a provincial journal) of 1866 officially reserved 355 ha of this Crown Land for "river protection". Other small areas were added to the reserve in 1879, 1922, and 1956.

The threat from floods was realised in the "Great Flood" of 1868, when the Kowhai River swept across the Plain, destroying several houses and flooding extensive areas of land. Subsequent concern among settlers led to a meeting in 1875, at which the need for a river board was identified. The first Kaikoura River Board was elected in January 1877, and in 1880 it acquired control of the Kowhai River Protection Reserve. Flood control works carried out by the Board included channel clearing, construction of crates, groyne works, stopbanking, rock raking, and willow and poplar planting. However, large floods were not contained by these works and the Kowhai River flooded the Kaikoura Plain in 1917, 1923, 1952, 1953, 1954, and 1963.

In 1964 the River Board and the Kaikoura County Council agreed that flood control should be taken over by a government-instigated administrative authority. Hence in 1966 all "property, contract, rights, obligations and liabilities" were transferred to the Marlborough Catchment Board.

In February 1969 P.A. Thomson (Chief Engineer) and R.S. Macarthur (Chief Soil Conservator) presented the Marlborough Catchment Board with a report entitled "River Control, Drainage and Erosion Control Scheme for Kaikoura". It included a recommendation that River Protection Reserves on the Kowhai and Waimangarara Rivers be used for production forestry. Replacement of the native forest by *Pinus radiata* was to maintain the protective function of the Reserves while also providing the Board with additional revenue. This scheme was approved by the Government early in 1976.

In 1970 a trial forestry block of 1.6 ha was cleared and re-planted within the Kowhai River Reserve (Habitat 13 of Fig. 2). This prompted the Royal Forest and Bird Protection Society to draw the Catchment Board's attention to the Reserve's large population of native robins, and request that planting of pines cease. The Board asked the Wildlife Service (Department of Internal Affairs) to survey the avifauna of Kowhai Bush. So accessible to research were the robins that Dr J.A.D. Flack began a study of them in May 1971.

Conversion of Kowhai Bush to pines was to have been financed through a Forest Service Local Body Forestry Encouragement Loan. In February 1972 the loan application by the Board was refused, mainly because of doubts about the suitability of river gravels for exotic forestry.

In July 1972 following a visit to Kowhai Bush, the Nature Conservation Council stated that the area should remain a river control reserve, but recommended that "disturbance of the existing bush by future flood control works be minimised". The Council supported applications in 1973 by the Catchment Board to the Forest Service and Lands Settlement Board for alternative areas on which to plant exotics. However, no suitable alternative areas were found.

Dr Flack's study showed that robins occupied 176 ha, a much larger area than was first thought. In March 1973 he identified 154 ha as suitable for a wildlife reserve within the River Protection Reserve. The following June, 150 Kaikoura residents petitioned the Catchment Board in support of a bush robin reserve. For several years the designation of a wildlife reserve within Kowhai Bush was discussed, but no binding decisions were made.

As part of its river control scheme for the Kaikoura Plain, the Catchment Board proposed a floodway to channel water from the Waimangarara River, and from Middle, Luke and Floodgate Creeks, into the Kowhai River. In 1975-76 an exploratory line was bulldozed for the terminal section of the Floodway, which bisects Kowhai Bush (Fig. 2).

In 1976-77, while a resource management student at the University of Canterbury, I prepared a management plan for the Kowhai Reserve (Hunt 1977). (Professor G.A. Knox of the Zoology Department, University of Canterbury, conceived this project and arranged its financial support.) In 1977 the plan was sent to the Marlborough Catchment Board, the Wildlife Service and other interested government departments. The management plan recommended:

1. That Kowhai Bush be managed to achieve a range of objectives.
2. That a scientific advisory committee be established to assist in multiple-objective planning.
3. That Kowhai Bush be given a special zoning in the Kaikoura District Scheme.
4. That control of Kowhai Bush remain with the Marlborough Catchment Board, unless the latter should fail to achieve multiple-objective management, in which case the Commissioner of Crown Lands (Marlborough) should request transfer of the control of the forest to the Department of Lands and Survey.

The Catchment Board adopted the second recommendation, and in February 1978 a Scientific Advisory Committee met for the first time. Its membership includes the chairman of the Board's Soil Conservation Committee, a Kaikoura member of the Board, the Commissioner of Crown Lands (Marlborough), a biologist from the University of Canterbury (Dr M.C. Crawley), a botanist from the D.S.I.R. (Dr B.J.P. Molloy) and a scientist from the Wildlife Service (Dr P.J. Moors).

The Floodway was cleared and excavated to its full width and depth in 1978, with the destruction of about 3 ha of forest. The Scientific Advisory Committee recently approved a rationalisation of the boundaries of the Protection Reserve. This will involve opening an area to grazing, and excluding stock from a larger area containing remnants of "old forest".

The Catchment Board intends to prepare its own management plan for the Kowhai Reserve, with scope for public comment at several stages.

3. PHYSICAL ASPECTS
by D.M. Hunt and B.J. Gill

Topography and Geology

The Kaikoura Plain, on which Kowhai Bush is centrally located, covers 166 km^2 between the Hapuku and Kahutara Rivers, and is bounded by mountains to the north-west and by sea to the south-east. The plain slopes steeply, half of it lying above 50 m altitude with a gradient of 45 m/km. Mount Fyffe, only 8 km from the nearest shoreline, reaches 1540 m.

The basement rocks of the area are dark grey, hardened sandstones (greywacke and argillite) of the Jurassic to Late Cretaceous period. Erosion of these produced the Late Quaternary alluvial gravels of the Kaikoura Plain (Chandra, S. 1968. Geomorphology of the Kaikoura Area. Unpublished M.Sc. thesis. University of Canterbury, Christchurch).

The region is tectonically unstable, and a major fault (the Hope Fault) runs NE-SW along the base of Mount Fyffe. The heavily faulted and folded landforms of the Kaikoura Ranges are liable to widespread and rapid erosion, accelerated since European settlement by devegetation through fire and grazing by wild and domestic mammals. Rivers on the Kaikoura Plain are severely aggraded and prone to flooding.

Climate

Kowhai Bush lies in an eastern climatic district characterised by moderate winters and very warm summers. The district experiences dry Foehn winds from the west which may produce day temperatures in summer above 32°C. The other predominant winds in the Kaikoura area are cool, wet southerlies and north-easterlies.

Climatic data for the Kaikoura Peninsula are given in Table 1. Rainfall is heaviest in autumn and least in spring. It is evenly distributed throughout the year, but may vary erratically over short periods. The coldest month is July and the warmest is February.

From April 1977 to December 1978, Mr R.G. Powlesland operated a small weather station in a paddock adjacent to Kowhai Bush just off Postman's Road. Average monthly temperatures [mean of (daily maximum + daily minimum)/2] and total monthly rainfall are given in Table 2. Each month the temperature was within about 1°C of that recorded on the Kaikoura Peninsula. However, monthly rainfall at the Bush was nearly always higher than, sometimes double, that on the Peninsula.

Clouds from the south shed their rain as they bank up against Mount Fyffe. Thus rainfall increases along the length of Kowhai Bush (and the Kaikoura Plain) from the seaward side. Average annual rainfall at the foot of the Seaward Kaikouras is 1,441 mm (Flack 1976a), compared with 865 mm on the Peninsula.

Table 1 - Average monthly and annual climatic data for the Kaikoura Peninsula (supplied by the Kaikoura Meteorological Office, Ministry of Transport).

	Period	Month J	F	M	A	M	J	J	A	S	O	N	D	Year
rainfall (mm)	1941-70	69	64	76	74	102	66	81	81	51	61	66	74	865
rain-days (frequency)	1949-75	11	9	10	12	13	12	12	12	11	12	10	10	134
temperature (^{o}C)	1964-75	15.9	16.1	14.4	12.3	10.3	7.8	7.4	8.9	9.7	11.8	13.7	14.9	12.0
sunshine (hours)	1960-75	211	188	168	161	132	128	130	153	166	210	211	210	2068

Table 2 - Average monthly temperature and total monthly rainfall recorded near Kowhai Bush by R.G. Powlesland.

Month	Mean temperature (°C) 1977	1978	Total rainfall (mm) 1977	1978
J		17.1		32.0
F		16.8		73.0
M		15.5		80.5
A	13.1	14.1	40.3	468.0
M	8.7	10.2	106.7	157.9
J	7.6	6.7	99.6	323.0
J	7.1	8.1	279.1	295.5
A	7.6	9.0	188.7	103.0
S	6.8		146.0	174.5
O	10.1	10.5	71.5	84.0
N	11.4	13.3	80.5	45.5
D	13.4	14.6	33.5	60.9

Mr Powlesland found that in five months during 1978 the mean temperature was slightly but consistently lower within Kowhai Bush than at the site of the nearby weather station. On the other hand, air temperatures within the forest may vary as much as 20°C in one day, especially when there is a change between cold southerly and warm westerly winds. Frosts are rare on the Peninsula but occur on more than 40 days per year closer to the mountains. However, they rarely penetrate the canopy of the Bush.

Hydrology

The catchment of the Kowhai River covers 68 km^2, rises to 2,610 m and is severely eroded. Over the 11 km from the Kowhai River gorge to the sea, the river flows down a steep alluvial fan which slopes 15-24 m/km. The riverbed is on or near the top of the fan, so that the slope to the side, such as through Kowhai Bush, is virtually the same as for the riverbed itself. The river carries a large load of unsorted material, from fine silt to boulders more than 2 m in diameter. The riverbed is mobile, but in past decades the vegetation of Kowhai Bush has filtered out deposits and prevented the river from changing its course across farmland towards Kaikoura. Floods occur after rain-storms in the catchment, and may be made worse in spring if warm rain from the north-east melts accumulated snow. Estimates for the flow of the river during floods are 370 - 1,050 m^3/s.

Three distinct aquifers are thought to underlie the Kaikoura Plain: a water-table aquifer, a deep or non-flowing artesian aquifer, and a flowing artesian aquifer (Brown, L.J.; Taylor, C.B. 1974. Geohydrology of the Kaikoura Plain, Marlborough, New Zealand. Proceedings of a Symposium on Isotope Techniques in Groundwater Hydrology. Vienna.). The Kowhai River contributes to groundwater by infiltration from its bed. Within Kowhai Bush there are two permanent natural ponds formed in washouts near Floodgate Creek (one is shown in Fig. 2).

Soils

The soils of Kowhai Bush have not been mapped in detail, but they are broadly classified as Waimakariri silt loam with boulders. The predominant parent rock is greywacke, but other types are present, for example limestone, which may improve soil fertility.

During past floods the vegetation slowed floodwaters, and caused deposition of sediments in the forest. Soils nearest the river are the most silty, as a result of deposition by minor floods. Also, major floods breaking through the forest have deposited fine silt in the backwash close to the river. Further from the river the substrate is coarser, and boulders are visible on the forest floor. Drainage in these areas is rapid.

4. VEGETATION

by A.T. Dobson

Kowhai Bush is one of the few remaining examples of forest on aggraded river gravels in the eastern South Island. The physiognomically dominant tree is kanuka (*Leptospermum ericoides*) except in maturer patches of forest where several broad-leaved trees dominate.

I surveyed the forest in 1973-74 after choosing 44 sites, each measuring 10 x 10 m. At each site all plants over 3 m in height were counted and identified, and their trunk diameters were measured. Basal areas were derived from trunk diameters using N.Z. Forest Service tables. For plants below 3 m in height a subjective estimate of abundance was made. Three soil samples from each site were analysed for texture.

Description

Apparently the two most suitable parameters for defining and describing the sites are the texture (coarseness) of the soil and the total basal area of the trees (over 3 m). In general, total basal area increases with increasing maturity of the site although there are a few anomalous sites with low basal areas due to a variety of chance factors, e.g. wind-throw, flood damage and grazing. Otherwise the sites may be divided into three main groups.

(1) The "old forest" (Habitats 5, 6 and 9; Fig. 2), from which kanuka is virtually absent. The dominant trees are broad-leaved, with *Melicytus ramiflorus* usually accounting for the largest proportion of the total basal area at a site. Other prominent species are *Myrsine australis*, *Pittosporum eugenioides*, *Carpodetus serratus*, *Hedycarya arborea* and the twining liane, *Ripogonum scandens*. Scattered matai and totara (*Podocarpus spicatus* and *P. hallii*) are also present, and in the understorey the shrubs *Coprosma australis*, *C. rotundifolia* and *Macropiper excelsum* are prominent.

(2) A group of young sites along the margin of the present riverbed and in the tongue of land between the riverbed and Floodgate Creek (Habitats 2 and 10; Fig. 2). Typically these have an open canopy of kanuka. *Coriaria arborea* is usually present. Saplings of *Melicytus ramiflorus*, *Pittosporum tenuifolium*, *Coprosma robusta* and *Cytisus monspessulanus* may be present in varying proportions. Basal areas are relatively low. The soils vary considerably in coarseness but most are subject to repeated floods which add fine material.

(3) Remaining sites (Habitats 1, 3, 4 and 7) representing the largest proportion of the forest and constituting the main-line vegetation sequence at Kowhai Bush. There is a clear relationship between soil coarseness and forest maturity. The most mature forest has developed on the finer, less drought-prone soils nearer the present riverbed. This mature forest has the highest basal areas and greatest diversity of trees. The least developed sites (Habitat 1) are very stony and drought-prone and are away from the riverbed. They have an open canopy of stunted and much-branched kanuka and manuka (*Leptospermum scoparium*).

FIG. 2 - The vegetation of Kowhai Bush (redrawn from an original map compiled by J.A.D. Flack and B.D. Lloyd). Note that the poplar-willow association (Habitat 11) occurs more widely than shown, along the edges of some sections of stop-bank.

KEY TO HABITATS:

1. Soils dry and stony. Canopy of stunted manuka and kanuka (*Leptospermum*). Ground flora dominated by mosses, lichens, grasses and hook sedges.

2. Continuous canopy of manuka and kanuka. Undergrowth of Montpelier broom (*Cytisus monspessulanus*) and tutu (*Coriaria arborea*). Other exotics common. Subject to drought.

3. Canopy (mostly mature kanuka) broken. Upper understorey thick and diverse. Undergrowth very diverse. Ground-cover mainly hook sedges and ferns.

4. Continuous canopy of young broad-leaved trees. Mahoe (*Melicytus ramiflorus*) and *Coprosma robusta* abundant. Scattered large kanukas emerge above the canopy. Undergrowth of broad-leaved saplings. Ground flora *Astelia* and ferns.

5. The "old forest". High, unbroken canopy of diverse, old trees. Some thickets of supplejack (*Ripogonum scandens*).

6. Resembles "old forest" but has a simpler structure due to grazing.

7. Canopy of scattered manuka and kanuka. Low, very dense undergrowth of divaricating coprosmas and *Helichrysum aggregatum*.

8. Kanuka with mosses and pasture grasses (grazed).

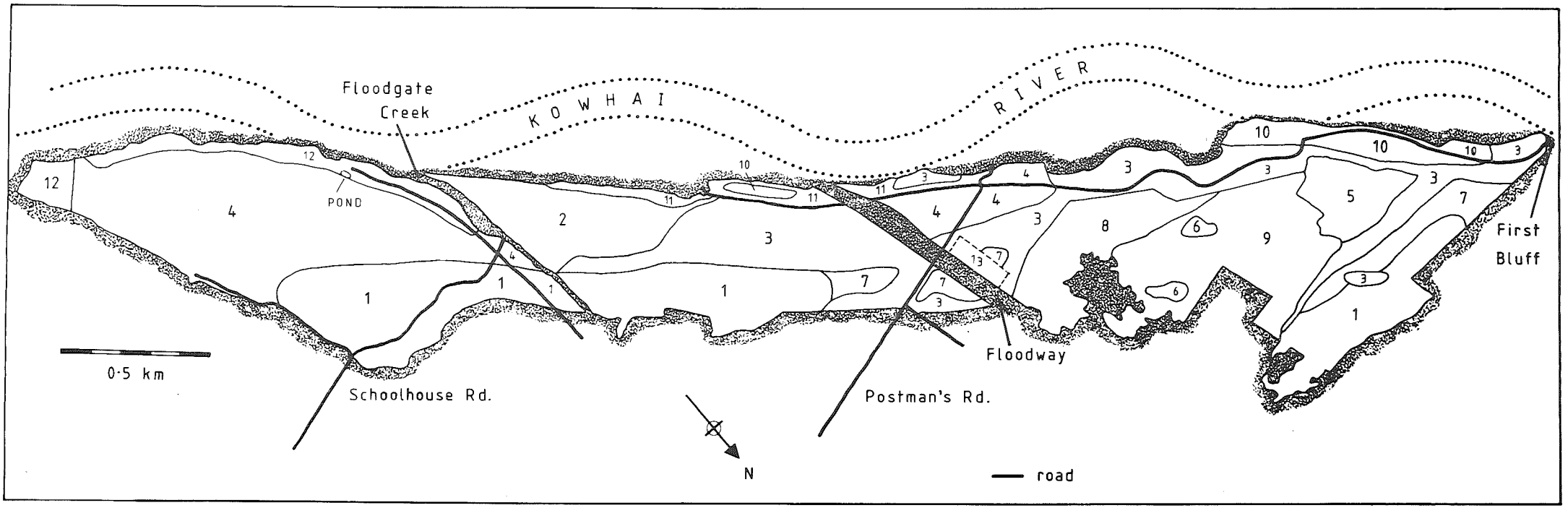
9. Remnants of "old forest" among bracken and grass.

10. Resembles Habitat 2 but with few exotics except broom. Less subject to drought.

11. Planted poplars and willows with gorse and grasses beneath.

12. Large willows, other exotics and some native species.

13. Experimental reafforestation plot of *Pinus*, *Pseudotsuga* and *Populus*.


Floodgate
Creek
KOWHAI
RIVER
POND
First
Bluff
Floodway
Schoolhouse Rd.
Postman's Rd.
0·5 km
N
road

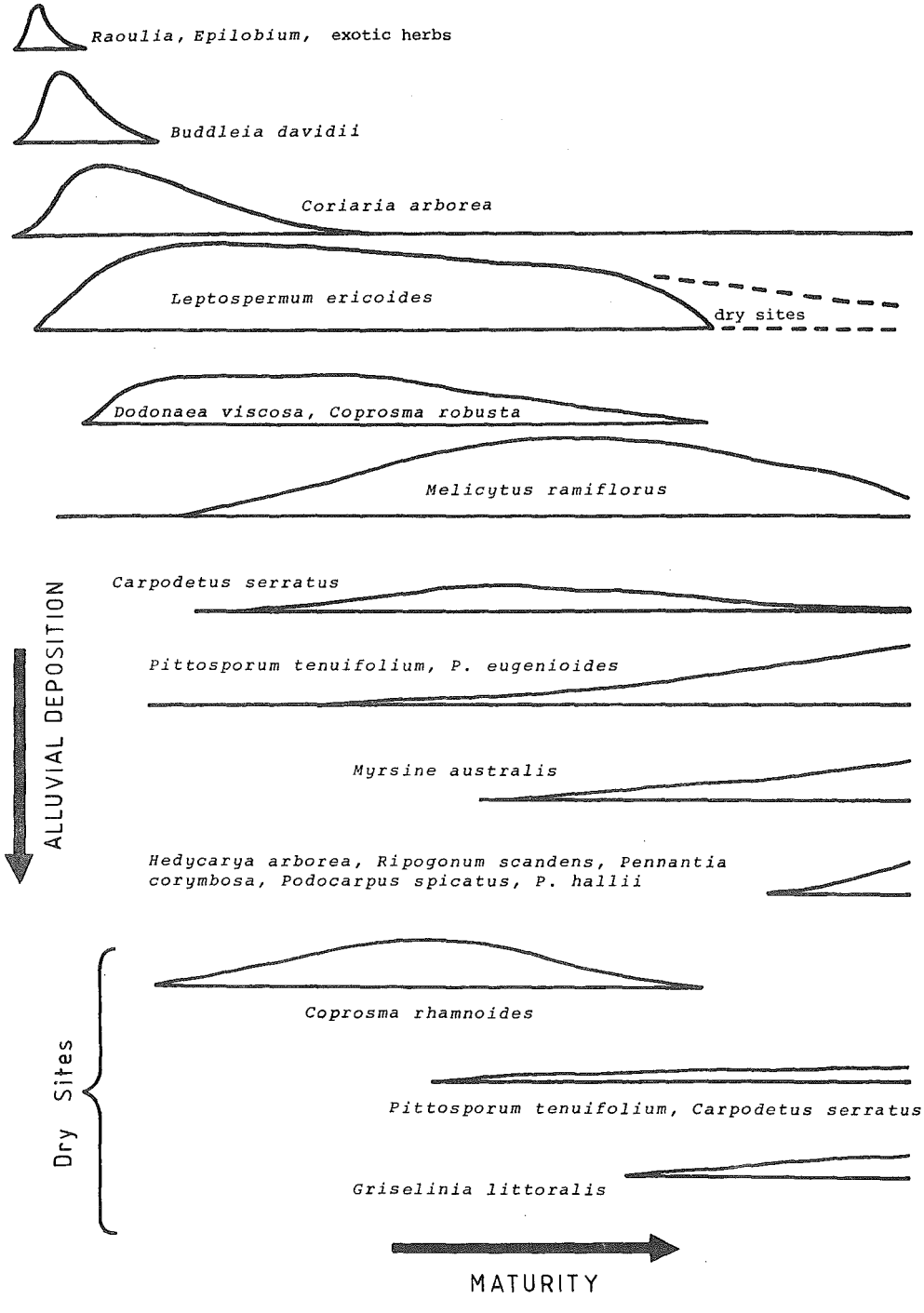


Figure 3 - The main successional sequence on the Kaikoura Plain. Maturity is a function of both time and soil coarseness.

The Successional Sequence

Using the information from Kowhai Bush and the Hapuku Scenic Reserve (12 km north-east of Kowhai Bush, and smaller) the main successional sequence on the Kaikoura flats is probably as follows (Fig. 3).

On newly deposited sands and gravels herbaceous species establish. Typically, species of *Epilobium* and *Raoulia* (scabweeds) are present, along with a number of exotic "weeds". Even in the first year after soil deposition the seedlings of woody plants appear. *Coriaria arborea* and the exotic genera *Buddleia*, *Cytisus* and *Ulex* establish in the first few years. *Coriaria* later overtops and suppresses the exotics. Although seedlings of kanuka and manuka establish on the bare riverbed, most establishment occurs beneath the *Coriaria* canopy. Kanuka subsequently overtops the *Coriaria* and suppresses most of the manuka. Kanuka forms a canopy 6-12 m high which may persist for perhaps a hundred years. Manuka occupies a wider range of habitats in New Zealand than kanuka, and dominates extreme sites (poor soils, high altitudes etc.) in the absence of kanuka. On moderate sites kanuka is longer-lived, potentially taller, and faster growing than manuka, and it eventually suppresses manuka (Burrows, C.J. 1973: The ecological niches of *Leptospermum scoparium* and *L. ericoides* (Angiospermae: Myrtaceae). *Mauri Ora 1:* 5-12). Conditions of soil and climate at Kowhai Bush are such that kanuka competitively excludes manuka (except in parts of Habitat 1).

In the shelter of the *Leptospermum* canopy other plants establish. In the dry stony areas these are graminoids, mosses and lichens. In slightly moist areas small-leaved shrubs occur, typically *Coprosma*, *Cyathodes* and *Corokia*. In still moister areas broad-leaved shrubs and trees establish, principally *Coprosma robusta*, *Melicytus ramiflorus*, *Dodonaea viscosa*, *Pittosporum* spp. and *Myrsine australis*. Less common are *Cordyline australis*, *Pseudopanax arboreus*, *P. crassifolius*, *Sophora microphylla* and *Myoporum laetum*. In the herb layer are found *Uncinia* spp. (hook sedges), the robust lily *Astelia fragrans* and *Phymatosorus*, *Polystichum*, *Asplenium*, *Blechnum* and other ferns.

Describing the final stage of development of forest is more problematical as the evidence is less abundant. The forest is eventually dominated by a mixture of podocarps and various broad-leaved trees. On the drier sites *Podocarpus hallii* and *Griselinia littoralis* dominate. On moist sites *Podocarpus spicatus*, *Elaeocarpus dentatus*, *Hedycarya arborea*, *Pennantia corymbosa* and broad-leaved species from the previous phase are common. *Ripogonum scandens* becomes an abundant liane in this forest. On wet sites a few trees of *Podocarpus dacrydioides* occur.

Podocarps are poorly represented in Kowhai Bush at present and this may be due to relatively few seed trees in the vicinity. Regeneration of podocarps is better in the Hapuku Reserve. Similarly *Elaeocarpus dentatus* is not yet present in Kowhai Bush although mature trees occur nearby on Mount Fyffe. The Hapuku Reserve contains several woody species not present in Kowhai Bush. All are species of lowland coastal forest, indicating that Hapuku is a warmer site, less exposed to southerly winds than Kowhai Bush.

5. INTERRELATIONSHIPS OF KANUKA AND MANUKA

by D.L. Gaynor

In 1974 I examined the density interrelationships of *Leptospermum ericoides* (kanuka), *L. scoparium* (manuka), and various associated understorey plants in a 7 ha section of Kowhai Bush near Schoolhouse Road. Approximately two-thirds of the study-area had a sparse understorey and a canopy completely dominated by *Leptospermum* (Habitat 1; Fig. 2). The remaining part had a very dense understorey, and a canopy and sub-canopy in which *Coprosma robusta*, *Melicytus ramiflorus* and *Dodonaea viscosa* were competing for dominance (Habitat 4). My survey was designed to show how the main species changed with regard to each other, and to explain why the plant composition differed in the two areas.

The densities of *Leptospermum* spp. (taller than 2 m), *C. robusta* (shorter than 1 m), *M. ramiflorus* (shorter than 1 m) and *D. viscosa* (all heights) were significantly positively correlated ($p = 0.05$). The densities of each species, and the overall canopy heights were significantly positively correlated with soil depth ($p = 0.05$). Also, the branching of *Leptospermum* spp. was significantly negatively correlated with soil depth ($p = 0.05$). I concluded that the reduction in soil depth, which possibly increases drought stress and/or decreases the availability of nutrients, was the main reason for the area of less densely populated, heavily branched *Leptospermum*, with very little understorey. The reduction in soil depth appeared to have been caused by gravel deposition during a flood in 1917.

Kanuka (21.4 plants/100 m^2) was dominant in the canopy over manuka (6.4 plants/100 m^2). The lack of a negative correlation between the two species, and the very low densities of manuka, suggest that kanuka dominates because manuka is intolerant of prevailing conditions, rather than because manuka fails to compete. The very low density of *Leptospermum* saplings (1-2 m tall) throughout the area suggests that *Leptospermum* is not regenerating.

6. TARDIGRADES
prepared on behalf of D.S. Horning

The dry, stony, stunted forest of the lower part of Kowhai Bush (Habitat 1; Fig. 2) is rich in mosses, lichens and fungi. These provide suitable habitats for tardigrades, microscopic animals closely related to the arthropods, and otherwise known as "water-bears".

In winter 1975 Dr Horning collected 220 samples of moss, lichen, fungi and other material, both on the ground and at various heights on trees. An unusually high proportion of samples (211) contained tardigrades.

Table 3 shows the average number of tardigrades per sample for various habitats. Samples of leaf-litter, kanuka-bark and fungi (especially sooty mould) had unusually high numbers. At Kowhai Bush there are 21 species of tardigrades in five genera: *Echiniscus*, *Pseudechiniscus*, *Hypsibius*, *Macrobiotus* and *Milnesium*. Three species (*Pseudechiniscus suillus*, *Hypsibius higginsi* and *H. baumanni*) had not been recorded in New Zealand before.

Some tardigrades were parasitised by fungi, an association not previously reported in the literature.

Table 3 - Average numbers of tardigrades per sample for various habitats in Habitat 1 at Kowhai Bush.

Microhabitat	Mean no. tardigrades per sample	No. of samples
kanuka bark	89	5
living grasses	26	30
dry grasses	33	5
ferns	26	20
other vascular plants	34	45
moss	116	35
foliose lichens	130	30
fruticose lichens	82	20
sooty mould	150	5
other fungi	132	5
mixed leaf-litter	119	5
soil	0	5
rock	0	5

7. INVERTEBRATES, AMPHIBIANS AND REPTILES
by B.J. Gill

The invertebrates of Kowhai Bush are largely unknown, but some species have been identified and a few communities studied. Only the most striking or interesting are mentioned here.

Kowhai Bush has two large native molluscs: the slug *Pseudaneitea aspera*, which occurs with its egg-clusters under damp stones and logs, and the snail *Rhytida (Wainuia) edwardi*. The snail is hard to find alive, but clusters of empty and broken shells are sometimes found on the ground. These are presumably the work of song thrushes, which use rocks as "anvils" on which to crack open snail-shells. *R. edwardi* has a restricted distribution in native bush from the Ashley Gorge to the Hapuku catchment. As with many large native land-snails its populations are declining and urgently need protection.

Giant (presumably native) earthworms occur at Kowhai Bush. Mr R.G. Powlesland has seen robins tugging from the ground and eating worms 20-25 cm long.

Spiders are common at Kowhai Bush, and the great diversity of orb-web spinners is apparent, especially during summer. In a revision of a group of small litter spiders, Dr A.D. Blest (1979. Linyphiidae - Mynogleninae. In Forster, R.R.; Blest, A.D. The Spiders of New Zealand. Part 5. Otago Museum Bulletin No. 5) listed *Mynoglenes subdola*, *Promynoglenes parvula* and *Novafroneta vulgaris* from Kowhai Bush. The last two were new species for both of which Kowhai Bush is the type-locality.

Many kanuka-trees (*Leptospermum ericoides*) at Kowhai Bush have small round holes in the trunks, which lead to tunnels and galleries occupied by the tree-weta *Hemideina femorata*. The tunnels are probably excavated by other insects, and merely enlarged and finished by the wetas. Small ground-wetas (*Hemiandrus* and *Isoplectron* spp.) are also found at the Bush.

From December to early May cicadas are vocal at Kowhai Bush, sometimes almost deafening, especially in January and February. Three species have been identified: *Amphipsalta strepitans*, *A. zealandica* and *Kikihia subalpina*.

Of beetles there are several large predatory carabids which shelter by day under logs and debris on the forest floor. *Megadromus wallacei* and *Mecodema fulgida* are hosts to an oxyuroid nematode to be described by Professor W.C. Clark (Canterbury University), and for which Kowhai Bush is the type-locality [see Clark: *Paradoxonema sciadiocara* sp., gen. et fam. nov. (Nematoda: Oxyuroidea): an unusual parasite from the crop of *Mecodema fulgida* (Coleoptera: Carabidae). Journal of Parasitology - in press]. Stick insects (Phasmatodea) are common in the Bush and may reach 10-15 cm long.

Between September 1974 and November 1975 Dr D.S. Horning surveyed the invertebrate fauna of leaf litter within Kowhai Bush. Once a month the litter covering about 36 m^2 of forest floor was collected at a site in each of six habitats. The samples were hung in wire baskets for 18 days and emerging invertebrates fell through a funnel into a jar of ethanol. As expected, diversity

of the litter fauna is highest in the "old forest" and in Habitats 3 and 4 (Fig. 2), and lowest in Habitat 1. More than half the animals in the litter are mites and collembolans. Fly and beetle larvae are also common (the adults, of course, being aerial or arboreal). About 70% of litter animals are less than 2 mm long.

In August 1973 Dr V.M. Stout sampled the small permanent pond near the junction of Floodgate Creek and the Kowhai River (Fig. 2). The pond is about 2 m deep and has clay banks. There are fallen trunks at the bottom and submerged leaves around the edges. The water was grey-green, slightly acidic (pH = 6.4) and highly conductive, suggesting a high content of nutrients, probably the result of organic inputs from surrounding forest. Mosquito larvae were the commonest animals in the pond. Dr Stout also identified two species of cyclopoids (Crustacea), *Simocephalus obtusatus* (Crustacea), a naiad oligochaete, mite larvae and vorticellids.

Kowhai Bush has one species of amphibian, the introduced Australian hylid frog *Litoria raniformis*, which breeds in stock-ponds near the Bush and occurs on the Kowhai river-bed. The only lizard identified from Kowhai Bush is the skink *Leiolopisma nigriplantare*, which frequents tracks and stop-banks but not the depths of the forest. A gecko (probably *Hoplodactylus*) also occurs; Mr Powlesland found one under a stone along a stop-bank. Diurnal tree-geckos (*Heteropholis*) have not been recorded, though elsewhere in New Zealand they associate with *Leptospermum*-scrub. (It is worth mentioning here that an unusual gecko has been found in the vicinity of Kaikoura, more specimens of which are needed before its taxonomic status can be resolved. Distinguishing features are the large size (up to 20 cm long), very long toes, large bulbous eyes and a cross-banded pattern.)

8. ECOLOGY OF BIRDS
by B.J. Gill

Kowhai Bush has a moderate diversity of birds (25 species breed or feed in the forest; Appendix 2), and by New Zealand standards densities are high. Sixteen families in seven orders are represented, eight species are New Zealand endemics, and 11 species (44%) are introduced. Half of the 16 regularly-breeding species are native. All species are resident except the migratory shining cuckoo which is common in summer as a brood-parasite of the grey warbler.

The tui (*Prosthemadera novaeseelandiae*) is absent and the yellow-breasted tit is rare, while their respective relatives the bellbird and robin are common. The former species may be excluded through competition with the latter, or alternatively, the seral nature and particular composition of the forest may be unsuitable habitat for tuis and tits. Kowhai Bush probably provides too few fruits and palatable leaves for the New Zealand pigeon; there is only one breeding record of this species (M. Powlesland, pers. comm.). The long-tailed cuckoo (*Eudynamis taitensis*) is rare (one sighting of a bird flying over the bush; R. Powlesland, pers. comm.) despite the abundance of one of its hosts, the brown creeper.

To assess the habitat-preference of the commonest species, I completed 363 5-minute stationary counts of birds seen and heard (Table 4). I counted about 30 times a month from September 1976 to August 1977, at eight stations in the main block of forest. The data are indices of abundance for single species, and inter-specific comparisons are not valid. Habitat 1 (see Fig. 2) was stunted forest, with an open interior, on stony soils between Schoolhouse Road and Floodgate Creek. The other habitats were adjacent to the river in the forest between Floodgate Creek and the Floodway. Habitat 2 (Fig. 2) has an understorey dominated by *Cytisus monspessulanus*, and Habitat 3 has a diverse understorey. The habitats from 1 to 3 are equivalent to progressive stages in the successional sequence which characterises Kowhai Bush.

Table 4 - Average numbers of passerines of various species seen and heard in 5-minute counts at Kowhai Bush in three habitats (see Fig. 2). September 1976 to August 1977.

Species	Habitat 1	2	3
Rifleman	0.27	0.12	0.03
Brown Creeper	1.89	2.52	0.55
Grey Warbler	0.71	1.03	0.70
Fantail	0.40	0.29	0.16
Robin	0.02	0.55	0.52
Turdus spp.	0.94	0.92	0.92
Silvereye	0.73	0.53	0.70
Bellbird	1.31	1.35	2.14
Chaffinch	0.66	0.37	0.35
Goldfinch	0.85	0.30	0.40
Redpoll	1.84	0.52	0.19
number of counts	122	122	119

Several species apparently prefer early seral stages. Riflemen, fantails and redpolls are decreasingly common from Habitats 1 to 3, and chaffinches and goldfinches are commonest in Habitat 1 and less numerous elsewhere. Brown creepers and grey warblers prefer intermediate habitat (Habitat 2), and the former species is three times commoner in Habitat 1 than in 3. Bellbirds strongly prefer Habitat 3, and robins, effectively absent from Habitat 1, are uniformly common elsewhere. Song thrushes and blackbirds taken together (not strictly valid), and silvereyes, show no preferences for habitat. It is interesting that two of the native song-birds (robin and bellbird), often absent from remnant forest elsewhere in New Zealand, favour mature habitat, while the other endemic species (rifleman and brown creeper) shun Habitat 3.

Systematic observations of feeding-habits showed that grey warblers feed almost exclusively from live foliage whereas brown creepers most often glean food from branches and trunks. Both species feed mostly in the forest's upper understorey, but brown creepers spend a third of their time in the lower understorey. About half the time, both species glean food by perching upright, but each has a specialised mode of feeding. Warblers hover in flight at the tips of branches, and creepers hang upside down from slender twigs. In these ways two closely related species co-exist by minimising competition for food. Both species feed three-quarters of the time from *Leptospermum* (especially *ericoides*), the physiognomic dominant at Kowhai Bush.

Several species of birds frequent the Kowhai river-bed adjacent to Kowhai Bush, and may be seen or heard flying over the forest. Three waders (the South Island pied oystercatcher, *Haematopus ostralegus*; the pied stilt, *Himantopus himantopus*; and the banded dotterel, *Charadrius bicinctus*) breed on the river-bed in spring and summer. Black-billed gulls (*Larus bulleri*) and black-fronted terns (*Chlidonias hybrida*) may also nest there, but not every year.

9. BIOLOGY AND ECOLOGY OF THE SOUTH ISLAND ROBIN
by J.A.D. Flack

From 1971 to 1977, with help from Mr B.D. Lloyd, I studied the population dynamics, breeding, habitat, territory and behaviour of the South Island robin (*Petroica australis australis*) along the forested flats of the lower Kowhai River. Annual productivity, mortality of eggs, nestlings, juveniles and adults, movements of independent young, and changes in territory size and location were among the aspects investigated. In the area between Floodgate Creek and the First Bluff (Fig. 2) all adults and nearly all young were colour banded and most nests were located. Most adults and many young were banded in peripheral areas on both sides of the river, and periodic searches were made to locate dispersing birds.

Robin populations in other localities, especially on islands, exhibit major differences in timing of the annual cycle, length of breeding season, productivity, mortality patterns and population stability. This outline cannot convey the individuality of response apparent in known birds in successive years, nor can it show the differences between habitats, territories, months, seasons and years.

Response to Habitat

While the robins use and appear to benefit from small openings and forest edges, they are highly intolerant of large treeless areas, and reluctant to cross even 100 m of open ground. This limits their ability to disperse between the numerous isolated forest relicts that characterize Kaikoura and many other parts of the species' range. Data from settling patterns of young, boundary display, nesting and feeding locations, and dispersal records, show that the favoured habitats at Kowhai Bush include various types of forest on better soils without extensive coarse ground cover. Every territory contains some edge created by clearings or old tracks, and these are frequently used. Habitats clearly selected against, are those with widely scattered trees, or those where large areas of the ground are dominated by various coarse monocots or sparse vegetation on harsh, droughty soils. Steep hillsides and mountain slopes are also selected against. When rank pasture grasses grow tall in open forest following exclusion of stock, robins end or greatly reduce their use of such areas and suffer higher mortality than in other habitats.

Territory and Breeding

Pairs remain together all year, having a bond in which males dominate females. However, pairs vary in the tolerance and degree of dominance of the individuals. New pair bonds can develop within 24 hours of the loss of a mate, or sometimes require several weeks of courtship. Few pairs separate, and mortality is the major cause of mate changes. Robins of both sexes participate in defence of territory, with the males' role being the more prominent. Adults are sedentary, but a few may suddenly resettle in a new locality, usually an area used

previously by the bird while a juvenile or immature. Territorial boundaries can remain stable for years or alter suddenly or gradually. Territory size varies from about 0.5 ha to over 5 ha. Boundaries are usually distinct for small territories, but they can be indistinct when a large area is covered. Size can alter radically on average or for particular pairs between years. These features and several others show this species to be less rigid in behaviour than definitions of territory imply. Established adults move through other territories, at their peril, to reach bathing pools; they occasionally feed in each other's territories, unnoticed in the dense vegetation; during their post-breeding moult adults are not able to defend territory from young of the year; owners of territory can be partially or totally displaced by invading young; dominance hierarchies are sometimes noticeable among several individuals trying to settle in the same area, and occasionally between established pairs or unmated adults.

Age of first breeding is usually 8-12 months (once 4½ months for a male), but for some males and females on islands it may be two years. Egg laying (and successful rearing of young) has occurred in every month from mid-May to early January. Regular breeding begins with the first clutches in August, sometimes July, and ends with last clutches in mid or late December. Moult begins in early December for bachelor males, while breeding birds show large variations in the onset of moulting, through to late January. By late February, feather development in many older independent young is complete and it is no longer possible to distinguish them from adults.

First clutches comprise mainly two eggs, especially clutches belonging to young of the year, while three and occasionally four eggs are laid in most subsequent nests from September until November, when two egg clutches may again become common. Individual pairs may raise three, rarely four, broods each season. Most pairs produce more than three and up to six clutches in a season as a result of renesting after losses. Mean clutch size for a season varies slightly around 2.75.

The rearing cycle is long, and occasionally subject to further lengthening during severe weather when time spent nest building, the interval before laying, and even growth of nestlings, can be drawn out considerably. The incubation period may also vary slightly. Normally, about a week to 10 days elapses between beginning nest construction and beginning incubation. Eggs are invariably laid at just over 24 hour intervals. Incubation takes about 18 days, usually beginning with the last egg, but sometimes starting with the second egg in three and four egg clutches. Thus hatching may take 48 hours, although most young hatch during a few hours. If not disturbed, young leave the nest after 20-22 days, although I have recorded an interval as long as 26 days, after cold winter periods when weight increase and feather development had been retarded. Normally, nestlings begin to open their eyes at 9-10 days and reach the range of adult weight by their 13th day. The development of the escape response begins as early as the 14th day, but usually is not well developed until about the 18th day. Feather development is normally inadequate for short flights until 21 days. Parental care continues for 4-7 weeks after fledging. Usually, hunting behaviour does not begin until 15-17 days after fledging. Females normally care for fledglings for much shorter

periods than males, usually delaying renesting activities for only 1-2 weeks. Sometimes female care of juveniles extends for several weeks to a month, particularly for large broods, or during severe weather, but occasionally it ceases immediately after the young leave the nest. Renesting is also delayed by losses to predators. The male continues to care for or tolerate his juveniles until the next clutch is hatched by his mate. There is sometimes a noticeable difference between juveniles in their willingness to become independent. Thus, the age of independence varies.

Mortality Patterns

During six breeding seasons at Kaikoura, 521 nests were visited regularly. Thirty-two per cent yielded at least one fledgling, 13% failed or were abandoned, and 55% were destroyed by predators. Stoats and weasels were the most important cause of failure in all years, accounting for nearly 40% of all nests. Ship rats destroyed 9% of all nests, but their importance varied widely between years and habitats. A few of the losses attributed to ship rats were probably due to mice and possibly Norway rats. Various types of evidence indicate that rats blunder on to nests, while mustelids find them by active search. This results in much higher losses of nestlings than eggs. Opossums occasionally blunder on to and squash nests, possibly sometimes eating contents, and cats may destroy a few low nests.

Survival after fledging and before independence is usually high, sometimes reaching 85%. Following independence, survival to first breeding is highly variable (10-90%) between years.

Survival of adults varies around 70% per year, showing a regular seasonal change. During the five months of the regular laying season the highest survival rates are normally recorded, and survival is also high during the short winter and during the summer moult. Over 50% of adult losses occur during the autumn, at the time when the young of the year are competing for space with adults emerging from moult. A test of this occurred in 1976 when there were almost no independent young joining the population; very little adult mortality occurred that autumn or winter.

The causes of mortality of independent birds are known for only a few individuals that were dragged off nests by mustelids or killed or injured in defence of nests. A few females were killed by ship rats at night while incubating eggs. Robins are not easy prey for mammals, having the quick reactions of fly-catchers. Predators are recognized and treated with alarm, while cattle and humans, and probably moas at an early time, are followed to take advantage of the invertebrates that they stir up.

Pox virus has been identified from lesions on robins at Kaikoura (J.A.R. Miles and F.J. Austin, pers. comm.), and it infected more than 10% of young birds during two seasons, 1971-1973, severely affecting some. Survival of affected birds was much lower than for those unaffected. Since that time it has been recorded infrequently.

Losses of eggs and nestlings to rodents were significantly greater in mature forest than in all other habitats. A large

proportion of losses to rodents not actually in mature forest occurred at its fringes. This pattern of mortality merits further investigation in other localities, because its implications are considerable for understanding local extinctions.

Population Change

The entire robin population on the flats of both sides of the Kowhai River fluctuated considerably from 1971, but change in different sections was often out of phase. The smallest fluctuations occurred in the area from Floodgate Creek to the First Bluff. This area has two important assets significant to population change. The habitat forms a continuous belt and much of it is of high quality. All other areas are broken into patches of variable quality, isolated from each other by unsuitable vegetation, riverbed or open land. The populations of various peripheral areas occasionally go to or near extinction. Dispersal records show these areas to heavily depend on immigrants from the large central area. The August population in the central area varied from 16 to 44 pairs between 1971 and 1978. The population was largest in 1971 and 1975, and smallest in 1973 and 1978. Even excluding the low of 1978, this population is much less stable than island populations.

The mechanisms that cause population change are complex. Important factors include:

1) High potential production, which when realized, provides a sudden influx of young that contributes heavily to adult mortality in autum.
2) The absence of a surplus of birds that can replace established adults that die during late winter, spring and early summer.
3) Sedentary behaviour which sometimes results in vacancies remaining unfilled even while an excess of robins contest for space elsewhere.
4) Low immigration.
5) Occasional years when survival of independent young is extremely low.
6) Occasional years when high losses of eggs and nestlings to predators and bad weather combine to severely limit production.

Since annual adult mortality usually remains fairly constant, factors causing it to rise would have a large impact on population change. Such factors include habitat destruction, poisoning and trapping for mammals, and large increases in populations of predators. The widespread occurrence in New Zealand of local extinctions of robins well into this century could be attributed to different single causes in different localities (pox epidemics, heavy mortality during rapid growth of rodent, mustelid and cat populations to levels well above those present today, or even food scarcities resulting from predation by those mammals on the large invertebrates important to robins). It is likely that combinations of these factors have operated together in some localities. The local extinctions that occur today are

attributable to single causes on islands, but the isolated populations of the mainland with their limited ability to disperse are likely to succumb when several factors that usually are absent or function independently combine by chance to operate in one or several years.

10. VOCALISATIONS OF THE SOUTH ISLAND ROBIN
prepared on behalf of R. Hay

During the 1972-73 and 1973-74 breeding seasons Mr Hay catalogued the vocalisations of robins (*Petroica australis*) at Kowhai Bush, and undertook a detailed study of vocal development and the production of, and variation in, song (Hay 1975).

Continuous sounds produced by robins vary in length from 0.02 to greater than one second, and in frequency from less than 1.5 to greater than 9 kHz. There are 18 different calls that may be grouped into four categories, as follows:

"Chucks". Syllables of short period and large frequency range given singly or in groups. These are the most common sounds produced by robins. There are six calls in this category, including a click made by snapping the mandibles together, and they are associated mainly with aggressive situations.

"Squeaks". Syllables of long period and narrow frequency range. Four calls are involved - the begging calls of young and mature nestlings (both may be given by a nestling of intermediate age), the hunger call of fledglings, and an adult "squeak" given during mildly aggressive encounters.

Harsh sounds. Calls of long period and broad frequency range, often with marked frequency modulation. The three types are the begging calls of juveniles and adults, and distress calls.

Complex sounds. Calls composed of several syllables of more than one of the above kinds. There are five types of call in this category. The "downscale" is a loud, short, individually variable call which gives other robins clues to the caller's location and identity. Feeding phrases are short segments of song given by adults (both sexes) before feeding juveniles, and by males before feeding females. Another example is full song.

Full song is given by adult males from April through autumn and winter to early spring. Robins rarely sing thereafter, and adults do not sing during the post-nuptial moult (January to March). However, during the moult immatures practise the song and it gradually develops adult qualities. The developing song is influenced by the songs of adults in surrounding territories. A juvenile will drop syllables not present, and adopt others present in songs heard in the vicinity. After the moult, bachelors sing more than paired males, probably to attract a mate.

Full song is an organised series of phrases taken from a total repertoire of 114 different syllables. Individual adults give 19-36 syllables. Bouts of song are normally continuous and stereotyped; syllables are ordered non-randomly. Variation in song is not spatially consistent within Kowhai Bush, but different populations of the South Island robin have distinguishable dialects (two populations may each have syllables not common to both). The tit (*Petroica macrocephala*), which occurs rarely at Kowhai Bush, has a shorter and more stereotyped song than that of robins.

11. TIME-BUDGETS OF THE SOUTH ISLAND ROBIN

by R.G. Powlesland

The way in which a species allocates time between various activities is important for its survival and success. A time-budget is an account for a species or population, of the allocation of time between its behavioural activities.

In August 1976 I began compiling time-budgets of the South Island robin's behaviour by observing individually colour-banded and known-age robins at Kowhai Bush and on Outer Chetwode Island (Marlborough Sounds). All activities were timed. They included foraging, vocalisations, body-maintenance behaviour (preening, bathing, scratching, stretching, sunning, etc.), interactions between members of a pair, interactions with other robins, interactions with other species (birds and mammals), nest-building, incubation, and the brooding and feeding of nestlings. Some activities were broken down further into categories which were timed separately. For example, vocalisations comprised full song, sub-song, downscale calls and chucking calls.

In compiling the time-budgets, I divided each day into six equal periods, the length of which varied from month to month with changes in day-length. This method allowed detection of diurnal rhythms for any activity. The activities of robins were timed with a stop-watch as I followed them closely about their territories. Nest activities were recorded at a distance of about 10 m, without a hide.

During the non-breeding season (January to July inclusive), robins gradually spend more of their foraging time locating food on the ground. Foraging time on the ground is lowest during February and March (40%) when cicadas and other arboreal invertebrates are plentiful, but increases to 70% by July. Early in the non-breeding season robins spend 50% of their foraging time perched at suitable vantage-points surveying the surrounding area for food. This type of foraging, called scanning, decreases to 25% by July. Foraging also involves hawking, flycatching, gleaning from trunks and branches, and storing surplus food. Earthworms are the most frequently stored prey. Items are usually hidden during the morning and retrieved in the late afternoon. The storage of excess food is a short-term process; most items are retrieved within two or three days. Indigestible portions of prey and seeds are cast as pellets (Powlesland, in press). The monthly rate of regurgitation is highest during the summer when cicadas form a large part of the diet.

In January, adult robins spend approximately 70% of their day foraging, but by July this activity increases to 90%, due to the shorter day-length, colder temperatures and probably the reduced abundance and activity of invertebrates. During the moult, from January to April, vocalisations are mainly the down-scale call which lasts only a few seconds. Females spend less than 1% of their time calling, and males about 4%, during the moult. However, once the moult is over, males begin giving full song. Full song advertises that the territory is occupied, and attracts unpaired females. By July paired males spend about 2% of their time singing whereas bachelors spend about 30%. Robins devote more time to resting and body-maintenance behaviour once breeding is completed and while moulting, than at any other time.

Each involves about 10% of their time, but this amount gradually declines to 2% by July. During the moult most robins are secretive and do not dominate intruders that enter their territories. However, once the moult is over, males evict intruders vigorously and dominate their mates. Many females at this time are found in areas of the territory rarely visited by the male. The time involved in intra-specific and pair-interactions increases from about 1% in February to 2.5% in April, when males reassert their dominance over intruders and their mates.

Inter- and intra-specific interactions of robins occur randomly throughout the day, but other activities show a distinct diurnal rhythm. During the longer days of January and March two peak feeding times occur (mid-morning and mid-afternoon). However, in winter (July-August) foraging tends to occur almost continuously throughout the day. Vocalisations occur mainly during the first two periods after sunrise. Resting and body-maintenance behaviour occur mostly about midday when foraging is minimal.

In general, robins breed from late July until January. During these months, bachelors spend nearly a third of their time singing, to attract a mate, and about 55% foraging. Paired males usually spend less than 10% of their time giving full song, but it varies according to the stage of their breeding-cycle.

Only the female robin builds the nest. Building takes as little as a few hours if she relines an old nest, or up to several days if a complete nest is constructed. About 37% of nests are built in old song thrush, blackbird and robin nests. Males spend about 75% of their time foraging while their mates are building. This is a larger proportion of time than for bachelors, because the paired males feed the female. Females spend about 38% of their time foraging, and use nearly all the rest to find suitable nest material, take it to the nest and incorporate it.

Once the nest is completed, a prelay stage of about four days occurs. Compared with the nest-building stage, males reduce the proportion of time spent foraging to 68% and increase the time spent singing to 15% (6% while the female is nest-building). Females feed for long periods during the prelay stage (72%), with the remainder of their time devoted mainly to resting (10%) and to body-maintenance behaviour (14%), especially preening.

Female robins lay their eggs on consecutive days and most clutches are of two or three eggs. During the laying stage, the males spend only about 5% of their time singing, a marked decrease from 15% during the prelay stage. However, the amount of time spent foraging increases to 74% and body-care behaviour takes up about 12% of their time compared to 6% previously. The laying females spend less time foraging (62%) and in body-care behaviour (10%) than during the previous breeding-cycle stage. Some females begin incubating before laying their last egg and this involves 14% of their time at this stage.

Female robins do all the incubation, which involves covering the eggs for about 80% of the day. Of the remaining time, most is devoted to foraging (13%) and body-maintenance activities (4%).

The female relies, to a large extent, on her mate for food. During the incubation stage males spend more time foraging (79%) and less time singing (2%) and preening (7%) than during the laying stage.

Once the nestlings hatch, the time-budgets of parent robins vary considerably depending on the number and age of the nestlings. The nestlings are brooded by the female and she spends about 50% of her time brooding and feeding her young and keeping the nest clean. Forty-five per cent of her time is spent foraging. Male robins more frequently visit the nestlings with food than females, and spend about 83% of their time finding food. During this stage the males again reduce, in comparison with previously, the time spent singing and preening (1% and 3% respectively).

After the nestlings fledge, and while they are dependent upon their parents for food, the male spends 79% of his time foraging. About 4% of his time is devoted to both singing and preening. The female, with no need to attend the nest, increases the proportion of her time spent foraging to 82%. Male and female robins feed specific juveniles. If an odd number of nestlings fledge, usually the male looks after the extra one. Once the female begins nest-building again, and especially when she starts incubating the next clutch, her juvenile(s) are fed by the male, if not yet independent.

12. BREEDING OF THE GREY WARBLER AND SHINING CUCKOO

by B.J. Gill

I studied the breeding of grey warblers (*Gerygone igata*) during three summers (August to January 1976/77 - 1978/79) by finding nests and visiting them regularly. This yielded data on eggs and nestlings, and revealed details of brood-parasitism by the shining cuckoo (*Chrysococcyx lucidus lucidus*). I colour-banded adult warblers that I caught in mist-nets, and nestlings, to create a population of marked birds individually recognisable at a distance in my main study-area near Schoolhouse Road.

Only male warblers sing, and only females build nests, incubate eggs and brood nestlings, so the sexes are easily told apart. During breeding warblers hold territories at Kowhai Bush of (on average) 0.45 ha in Habitat 2 (dense forest; Fig. 2) and 0.92 ha in Habitat 1 (stunted forest). Thus density is about three breeding warblers per ha, and the total adult population at Kowhai Bush is probably over 700.

Adults are sedentary all year, though territoriality weakens during autumn and winter, during which time warblers occupy overlapping home ranges. Only about 20% of breeding adults die each year, and the average life-expectancy of adults is nearly five years. Fledglings survive well while cared for by their parents, but once independent, juveniles disperse from the natal area and only a small proportion (about 5%) are recruited to the breeding population.

Warblers raise up to two successful broods per season, but will re-nest if a previous clutch or brood fails. Warblers take 2-4 weeks to build early nests and delay 2-8 days between building and laying. Later in the season these periods are shorter. Building occurs between late July and late November. The nest is enclosed with a small entrance (3 cm in diameter) at one side. Most entrances face east at Kowhai Bush, away from the direction of prevailing winds. Nests are 3.5 m above ground on average, and most are built in trees with leaves less than 2 cm long - especially in kanuka, gorse and Montpelier broom. Warblers tend to build closer to the canopy in Habitat 1 (no understorey) than in the denser Habitat 2.

Warblers lay at Kowhai Bush during 15-16 weeks from late August to late December. An unusual property of the species is that eggs of a clutch are laid on alternate days. Warblers nearly always lay four eggs (clutches of three or five occur, but rarely). The incubation period is 17-21 days and the nestling period 15-19 days. At Kowhai Bush nestling warblers are fed mostly on caterpillars which defoliate kanuka. More than 40% of items fed to nestlings 10 days or older are only 1-5 mm long. Parents feed fledglings for up to 35 days.

Of nests receiving eggs, only 42% yield one or more fledgling warblers. Seventy per cent of warbler-eggs hatch and 38% yield a fledgling. Fifty-four per cent of nestlings fledge. Predation by mammals is the greatest single cause of mortality of nestlings.

Shining cuckoos are migratory, and allegedly spend the New Zealand winter in the Solomon Islands. They are first seen or heard at Kowhai Bush in late September or early October, and last noted in mid-March. One cuckoo which I banded as a nestling in December 1976, was present and possibly breeding a kilometre from its natal area in November 1978, suggesting a return to natal sites.

Shining cuckoos at Kowhai Bush are rather few and far between. The banded cuckoo that I saw occupied at least 8 ha of forest, that embraced nine warbler-territories. From other considerations I estimated that a female cuckoo at Kowhai Bush requires for her reproductive activities at least 20 ha. Thus, perhaps only 12 females breed in Kowhai Bush as a whole.

In parasitising a warbler's nest the cuckoo lays a single egg that is apparently swapped for one of the host's, such that the total clutch-size remains unchanged. Cuckoos may lay from the day of the warbler's penultimate egg to at least seven days after the warblers start incubating (upon completing their clutch). The cuckoo's egg is only fractionally larger and heavier than the warbler's.

Cuckoos lay during 10 weeks at Kowhai Bush, from mid-October to mid-December. Thus they begin laying seven weeks after warblers do, and the latter's first clutches escape parasitism. The average frequency of parasitism is 55% of late nests.

The cuckoo's incubation period is 13-17 days and the nestling period 19 days. Three to seven days after hatching the nestling cuckoo evicts all eggs or other nestlings from the nest. The growth of nestling cuckoos is rapid; the maximum average daily increase in weight is nearly 3 g. Seventy per cent of cuckoo-eggs hatch and 52% yield fledglings. Seventy-five per cent of nestlings fledge.

Parasitism has little effect on the reproductive success of warblers. I calculated that cuckoos prevent only 17% of warbler-eggs in late nests from surviving to fledging. Age for age, a nestling cuckoo is equivalent in weight to only two warblers for the first nine days, then it increases to the weight of approximately three. Warblers feed a nestling cuckoo less often on average than broods of three or four warblers, suggesting that a cuckoo involves the foster-parents in less effort than unparasitised broods of normal size.

13. BREEDING OF THE SOUTH ISLAND FANTAIL

by M.H. Powlesland

I studied the breeding of the South Island fantail at Kowhai Bush in 1976 and 1977. Breeding begins in August-September and continues until January-February. A pair of birds can raise two and sometimes three successful broods in a season. However, most pairs have one or more unsuccessful nests, usually due to predation by mustelids or rodents, and in these cases up to five nests may be attempted. Both sexes take part in all nesting activities: building, incubation, feeding and brooding nestlings, and feeding fledglings.

Building of the first nest may take more than 15 days, but building-time decreases for later nests, and may be as short as three or four days. There are often false starts (perhaps due to bad weather), when a site is chosen and a small amount of building done, then the site abandoned for another. Nests are commonly built upon several thin branches and are usually sheltered from above by foliage. The main building materials are moss, wood-fibres and cobweb with a lining of dried grass, rootlets, moss-setae or some other fine material. Plants most frequently built in are mahoe (*Melicytus ramiflorus*) and kanuka (*Leptospermum ericoides*), although a large number of other species are also used. Nest-height is 0.8 - 6.5 m with most nests between 1.5 m and 4.5 m.

Egg-laying commences a few days after completion of the nest, the length of the prelay period decreasing over the season. Eggs are laid daily. Clutch-size varies from two to five, though clutches of two could arise by loss of an egg from a three-egg clutch. Average clutch-size for the two years was 3.4 (116 clutches). Clutch-size varies over the season, most of the first clutches being three with an increasing number of four-egg clutches in subsequent nests. A slight decrease in clutch-size occurs towards the end of the season. Monthly averages for the two years together were: September 2.9 (18 clutches); October 3.2 (32 clutches); November 3.7 (40 clutches); December 2.8 (23 clutches); January 3.0 (3 clutches).

The birds are usually seen on the nest on the day the second egg is laid, and occasionally on the day of the first egg, but calculations of incubation period were taken from the laying of the last egg. On this basis incubation periods were 13 days (two clutches), 14 days (16 clutches), and 15 days (five clutches) Seventy-seven per cent of eggs hatch (n = 84 clutches where the number hatched was known).

Brooding is frequent while the nestlings are young but decreases as they get older and is rarely observed close to fledging. The length of the nestling period was determined accurately for nine broods; it varied between 12 and 14 days (12 days for six broods, 13 days for two broods, and 14 days for one brood).

Forty-two per cent of eggs survive to produce fledglings. For the first few days after fledging juveniles rely solely on the parents for food and spend much of the time perched together, although they are capable of rapid movement if disturbed. As they get older they spend more time flying and begin catching

food themselves. It is not known how long the adults continue to feed the young; in one case feeding was observed 24 days after fledging. It is often difficult to find the juvenile-groups, especially when they become more mobile, and in some cases I did not see the juveniles at all after they fledged. In other cases the family groups moved considerable distances from the nest site, and they sometimes came in contact with other groups. Occasionally a juvenile from one group joins the other group and is fed by the adults. This can be detected if at least one group is colour-banded, or if the juvenile is of a different age to the other juveniles (indicated by tail-length). In one case where the intruding juvenile was of a similar age to the others it became established in the group and may have survived to independence. However, where the intruder is significantly younger it usually disappears after a few days.

The time taken to recommence nest-building after fledging varies, being longer (up to 18 days) earlier in the season than later (sometimes as short as one or two days). The same nest may be re-used (though not more than once) in which case it is re-lined and added to. Fourteen out of 152 nests found over the two seasons were re-used. Sometimes the new nest is built a considerable distance from the previous one.

In 1976, 39 nestlings and one adult were metal-banded and another 22 nestlings were colour-banded. Of these I saw only one, a metal-banded bird, in the breeding population in 1977. I caught and banded 40 adults during autumn and winter 1977, and found six of these on territories in the area during the 1977 breeding season. Four adults and 111 nestlings were colour-banded in the 1977 breeding season, of which only a couple were seen during the 1978 breeding season. Clearly, the turn-over of birds is exceptionally high.

14. MAMMAL POPULATIONS
by P.J. Moors

All species of mammals at Kowhai Bush (Appendix 3) have been introduced to New Zealand since European colonisation. Several, notably rodents and mustelids, have been blamed for declines in the numbers and distributions of native bush birds, but relatively little is known in this country of their biology or impact as predators. My study with Dr Flack (Section 15) on the effects of introduced predators on bush birds, especially the South Island robin, required information on seasonal changes in abundance of these mammals. The only satisfactory census technique which could be applied to the several species involved was the use of tracking tunnels: animals passing through them in either direction leave their footprints on chemically treated papers. In June 1974, 40 tunnels were laid under piles of logs, litter and stones at 100 m intervals along tracks through the main block of forest. Nine more tunnels were installed in June 1975. They were inspected fortnightly from July 1974 until August 1977, and papers with tracks were collected and replaced.

Potential predators of arboreal nests at Kowhai Bush are mice, ship rats and mustelids (stoats and weasels), and tracks from these three groups, as well as those of hedgehogs, are readily distinguished. A monthly tracking index for each of these four groups was calculated from the numbers of their tracks per "tunnel day" (no. tunnels operating x no. days since last inspection). Changes in indices for the groups are assumed to parallel changes in abundance. Detailed descriptions of the tracking technique are given in King and Edgar (1977) and Moors (1978).

Most tracking papers were marked by only one species, although there were frequently several tracks in one tunnel. Whether multiple tracks were due to several individuals, or to one animal passing repeatedly through the tunnel was unclear. A total of 1,972 sets of tracks was identified, with an average of 26.3 sets collected at each inspection from an average of 22.6 tunnels. Mouse tracks were most common (59%), followed by those of rats (17%), hedgehogs (12%), and stoats and weasels (11%). Insects (probably mainly wetas) were often recorded, as were ferrets and birds occasionally. The numbers of rat and mouse tracks are apparently unrelated, whereas there was a tendency for rodent tracks to be fewer in tunnels with higher numbers of hedgehog tracks. Stoat and weasel tracks show no consistent relationship with numbers of other tracks.

The monthly tracking indices are presented in Figure 4. Mice exhibit the highest monthly indices and the greatest seasonal amplitude, presumably as a result of their ability to increase their density rapidly. Indices for mice, and to a lesser extent rats, undergo annual cycles with peaks in late autumn and troughs in late spring. This pattern is similar to that known to occur in rodent populations elsewhere in New Zealand, and supports the assumption that the index is proportional to abundance. However, the index is also influenced by other factors, such as behaviour. For example, in August 1975 strong winds damaged parts of Kowhai Bush and altered the availability of foods for mice, which were forced to alter their

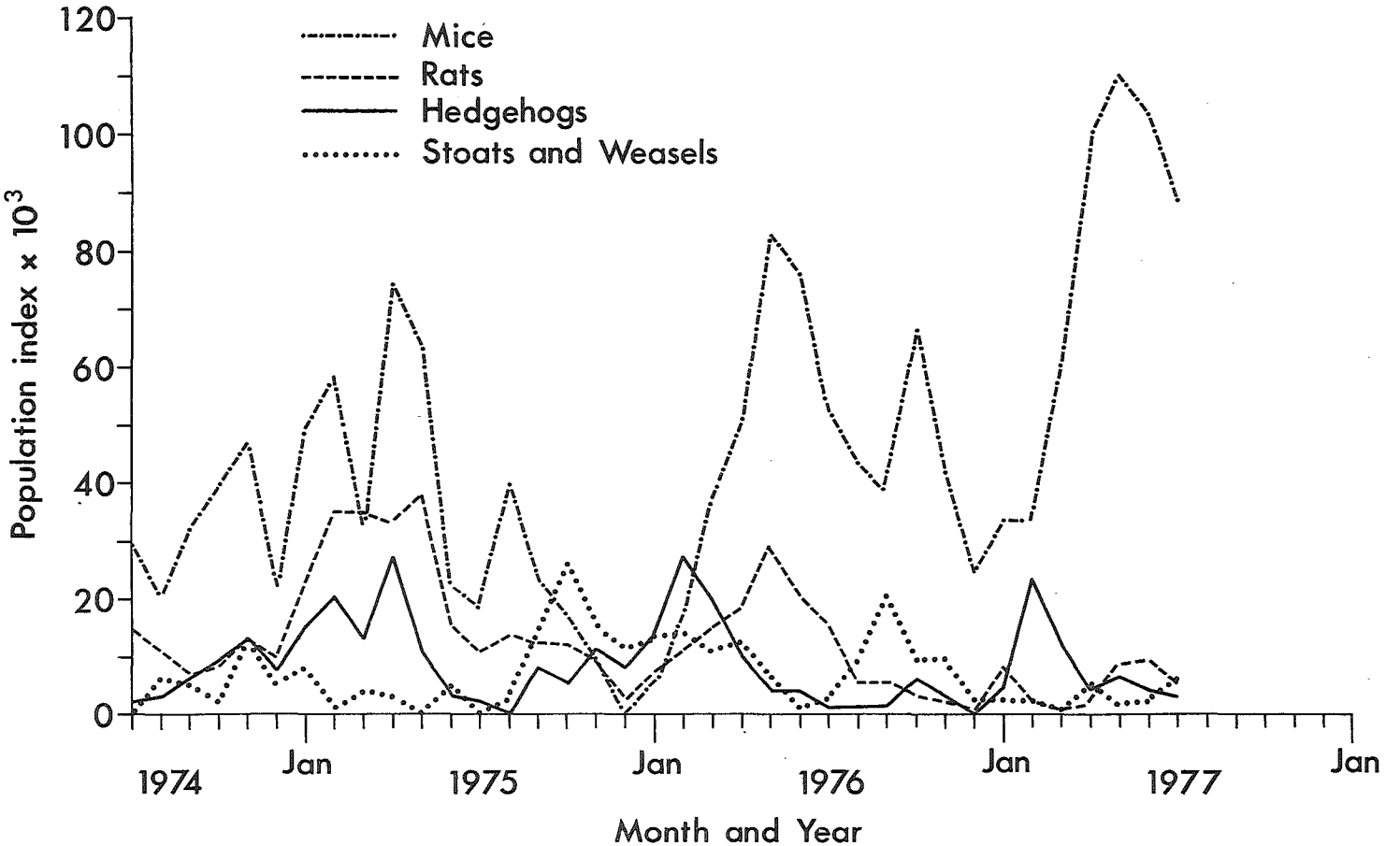


Figure 4 - Monthly tracking indices of mammals at Kowhai Bush.

foraging activities. This resulted in a temporary increase in their tracking index for that month. Similarly, a minor flood in March 1975 was probably responsible for the reduced mouse index, because some tunnels were isolated on small islands.

In 1975 and 1976 there were clear peaks in the mustelid index in spring, when adult stoats and weasels bred, and juveniles became independent. Thereafter the indices declined to low, but fluctuating, levels. Tracks cannot be used to estimate the relative abundance of these two species because their footprints cannot be reliably distinguished (male weasels and female stoats are similar in size). During most of the year there are probably few resident mustelids in Kowhai Bush because even weasels, the smallest mustelid, have ranges up to 16 ha in area (Corbet and Southern, 1977. The Handbook of British Mammals. 2nd ed. Blackwell, Oxford).

The tunnels were too small to admit ferrets comfortably, and the low numbers of their tracks do not necessarily reflect scarcity. Hedgehog indices show regular annual cycles. Highest values were usually in February, after which there was a rapid decline to low levels in winter and a subsequent increase in late spring. The peak indices presumably reflect the higher numbers after the breeding season and possibly greater activity before hibernation, which accounts for the winter decline. However, hedgehogs at Kowhai Bush do not seem to hibernate throughout winter; a few are usually active, even in mid-winter.

Tracks also provide an estimate of the distribution of mammals in the main habitats of Kowhai Bush. Mouse tracks were common in tunnels in all habitats, with no clear preferences. Rat tracks were conspicuously clumped: there were few (1.6 per tunnel from nine tunnels) in the simple *Leptospermum* forest (Habitat 2; see Fig. 2), but high numbers (15.4 per tunnel from nine tunnels) in the mature broad-leaf forest and nearby intermediate-aged forest on good soils (Habitats 3 and 4). Stoat and weasel tracks occurred in low numbers throughout Kowhai Bush, with no preferred habitat. The number of their tracks did not necessarily increase in habitats where rodent tracks were common. Hedgehog tracks tended to be common in areas with an open understorey, or which adjoined paddocks or grassy clearings.

No detailed information is available on the abundance or distribution of other mammals, although sightings and other evidence of their presence suggest densities of most are relatively low. Rabbits are shot or poisoned at intervals by the local Pest Destruction Board, and a few opossums are trapped for their fur. Browsing by opossums is light and has had little effect on the vegetation. Lagomorphs are most common in the stunted open forest (Habitat 1).

15. PREDATION BY MAMMALS ON EGGS AND NESTLINGS OF BIRDS

by P.J. Moors and J.A.D. Flack

Flack (1973) showed that a large proportion of nests of South Island robins at Kowhai Bush are plundered by introduced mammalian predators, and that other birds suffer similarly. The signs of predation left at nests fall into a few easily defined groupings, so we initiated studies to identify the predators involved with greater certainty. Thus we hoped to assess their relative importance, and estimate their impact, particularly on robins (Moors 1975).

Our data came from information collected by P.J.M. on the predator populations (1974-77; Section 14), from a study by P.J.M. of predation on the nests of several bird species (December 1976 and 1977), and from detailed observations by J.A.D.F. and Mr B.D. Lloyd on the robins (1971-76; Section 9). Knowledge of the outcome of hundreds of nests was supplemented with laboratory feeding trials, and tracking tunnels installed on nest trees (Moors 1978). The identity of predators was established from tracks left in tree tunnels, or inferred from remains in nests (Flack and Lloyd 1978; Moors 1978).

Twenty-five tunnels (16 in 1974; 9 in 1975) were installed on trees containing robin nests. Eight nests (7 in 1974; 1 in 1975) were robbed by predators, but tracks were left at only four: in 1974, two sets by mustelids and one by a mouse; in 1975, one by a rat. The mouse preyed on a clutch of three eggs and the others on nestlings. In both years nests in trees with tunnels were more successful than those without, presumably because predators shunned the tunnels. Consequently none was installed after October 1975.

Two main classes of sign were left at plundered nests. Most commonly the nest itself was undisturbed, and no remains, or only cleanly sheared fragments of eggs or nestlings, were left. These contrasted with "messy" predations in which shattered or partly eaten eggs or nestlings were scattered about the nest and the nest lining was disarranged. Laboratory feeding trials showed that rodents were responsible for the latter type of predation. Most rodent predations were probably by ship rats, which are agile climbers; mice would be handicapped by their small size, and Norway rats (if they occur at Kowhai Bush) are almost entirely terrestrial. Mustelids kill their prey rapidly and cleanly, and carry them off for consumption elsewhere. Therefore the former type of predation was ascribed to stoats and weasels (ferrets do not climb).

The fates of 626 robin nests and 111 other nests are presented in Table 5. The per cent predation was uniformly high: 44-66% for robins and 58.6% on average for eight other species of birds. Stoats and weasels are the most frequent predators of nests at Kowhai Bush, and few nests seem beyond their reach, even if they are in thin saplings or high in the canopy. In contrast, there were few rodent predations. Ship rats are less carnivorous than mustelids, are relatively scarce when birds are breeding (Section 14), and may be inefficient at discovering nests.

Table 5 - Predation by mustelids and rodents on nests of nine species of birds at Kowhai Bush. For robins data refer to the whole breeding season. For other species data are for December 1976 and 1977. Except in 1971 all pairs of robins in the Bush were observed. The fate of robin nests not found but known (*) was deduced from other evidence.

Species	No. of nests with eggs found	known*	total	No. nests preyed upon mustelid	rodent	other	unknown*	total	% nests preyed upon
robin 1971	38	-	38	16	6	3	-	25	66
" 1972	75	14	89	27	2	2	8	39	44
" 1973	95	8	103	42	2	1	8	53	52
" 1974	137	1	138	57	15	4	0	76	55
" 1975	136	9	145	56	24	5	9	94	65
" 1976	108	5	113	62	4	3	4	73	65
total (robin)	589	37	626	260	53	18	29	360	
fantail	42	-	42	12	2	7	-	21	50
song thrush	18	-	18	9	0	0	-	9	50
grey warbler	18	-	18	4	2	4	-	10	56
brown creeper	9	-	9	7	1	0	-	8	89
chaffinch	8	-	8	4	2	0	-	6	75
blackbird	7	-	7	2	2	0	-	4	57
redpoll	5	-	5	3	0	1	-	4	80
rifleman	4	-	4	1	2	0	-	3	75
total (others)	111	-	111	42	11	12	-	65	

The average height of all robbed nests (2.7 m) was similar to that of successful nests (2.6 m), so height is no protection. There was no appreciable difference in the average height of nests preyed on by rodents or mustelids (2.5 m and 2.7 m respectively), although the range was greater for the latter (0.4-4.5 m versus 0.7-8.0 m).

There is apparently no constant or direct relationship between numbers of predators (as determined from tracking indices; Section 14) and the frequency of predation on robin nests. Although in 1974, for example, there was a significant correlation ($r = 0.89$; $P < 0.05$) between the combined monthly tracking indices of rats and mice, and monthly predation by rodents, this was not the case in 1975. In that year, rodent predation was the heaviest recorded (Table 5), but tracking indices were low and decreasing when predation was constant or increasing. Predation by stoats and weasels was quite high in summer 1975 and 1976, at a time when their tracking indices were also high, but when those of rodents, their preferred prey, were very low. This suggests that mustelid predation on nests may be affected by the availability of rodents, and increases as the latter become scarce. Other factors influencing predation include the relative distribution of nests and predators in Kowhai Bush, and the size, age and conspicuousness of broods.

The robin population of Kowhai Bush varied erratically from 26 - 44 breeding pairs between 1971 and 1976, despite the high rate of predation on nests (Flack 1976b). The resilience of the population is due to the generally good survival of adults and especially their ability to renest repeatedly. Other birds at Kowhai Bush also appear to be coping with the introduced mammalian predators.

APPENDIX 1 - Checklist of Plants.

Compiled by A.T. Dobson, with additions by D.S. Horning, B.J. Gill and M.H. Powlesland. Lichens were identified by Dr D.J. Galloway, fungi by Ms J. Dingley, and liverworts and most mosses by Dr J. Lewinsky. Vascular plants identified from Kowhai Bush number 202 species, as follows: 79 trees and shrubs (19 exotic), 12 lianes (three exotic), 27 ferns (one exotic), 49 herbs (25 exotic), six orchids (all native) and 29 graminoids (10 exotic). The lists of non-vascular plants are not exhaustive. Abundance of vascular plants is given on a 5-point scale:

1. rare or a single specimen; usually localised
2. uncommon; usually in a limited range of habitats
3. widespread; may be locally plentiful
4. common but may be absent from some areas
5. abundant and widespread; often dominating the vegetation.

* = introduced species.

TREES AND SHRUBS

**Acacia dealbata* Link (Mimosaceae) silver wattle	3
**Acer pseudoplatanus* Linn. (Aceraceae) sycamore	1
Aristotelia serrata (J.R. et G. Forst.) W.R.B. Oliver (Elaeocarpaceae) wineberry	2
**Berberis glaucocarpa* Stapf. (Berberidaceae) barberry	3
**Buddleia davidii* Franch. (Loganiaceae) buddleia	3
Carmichaelia 'robusta - violacea' complex (Fabaceae) native broom	1
Carpodetus serratus J.R. et G. Forst. (Escalloniaceae) marbleleaf, putaputaweta	4
Cassinia fulvida Hook.f. (Asteraceae) tauhinu	1
C. leptophylla (Forst.f.) R. Br.; tauhinu	1
C. vauvilliersii var. *albida* Kirk; tauhinu	1
Coprosma australis (A. Rich.) Robinson (Rubiaceae) raurekau	1
C. crassifolia Col.	2
C. x *cunninghamii* Hook.f.	2
C. foetidissima J.R. et G. Forst.	1
C. lucida J.R. et G. Forst.	1
C. parviflora Hook.f.	1
C. propinqua A. Cunn.	3
C. rhamnoides A. Cunn.	4
C. robusta Raoul; karamu	5
C. rotundifolia A. Cunn.	2
Cordyline australis (Forst.f.) Endl. (Agavaceae) cabbage tree	2
Coriaria arborea Lindsay (Coriariaceae) tree tutu	3
C. sarmentosa Forst.f.; tutu	1
Corokia cotoneaster Raoul (Cornaceae) korokio	2
**Crataegus monogyna* Jacq. (Rosaceae) hawthorn	2
Cyathodes fasciculata (Forst.f.) Allan (Epacridaceae) mingimingi	2
C. fraseri (A. Cunn.) Allan; patotara	1
C. juniperina (J.R. et G. Forst.) Druce; mingimingi	1
**Cytisus monspessulanus* Linn. (Fabaceae) Montpelier broom	4
**C. scoparius* Linn.; broom	1
Discaria toumatou Raoul (Rhamnaceae) matagouri	1
Dodonaea viscosa Jacquin (Sapindaceae) akeake	4
**Fraxinus* sp. (Oleaceae) ash	1
Fuchsia excorticata (J.R. et G. Forst.) Linn.f. (Onagraceae) kotukutuku	2
Griselinia littoralis Raoul (Cornaceae) broadleaf	3

Haloragis erecta (Banks ex Murr.) Eichl. (Haloragaceae)	1
Hebe parviflora (Vahl) Ckn. et Allan (Scrophulariaceae)	1
H. stricta (Benth.) L.B. Moore; koromiko	1
H. traversii (Hook.f.) Ckn. et Allan	1
Hedycarya arborea J.R. et G. Forst. (Monimiaceae) pigeonwood	2
Helichrysum aggregatum Yeo (Asteraceae) = *H. glomeratum*	2
H. filicaule Hook.f.	2
Hoheria angustifolia Raoul (Malvaceae) narrow-leaved lacebark	1
Hymenanthera crassifolia Hook f. (Violaceae) porcupine shrub	1
Leptospermum ericoides A. Rich. (Myrtaceae) kanuka	5
L. scoparium J.R. et G. Forst.; manuka	2
**Leycesteria formosa* Wallr. (Caprifoliaceae) Himalayan honeysuckle	2
Loranthus micranthus Hook f. (Loranthaceae) mistletoe	3
Macropiper excelsum (Forst.f.) Miq. (Piperaceae) kawakawa	1
**Mahonia aquifolium* (Pursh) Nutt. (Berberidaceae)	1
Melicope simplex A. Cunn (Rutaceae)	1
Melicytus ramiflorus J.R. et. G. Forst. (Violaceae) mahoe, whiteywood	5
Myoporum laetum Forst.f. (Myoporaceae) ngaio	2
Myrsine australis (A. Rich.) Allan (Myrsinaceae) mapou	2
Nothofagus fusca (Hook.f.) Oerst. (Fagaceae) red beech	1
Olearia coriacea Kirk (Asteraceae)	1
O. paniculata (J.R. et G. Forst.) Druce; akiraho	2
Pennantia corymbosa J.R. et G. Forst. (Icacinaceae) kaikomako	1
**Pinus pinaster* Ait. (Pinaceae) maritime pine	1
**P. radiata* D. Don; radiata pine	1
Pittosporum eugenioides A. Cunn. (Pittosporaceae) lemonwood	2
P. tenuifolium Sol. ex Gaertn.; kohuhu	4
Podocarpus dacrydioides A. Rich. (Podocarpaceae) kahikatea	1
P. hallii Kirk; Hall's totara	1
P. spicatus R. Br. ex Mirbel; matai	1
**Populus alba* Linn. (Salicaceae) white poplar	2
**P. nigra* var. *italica* Du Roi; Lombardy poplar	2
**Prunus* sp. (Rosaceae)	1
Pseudopanax arboreus (Murr.) Philipson (Araliaceae) five finger	2
P. crassifolius (Sol. ex A. Cunn.) C. Koch; lancewood	2
Pseudowintera colorata (Raoul) Dandy (Winteraceae) pepperleaf	1
**Ribes sanguineum* Pursh. (Grossulariaceae) flowering currant	2
**Rosa rubiginosa* Linn. (Rosaceae) sweet briar	1
**Salix fragilis* Linn. (Salicaceae) crack willow	2
Schefflera digitata J.R. et G. Forst. (Araliaceae) pate, seven finger	1
Senecio monroi Hook.f. (Asteraceae)	1
Sophora microphylla Ait. (Fabaceae) kowhai	2
S. prostrata Buchan.	1
Teucridium parvifolium Hook.f. (Verbenaceae)	1
**Ulex europaeus* Linn. (Fabaceae) gorse	2

LIANES

Calystegia tuguriorum (Forst.f.) R. Br. ex Hook.f. (Convolvulaceae)	2
**Clematis vitalba* Linn. (Ranunculaceae) old man's beard	3
Clematis sp.	1
**Hedera helix* Linn. (Araliaceae) ivy	1
Muehlenbeckia australis (Forst.f.) Meissn. (Polygonaceae)	2
M. axillaris (Hook.f.) Walp.	2
M. complexa (A. Cunn.) Meissn.; pohuehue	2
Parsonia heterophylla A. Cunn. (Apocynaceae) New Zealand jasmine	2
Ripogonum scandens J.R. et G. Forst. (Smilacaceae) supplejack	2
Rubus cissoides A. Cunn. (Rosaceae) bush lawyer	1
**R. fruticosus* agg.; blackberry	1
R. squarrosus Fritsch.; bush lawyer	1

FERNS

Adiantum cunninghamii Hook (Adiantaceae) maidenhair fern	1
Asplenium bulbiferum Forst.f. (Aspleniaceae) hen and chickens fern	3
A. flabellifolium Cav.; necklace fern	1
A. flaccidum aggregate; hanging spleenwort	2
A. lucidum Forst.f.; shining spleenwort	1
A. richardii Hook.f.	2
Blechnum chambersii Tindale (Blechnaceae) = *B. lanceolatum*	2
B. discolor (Forst.f.) Keys; crown fern	1
B. fluviatile (R. Br.) Salom.	1
B. minus (R. Br.) Allan	1
B. penna-marina (Poir.) Kuhn	2
B. procerum (Forst.f.) Swartz; kiokio	2
Botrychium australe R.Br. (Ophioglossaceae) parsley fern	1
Cyathea dealbata (Forst.f.) Swartz (Cyatheaceae) silver fern	1
C. medullaris (Forst.f.) Swartz; mamaku	1
Dicksonia squarrosa (Forst.f.) Swartz (Dicksoniaceae) wheki	1
**Dryopteris filix-mas* (Linn.) Schott. (Dryopteridaceae) male fern	1
Histiopteris incisa (Thunb.) J. Smith (Pteridaceae)	2
Hypolepis tenuifolia (Forst.f.) Bernh. (Dennstaedtiaceae)	2
Lycopodium volubile Forst.f. (Lycopodiaceae)	1
Pellaea rotundifolia (Forst.f.) Hook. (Adiantaceae)	3
Phymatosorus diversifolius (Willd.) Pic. Ser. (Polypodiaceae) = *Phymatodes*	4
Pneumatopteris pennigera (Forst.f.) Holttum = *Thelypteris*	1
Polystichum richardii (Hook.) J. Smith (Dryopteridaceae)	2
P. vestitum (Forst.f.) Presl; shield fern	2
P. richardii x *vestitum*	1
Pteridium esculentum (Forst.f.) Kuhn (Pteridaceae) bracken	1
Pyrrosia serpens (Forst.f.) Ching (Polypodiaceae)	1

HERBS

Acaena novae-zelandiae Kirk (Rosaceae) bidi-bidi	1
Aciphylla sp. (Apiaceae)	1
Cardamine debilis Banks ex DC. (Brassicaceae)	2
Celmisia spectabilis Hook.f. (Asteraceae) mountain daisy	1
**Centaurium erythraea* Raf. (Gentianaceae) centaury	1
Cotula perpusilla Hook.f. (Asteraceae)	1
Dichondra repens J.R. et G. Forst. (Convolvulaceae) Mercury Bay weed	1
**Digitalis purpurea* Linn. (Scrophulariaceae) foxglove	1
Epilobium alsinoides A.Cunn. ssp. *atriplicifolium* (A.Cunn) Raven et Engelhorn (Onagraceae)	1
**Erigeron canadensis* Linn. (Asteraceae) Canadian fleabane	1
**Euphorbia peplus* Linn. (Euphorbiaceae) spurge	1
**Galium aparine* Linn. (Rubiaceae) cleavers	1
G. propinquum A. Cunn.	1
**Geranium robertianum* Linn. (Geraniaceae) herb robert	1
Gnaphalium audax Drury (Asteraceae)	1
G. sphaericum Drury	1
**Hieracium pilosella* Linn. (Asteraceae) mouse-ear hawkweed	1
Hydrocotyle moschata Forst.f. (Apiaceae)	1
H. novae-zelandiae DC.	1
**Hypericum androsaemum* Linn. (Hypericaceae) tutsan	2
**H. pulchrum* Linn.; St. John's wort	1
**Hypochoeris radicata* Linn. (Asteraceae) cat's ear	3
Lagenifera pumila (Forst.f.) Cheesem. (Asteraceae)	1
L. strangulata Col.	1
**Mycelis muralis* (Linn.) Rchb. (Asteraceae) wall lettuce	3

Myosotis arvensis (Linn.) Hill. (Boraginaceae) forget-me-not 1
Nertera setulosa Hook.f. (Rubiaceae) 1
Orbanche minor Linn. (Orbanchaceae) broomrape 1
Pratia angulata (Forst.f.) Hook.f. (Lobeliaceae) 2
Prunella vulgaris Linn. (Lamiaceae) selfheal 1
Ranunculus hirtus Banks et Sol. ex DC (Ranunculaceae) bush buttercup 1
R. repens Linn.; creeping buttercup 1
Senecio dunedinensis Belcher (Asteraceae) 1
S. jabobaea Linn.; ragwort 1
S. quadridentatus Labill. 1
S. minimus Poir 1
Sonchus asper (Linn.) Hill (Asteraceae) prickly sowthistle 1
S. oleraceus Linn.; sowthistle 1
Stellaria parviflora Banks et Sol. ex Hook.f. (Caryophyllaceae) bush chickweed 2
Taraxacum officinale Weber (Asteraceae) dandelion 1
Torilis japonica (Houtt.) DC. (Apiaceae) 1
Trifolium pratense Linn. (Fabaceae) red clover 1
T. repens Linn.; white clover 1
Urtica incisa Poir. (Urticaceae) nettle 1
Veronica arvensis Linn. (Scrophulariaceae) speedwell 1
Vicia hirsuta (Linn.) S.F. Gray (Fabaceae) hairy vetch 1
V. sativa Linn.; common vetch 2
Wahlenbergia albomarginata Hook. (Campanulaceae) New Zealand harebell 1
W. gracilis (Forst.f.) Schrad. 1

ORCHIDS

Caladenia carnea R. Br. 1
?*Corybas trilobus* (Hook.f.) Reichb.f. 1
Microtis unifolia (Forst.f.) Reichb.f. 2
Pterostylis areolata Petrie 1
P. trullifolia Hook.f. 1
Thelymitra carnea R. Br. 1

GRAMINOIDS

Aira caryophyllea Linn. (Poaceae) silvery hair grass 2
A. praecox Linn.; early hair grass 1
Agrostis tenuis Sibth. (Poaceae) browntop 2
Anthoxanthum odoratum Linn. (Poaceae) sweet vernal grass 2
Arrhenatherum elatius (Linn.) Beauv. (Poaceae) false oat grass 1
Astelia fragrans Col. (Liliaceae) 2
Brachypodium sylvaticum (Huds.) Beauv. (Poaceae) 1
Carex breviculmis R. Br. (Cyperaceae) 1
C. dissita Boott. in Hook.f. 1
C. forsteri Wahl. 1
C. geminata Schkuhr 1
C. raoulii Boott. in Hook.f. 1
C. secta Boott. in Hook.f.; niggerheads 1
Cortaderia richardii (Endl.) Zotov (Poaceae) toetoe 1
Dactylis glomerata Linn. (Poaceae) cock's foot 2
Dichelachne crinita Hook.f. (Poaceae) plume grass 1
Echinopogon ovatus Beauv. (Poaceae) hedgehog grass 1
Holcus lanatus Linn. (Poaceae) Yorkshire fog 1
Iris foetidissima Linn. (Iridaceae) 1
Libertia ixioides (Forst.f.) Spreng. (Iridaceae) native iris 1
Luzula picta var. *picta* (A. Rich.) Hook.f.(Juncaceae) 1
Microlaena avenacea Hook.f. (Poaceae) bush rice grass 2
Notodanthonia unarede (Raoul) Zotov (Poaceae) 2

Phormium tenax J.R. et G. Forst. (Agavaceae) New Zealand flax, harakeke 1
Poa imbecilla Forst. (Poaceae) 1
P. laevis R. Br.; silver tussock 1
Uncinia leptostachya Raoul (Cyperaceae) hook sedge 3
U. uncinata (Linn.f.) Kuk.; hook sedge 3
**Vulpia bromoides* (Linn.) S.F. Gray (Poaceae) 1

LIVERWORTS

Frullania deplanata Mitt. (Frullaniaceae)
F. falciloba Tayl.
F. cf. *pentapleura* Tayl.
F. squarrosula (Hook. f. et Tayl.) Tayl.
Lejeunea sp. (Lejeuneaceae)
Lophocolea bidentata (L.) Dum. (Lophocoleaceae)
L. semiteres (Lehm.) Mitt.
Metzgeria colensoi Steph. (Metzgeriaceae)
M. furcata (L.) Dum.
Porella elegantula (Mont.) Hodgs. (Porellaceae)

MOSSES

Acanthocladium extenuatum (Brid.) Mitt. (Sematophyllaceae)
Acrocladium chlamydophyllum (Hook. f. et Wils.) C. Muell. (Lembophyllaceae)
Barbula pseudopilifera Hamp. et. C. Muell. (Pottiaceae)
Breutelia pendula (Sm.) Mitt. (Bartramiaceae)
Bryum argenteum Hedw. (Bryaceae)
B. pseudotriquetrum (Hedw.) Schwaegr.
Bryum spp. (x2)
Campylopus clavatus (R. Brown) Wils. (Dicranaceae)
C. introflexus (Hedw.) Brid.
Ceratodon purpureus (Hedw.) Brid. (Ditrichaceae)
Cryphaea tenella (Schwaegr.) C. Muell. (Cryphaeaceae)
Dicranoloma sp. (Dicranaceae)
Hypopterygium novae-zelandiae C. Muell. (Hypopterygiaceae)
Hypnum cupressiforme Hedw. (Hypnaceae)
Lembophyllum divulsum (Hook. f. et Wils.) Lindb. (Lembophyllaceae)
Macromitrium eucalyptaceum C. Muell. et Hamp. (Orthotrichaceae)
Orthotrichum acroblepharis C. Muell. (Orthotrichaceae)
O. cyathiforme R. Brown ter.
Philonotis tenuis (Tayl.) Reichdt. (Bartramiaceae)
Plagiomnium novae-zealandiae (Col.) T. Kop. = *Mnium longirostre* Brid. (Mniaceae)
Polytrichum juniperinum Hedw. (Polytrichaceae)
Pottia truncata (Hedw.) B.S.G. (Pottiaceae)
Pseudoscleropodium purum (Hedw.) Fleisch. (Brachytheciaceae)
Ptychomnion aciculare (Brid.) Mitt. (Ptychomniaceae)
Racomitrium lanuginosum (Hedw.) Brid. (Grimmiaceae)
Racopilum strumiferum (C. Muell.) Mitt. (Racopilaceae)
Rhynchostegium laxatum (Mitt.) Par. (Brachytheciaceae)
R. tenuifolium (Hedw.) Reichdt.
Schistidium apocarpum (Hedw.) B.S.G. (Grimmiaceae)
Sematophyllum contiguum (Mitt.) Mitt. (Sematophyllaceae)
Thuidiopsis furfurosa (Hook. f. et Wils.) Fleisch. (Thuidiaceae)
Tortula papillosa Wils. (Pottiaceae)
T. princeps De Not.
Triquetrella papillata (Hook. f. et Wils.) Broth. (Pottiaceae)

Weissia controversa Hedw. (Pottiaceae)
Zygodon intermedius B.S.G. (Orthotrichaceae)

LICHENS

Cladonia coniocraea (Flörke) Spreng. (Cladoniaceae)
C. leptoclada Des. Abb.
Dimerella lutea (Dicks.) Trevis. (Gyalectaceae)
Hypogymnia enteromorpha (Ach.) Nyl. (Parmeliaceae)
Lecanactis sp. (Lecanactidaceae)
Lecidea cinnabarodes Nyl. (Lecideaceae)
Leptogium brebissonii Mont. (Collemataceae)
L. cyanescens (Ach.) Körb.
Menegazzia circumsorediata R. Sant. (Parmeliaceae)
Normandina pulchella (Borr.) Nyl. (Verrucariaceae)
Pannaria sp. I (Pannariaceae)
Pannaria sp. II
Parmelia dilatata Vain. (Parmeliaceae)
P. maura Pers.
P. perlata Ach.
Parmeliella nigrocincta (Mont.) Müll. Arg. (Pannariaceae)
Peltigera dolichorhiza (Nyl.) Nyl. (Peltigeraceae)
Pseudocyphellaria aurata Vain. (Stictaceae)
P. billardierii (Del.) James ined.
P. crocata (Linn.) Vain
P. flavicans (Hook.f.) Vain.
P. granulata Kalme
Psoroma leprolomum (Nyl.) Räs. (Pannariaceae)
Stereocaulon ramulosum (Sw.) Raüsch. (Stereocaulonaceae)
Sticta fuliginosa (Dicks.) Ach. (Stictaceae)
Usnea rubiginea (Michaux) Massal. (Usneaceae)

FUNGI

Calycella citrina (Hedw. et Fr.) Boud. (Helotiaceae)
Clavulina sp. (Clavariaceae)
Euantennaria pacifica S.J. Hughes (Caprodiaceae)
Laccaria ?tetraspora Singer (Tricholomataceae)
Phellinus robustus (P. Karst.) Bourd. et Galz. (Polyporaceae)
Stereum fasciatum (Schw.) Dr. (Thelephoraceae)
Trametes scutellata (Schw.) G.H. Cunn. (Polyporaceae)

APPENDIX 2 - Checklist of Birds.

Compiled by B.J. Gill with additions by R.G. and M.H. Powlesland. Only those species which breed in the forest or obtain food from it are listed. Other birds which fly over the Bush or live at its edges include the skylark (*Alauda arvensis*), the New Zealand pipit (*Anthus novaeseelandiae*), the paradise duck (*Tadorna variegata*) and various waders, gulls and terns. Sub-species are indicated only where more than one occurs on the New Zealand mainland. The list is annotated as follows:

Column 1 - status	Column 2 - abundance at Kowhai Bush	Column 3 - breeding status at Kowhai Bush
E = species endemic to N.Z.	C = common	R = breeds regularly
N = species native but not endemic	U = uncommon	I = breeds infrequently
I = introduced	M = migratory	U = breeding unknown

	1	2	3
Falconiformes			
ACCIPITRIDAE			
Circus approximans (Australasian harrier)	N	C	U
FALCONIDAE			
Falco novaeseelandiae (New Zealand falcon)	E	U	U
Galliformes			
PHASIANIDAE			
Lophortyx californica (Californian quail)	I	C	R
Columbiformes			
COLUMBIDAE			
Hemiphaga novaeseelandiae (New Zealand pigeon)	E	U	I
Cuculiformes			
CUCULIDAE			
Chrysococcyx lucidus (shining cuckoo)	N	M	R
Strigiformes			
STRIGIDAE			
Ninox novaeseelandiae (morepork)	N	U	U
Coraciiformes			
ALCEDINIDAE			
Halcyon sancta (New Zealand kingfisher)	N	U	U
Passeriformes			
XENICIDAE			
Acanthisitta chloris chloris (South Island rifleman)	E	C	R
PRUNELLIDAE			
Prunella modularis (hedge sparrow)	I	C	R
MUSCICAPIDAE			
Finschia novaeseelandiae (brown creeper)	E	C	R
Gerygone igata (grey warbler)	E	C	R
Rhipidura fuliginosa fuliginosa (South Island fantail)	N	C	R
Petroica macrocephala macrocephala (yellow-breasted tit)	E	U	U
P. australis australis (South Island robin)	E	C	R
Turdus philomelos (song thrush)	I	C	R
T. merula (blackbird)	I	C	R
ZOSTEROPIDAE			
Zosterops lateralis (silvereye)	N	C	R
MELIPHAGIDAE			
Anthornis melanura (bellbird)	E	C	R

	1	2	3
EMBERIZIDAE			
Emberiza citrinella (yellowhammer)	I	C	R
FRINGILLIDAE			
Fringilla coelebs (chaffinch)	I	C	R
Carduelis chloris (greenfinch)	I	U	I
C. carduelis (goldfinch)	I	C	R
Acanthis flammea (redpoll)	I	C	R
STURNIDAE			
Sturnus vulgaris (starling)	I	U	U
CRACTICIDAE			
Gymnorhina tibicen hypoleuca (white-backed magpie)	I	C	I

APPENDIX 3 - Checklist of Mammals.

Compiled by P.J. Moors. Only those species frequenting the Bush or its edges are included; farm stock are disregarded. In addition the Norway rat (*Rattus norvegicus*) probably occurs in small numbers, but there are no definite records. All species have been introduced since European colonisation. The list is annotated as follows:

Column 1 - abundance at Kowhai Bush

C = common
U = uncommon
R = rare
T = transient or irregular visitor

Column 2 - diet

C = carnivore
H = herbivore
O = omnivore
I = insectivore
(For mixed diet, main type is given first.)

	1	2
Marsupialia		
PHALANGERIDAE		
Trichosurus vulpecula (brushtailed opossum)	U	H
Insectivora		
ERINACIDAE		
Erinaceus europaeus (hedgehog)	C	I
Lagomorpha		
LEPORIDAE		
Oryctolagus cuniculus (rabbit)	C	H
Lepus capensis (hare)	C	H
Rodentia		
MURIDAE		
Mus musculus (house mouse)	C	HC
Rattus rattus (ship rat)	C	HC
Carnivora		
MUSTELIDAE		
Mustela nivalis (weasel)	R	C
M. erminea (stoat)	U	C
M. putorius forma *furo* (ferret)	U	C
FELIDAE		
Felis catus (feral cat)	U	C
Artiodactyla		
SUIDAE		
Sus scrofa (feral pig)	T	O
CERVIDAE		
Cervus elaphus (red deer)	T	H

APPENDIX 4 - List of Contributors.

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* = not primarily concerned with data from Kowhai Bush.

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APPENDIX 6 - Suggestions for Further Research.

The physical advantages of Kowhai Bush as a study-area are covered in Section 1. The Bush is particularly suitable as a study-area for students wishing to do a thesis in biology that involves field-work. This is the more so because of the opportunity to draw on and supplement the results of earlier investigations, as here summarised. Accommodation and/or laboratory facilities at the Edward Percival Field Station (Kaikoura) may be available (at a nominal fee) to bona fide graduate students engaged in field-work at Kowhai Bush for a thesis. (Application should be made to the Head, Department of Zoology, University of Canterbury, Christchurch.) To date, theses or Honours projects involving Kowhai Bush have been supervised by the Departments of Zoology and Botany, University of Canterbury, and the Zoology Department, University of Auckland. The following are some topics which could be studied at Kowhai Bush.

A. VEGETATION

1. Collection and identification towards compiling a complete list of non-vascular plants.

2. Detailed description and analysis of the vegetation of different successional stages. This could include establishing permanent plots to record long-term changes, the clearance of a small plot of river gravel to analyse the initial succession (growth to 1 m high in one season could be expected), or an emphasis on the vegetational history (effects of flooding, felling, grazing etc.).

3. A comparison of the rate of accumulation and decomposition of litter in various seral stages.

4. General ecological and phenological studies of selected species, e.g. kanuka, Montpelier broom, or plants important as sources of food for birds and rats.

B. INVERTEBRATES

1. Collection and identification towards compiling a species list.

2. Quantitative surveys of abundance. For example, the canopy of much of Kowhai Bush is a virtual monoculture of kanuka, the foliage of which is defoliated by several species of caterpillar. Identifying these and unravelling their life-cycle, seasonality and abundance would be interesting, and complementary to existing knowledge of the biology of insectivorous birds at Kowhai Bush.

3. Biology and ecology of *Rhytida edwardi* or *Pseudaneitea aspera*.

4. An investigation of spider communities.

5. An analysis of soil faunas in different stages of the vegetational succession.

C. BIRDS

1. Development and comparison of methods for censusing populations or communities.

2. Quantification of feeding-habits or habitat-preference of a selected species (e.g. rifleman, bellbird).

3. Analysis of vocalisations of brown creepers, grey warblers or bellbirds.

4. A study of breeding in the rifleman, silvereye, bellbird, chaffinch or redpoll. A keen worker could find sufficient nests. Rifleman may take to boxes since natural nest-sites are few.

5. Comparison of feeding-habits and food of robins, blackbirds and thrushes to test for competitive interactions.

6. Population dynamics and foraging of the Californian quail.

7. Compilation of an energy-budget for the South Island robin, following from existing data on the bird's time-budget (Powlesland, in preparation).

8. Analysis of weights of robins by training birds to perch on a balance.

D. MAMMALS

1. Diet (by faecal analysis) and feeding-habits of:
   (i) predators, especially mustelids and cats;
   (ii) ship rats;
   (iii) house mice.

2. Population-dynamics of ship rats and house mice in early and late seral habitats (rats are scarce in the former).

3. Population dynamics, movements and habitat preference of hedgehogs.

4. The pattern of predation on eggs and nestlings of blackbirds and thrushes. Both build low, obvious nests which are easy to find at Kowhai Bush.