Habitat and diet of kakapo (*Strigops habroptilis*) in the Esperance Valley, Fiordland, New Zealand

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Abstract Vegetation in the Esperance Valley, Milford catchment, Fiordland, as it was in February and March 1974, is described using quantitative data for part of the valley that included home ranges of two male kakapo (*Strigops habroptilis*). One home range, of only 1.8 ha, was sited at 700 - 730 m altitude and extended over a gently-sloping river terrace covered in snow totara (*Podocarpus nivalis*) scrub with short silver beech (*Nothofagus menziesii*) forest at its margins. The other home range was 4 ha in area, sited on a very steep (42°) valley wall mantled with unconsolidated avalanche debris at 800-860 m altitude, faced NW and was covered by *Blechnum capense* fern - shrubland and short silver beech forest communities. At that time, this valley differed from most other parts of Fiordland: although possums (*Trichosurus vulpecula*), stoats (*Mustela erminea*) and rats (*Rattus spp.*) were present, ungulates were absent or very localised. Results gave no indication that food was limiting kakapo numbers in the Esperance Valley and we conclude that, because of the extreme vulnerability of females and their eggs, nestlings and fledglings to introduced mammalian predators, stoats were the most probable primary cause of kakapo decline in Fiordland.

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INTRODUCTION

Whether judged by aesthetic or scientific criteria, the kakapo (*Strigops habroptilus* Gray) ranks as one of the world's most remarkable birds. Its rarity, cryptic plumage and nocturnal habits make it difficult to study, particularly in the mountainous terrain of Fiordland where it survived until the late 1980s.

In 1974, the Wildlife Service, Department of Internal Affairs, sought to locate kakapo still existing in Fiordland with a primary aim of transferring any found to Maud Island in the Marlborough Sounds. This initiative was led by DVM and the Esperance Valley in the Milford catchment (Fig. 1) was the focal point of the first search between 12 February and 2 March 1974. Two male birds were caught and subsequently transferred to Maud Island. During the search, J.L. Kendrick and DVM made the first recordings of kakapo calls. Responses of the birds to these recorded calls yielded information on habitat use, and subsequently enabled further kakapo to be found.

A second aim of the study was to identify factors that influenced habitat selection by kakapo and evaluate whether aspects of vegetation composition could have contributed to the decline of kakapo in Fiordland.

HISTORY OF KAKAPO IN THE GULLIVER AND ESPERANCE VALLEYS

Following the 1914-18 war, students from Otago University began constructing tracks in the Hollyford and Gulliver - Esperance Valleys on both sides of the Grave-Talbot Pass. During the 1921-22 summer, D.R. Jennings (pers. comm.) and party, using a dog, found a kakapo asleep in a tree in the Gulliver Valley, about 0.8 km from its junction with the Cleddau River. The following summer they heard kakapo ("not less than two and possibly as many as five") booming near their camp, between 1.5 and 2.5 km from the Cleddau River.

We have been unable to find further records of kakapo in the Gulliver Valley and subsequent searches of this valley have been negative. However, after close examination of a browsed frond of *Blechnum capense* agg. that we collected in March 1974 from a small bench in subalpine scrub high up on the eastern wall of this valley, we concluded that it had been browsed by a kakapo. This bird was possibly "Richard Henry" because, early in 1975, he was caught high above the junction of the Esperance and Gulliver Rivers. At that time there was much old kakapo sign in the Gulliver Valley: droppings beneath dry overhangs and old bowls on spurs.

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Table 1 Rainfall (mm) and temperature data from Milford Sound (source: N.Z. Meteorological Office, 1973). Mean number of days/yr with ground frost (1961-70) = 56.

Rainfall	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean (mm) 1941- 70	531	569	630	526	483	419	378	424	538	546	638	554	6236
Mean no. of raindays (>1 mm), 1929-70	16	14	15	15	15	14	13	15	16	18	17	16	183
Max. daily rainfall (mm), 1929-70	302	520	445	467	229	294	200	235	229	375	369	307	520

Mean temperatures (° C)		
Annual, 1931-60	Jan. daily max, 1934-70	July daily min, 1934-70
10.1	18.4	1.5

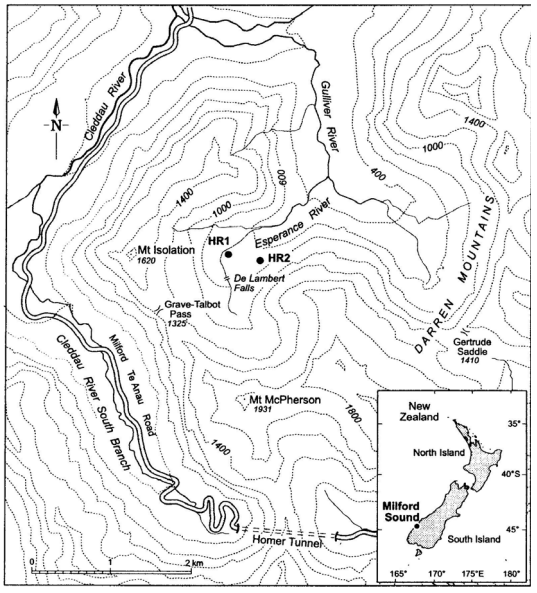

Figure 1 Map showing location of Esperance Valley, Milford catchment, Fiordland (altitude in metres). HR1 and HR2 indicate the locations of two home ranges of male kakapo found in 1974; more detail is provided in Fig. 4.

No definite records of kakapo in the Esperance Valley during the 1920s are known to us but D.R. Jennings (pers. comm.) reported that when climbing some of the higher ridges of the valley they sometimes saw what they took to be kakapo tracks. Construction of the Homer Tunnel began in 1935. Mr J.A.B. Brown, then in charge of the bush-clearing party, reported (pers. comm.) that, about that time, they caught, photographed and released a kakapo in the Esperance Valley. Considering the use made of the McPherson Hut in the valley during the 1930s, there are few indications of kakapo presence. Neither L.R. Stewart or K. Suter (pers. comms.) saw or heard kakapo during their numerous visits between 1933 and 1940. However, the hut was located near a high waterfall so a casual observer would not have heard kakapo calls above the water noise.

In February 1959, M.M. Small and N. Ewing, both Wildlife Service staff, searched the Esperance Valley and found kakapo feathers and fibrous chews in the area of home range 1 (see below) as well as feathers in the short silver beech forest of the head basin (Small unpub. 1959). In December 1959, a second party failed to find sign in the same area but found fibrous chews and recent kakapo droppings in three other places: the main talus cone of the valley floor, tussockland and scrub on slopes opposite the McPherson Hut (true left bank of river), and below the beech forest of the head basin (M.Small unpub. 1960; I. Hogarth pers. comm.). On this visit Small heard what was probably booming.

Two further searches were made in the Esperance Valley by Wildlife Service staff in October and November 1966 when fibrous chews and small amounts of old droppings were found. In March 1973 another Wildlife expedition found fresh droppings and a feather in the area of home range 2 (Fig. 4; see below) (G. Anderson unpub. 1973). In September 1973, R. Nilsson (unpub. 1973) again found kakapo sign in the valley, including that within the area of home range 1.

Our searches in March 1974 showed that, in addition to the two home ranges in current use (described below), old kakapo droppings were present elsewhere in the valley. These were at the base of the largest talus cone at the western end of the valley, and in the open forest on the true right side of the river below home range 1.

The earliest reliable information on kakapo habitat and behaviour in Fiordland is that of Henry (1895-1908, 1903). More recent studies are those of Hall-Jones (1960a) and Williams (1960) and the detailed investigations of Johnson (1976) and Gray (1977).

STUDY AREA

Topography and geology

The Esperance Valley lies in the south-eastern corner of the Milford catchment. Its valley head is *c.* 2 km north of the Homer Tunnel and is flanked by Mts Macpherson (1931 m) and Talbot (2124 m). It is a glacially-cut hanging valley of typical U-shape, oriented NE-SW. The Esperance River flows north-east to join the Gulliver River, then north-west to the Cleddau River and ultimately flows into the upper part of Milford Sound. It is flanked by mountains 1500 - 2000 m high, from which numerous avalanches of debris or snow have scoured their way down to the valley floor. The valley itself is 0.4 - 0.8 km wide, rises gradually from an altitude of 400 m at its opening into the Gulliver Valley to 750 m below the de Lambert Falls, a distance of 1.2 km. Above these

falls there is a steeply sloping head basin mantled with boulders and shallow deposits of unconsolidated debris. The basin rises to over 1230 m before terminating in cliffs with steep tussock-covered ledges. Some 300 m below the falls, the river swings sharply so that both the falls and the head basin face north-west (Fig. 1). The valley floor is covered with moraine debris and boulder alluvium upon which steep fans of very coarse talus have fallen from the adjacent valley walls.

Like most of the eastern headwaters of the Milford catchment, the metamorphic rocks of the Esperance Valley are massive, weakly gneissic diorites and granodiorites (Wood 1962).

Climate

Relevant data from the nearest climate station, 8 km north-west of Esperance Valley at the head of Milford Sound, are given in Table 1. Considering the altitudinal difference between the study area and Milford (at sea-level), annual rainfall in the Esperance Valley is probably in the order of 7000 mm (J.D. Coulter, NZ Met. Service, pers. comm. 1974). More than half the days of the year are rain-days and high-intensity rain storms fall in any month, although highest rainfalls are in summer. Assuming a lapse rate of 6ºC / 1000 m altitude, mean annual temperature in the Esperance Valley (extrapolated from Milford) would be 5.9ºC. Diurnal temperature changes were very marked during February and March 1974, with frosts followed by warm sunny days. Surrounding mountains exclude direct sun from the valley for much of winter when snow is likely to cover all but the steepest valley sides. On a cloudless day close to the autumn equinox (18 March), 6.5 hrs of sunshine were recorded on the valley floor in the home range of kakapo 1.

METHODS

Vegetation

Ground traverses, line transects and aerial photographs were used to describe and map the home ranges of two kakapo living in the valley. Plant names follow the listing of Parsons *et al*. (1995). Naming of vegetation types follows the conventions suggested by Atkinson (1985) and Atkinson & Blaschke (1995). Transect locations were selected subjectively as representative of the differing vegetation types present. Canopy and under-storey cover along transects was quantified using a step-point technique (Atkinson 1962), with points at two, five or 10-pace intervals depending on vegetation height. The under-storey in the home range of kakapo 1 was analysed by recording the frequency with which plant species, in 0 - 30 cm and 30 - 60 cm height ranges, touched a 5 cm diameter rod dropped vertically through the vegetation at metre intervals along a 100 m tape. Home ranges of the two kakapo were determined from the distribution of their feeding sign, feathers, droppings, tracks and roost-site positions, as well as night records of their movements determined from their calls.

Introduced mammals

Covered break-back traps were used to catch rats (ship rat *Rattus rattus* and kiore *R. exulans*) and mice (*Mus musculus*), covered Fenn traps were used for stoats (*Mustela erminea*), and double-opening wire mesh treadle traps for brushtail possums (*Trichosurus vulpecula*).

Distinguishing between droppings of kakapo and those of other animals.

The most characteristic droppings made by kakapo are more-or-less rounded masses of faecal material, 2 - 3 cm in diameter, although sometimes larger. Each dropping consists of tightly coiled worm-like casts, *c*.5 mm diameter, together with smaller sub-spherical casts. Colour is dark green or chestnut-brown to black, frequently blotched or speckled with whitish uric acid. The coiled worm-like structure of these droppings makes them readily distinguishable from the droppings of ungulates or possums. They are firm when fresh, are composed of finely macerated material, occasionally with entire seeds, and generally have little or no odour.

Kakapo sometimes left droppings of "blackberry jam" consistency containing seed from succulent fruit. Such droppings are not unequivocal evidence of kakapo presence as they are also made by kea (*Nestor notabilis*) and possibly kaka (*Nestor meridionalis*) as well as pigeons (*Hemiphaga novaeseelandiae*) and blackbirds (*Turdus merula*).

Distinguishing browse signs of kakapo from those of possums

Kakapo "chews" consist of crescent-shaped wads of fibre, resulting from compression within the bill, or irregular tangles of fibres that generally bleach within a few days of formation. They are distinctive whether still attached to the plant or lying at its base. Browsing by possums never leaves crescent-shaped wads of fibre. The manner in which these chews are formed within the bill of a kakapo is illustrated by Gray (1977 - see Butler 2006).

Typical crescent-shaped chews can result from feeding by kakapo on mosses, ferns, grass and tussock-grass leaves, seed heads and tiller bases, bark of *Podocarpus hallii* and *Leptospermum scoparium*, petioles and leaves of *Brachyglottis* spp., and foliage of *Dracophyllum* spp., *L. scoparium*, and *P. hallii*. Tangles or "strings" of fibrous material can be left after kakapo feed on the leaves of flax (*Phormium* spp.), grasses (including tussock grasses) (Fig. 2), sedges and *Aciphylla* spp.

When fibrous material does not remain after browsing it is difficult to distinguish browse signs of kakapo from those of possums, e.g., browsed leaves of *Blechnum* spp. and *Coriaria plumosa*. However, a close examination of *Blechnum* or *Coriaria* leaves after browsing by kakapo shows (Figs. 2, 3):

(1). Some browsed pinnae or leaf segments with scalloped or shallowly indented crenate edges (Fig. 2). The indentations lie towards the midrib and vary in depth. The width of the indentations also varies: 5 - 10 mm

Figure 2 Browse sign left by kakapo on leaves of *Chionocloa conspicua* (upper) and on a frond of *Blechnum capense* agg. (lower).

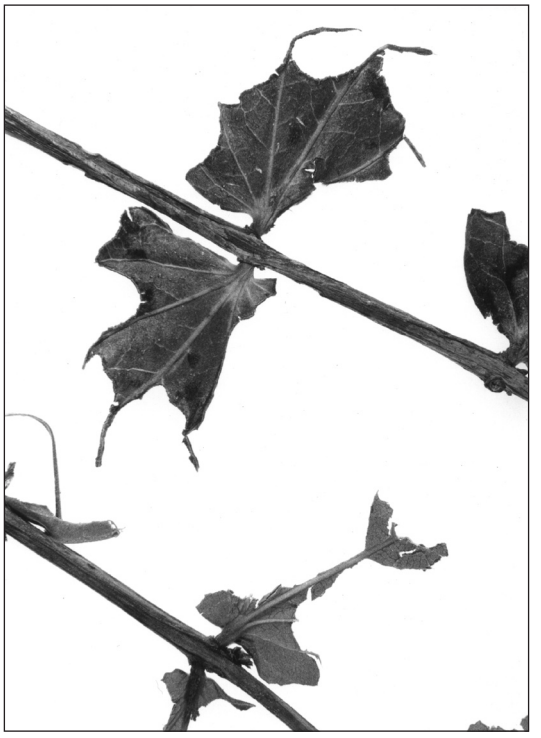

Figure 3 Browse sign on leaves of *Coriaria sarmentosa* left by kakapo (upper) and possum (lower).

(mean = 7 mm, n = 12). This dimension is presumably related to the size of a bite when the bill is closed.

(2). Cut leaf edges are mostly cut cleanly without small tears or attached leaf fragments.

Examination of leaves of the same species browsed by possums shows:

(1). Absence of scalloped or crenate leaf edges after browsing (Fig 3);

(2). Small tears at right angles to the cut leaf edge and torn fragments of lamina still attached. These presumably result from a ripping and pulling action when a possum holds a leaf in its paws and pulls individual leaf segments or fern pinnae through its teeth.

RESULTS

Vegetation types (Appendices 1 - 8)

In 1974, about two-thirds of the valley-floor was covered by silver beech (*Nothofagus menziesii*) forest with stands extending up to 900 m a.s.l. along the eastern wall of the valley. The remainder of the valley floor was covered by sub-alpine scrub and tussock-land. A small stand of silver beech grew in the head-basin but most of this area was covered by a mosaic of rock, scrub, tussock-land and herb fields. Higher slopes of the valley were largely bare rock. Most forest, and all the scrub in the valley, had dense undergrowth difficult to penetrate. Fig. 4 shows the vegetation pattern as it was in 1974. Changes in this pattern

induced by avalanches, and possibly floods, will have resulted since 1974. Descriptions of the major vegetation types present at that time are summarised below in order of decreasing degree of structural development.

Tall silver beech forest (Appendices 1 - 4)
Mature silver beech forest extends from Gulliver Valley along the floor of the Esperance Valley and up to an altitude of about 850 m. There it terminated near the first major fork in the Esperance River. Soils were generally bouldery with many individual boulders exceeding 5 m diameter. The trees were mostly 15 - 20 m high and 60 - 90 cm dbh, forming a canopy with 50 - 80% cover. Juvenile silver beech was abundant. Below 500 m, kamahi (*Weinmannia racemosa*) was the only other important canopy tree but Hall's totara (*Podocarpus hallii*) and miro (*Prumnopitys ferruginea*) were present in small numbers. Above 500 m, broadleaf (*Griselinia littoralis*) contributed a small part of the canopy. Understorey and ground layers were notable for their density, particularly between 0.3 and 2 m height, and for the abundance of plants palatable to deer: mountain fivefinger (*Pseudopanax colensoi* var. *fiordensis*), stinkwood (*Coprosma foetidissima*), broadleaf and locally the fern *Asplenium bulbiferum*.

Short silver beech forest and silver beech scrub
Silver beech was the leading species with a canopy cover frequently of 90 - 100%. The trees ranged in height from 20 m at lower altitudes to 6 m at the treeline (*c.* 900 m a.s.l.), with a majority of trees having trunk diameters of 20 - 60 cm dbh. The understorey was remarkable for the abundance of species palatable to deer: broadleaf, *Pseudopanax simplex*, mountain fivefinger and stinkwood (Appendices 2 - 4: home range and head basin samples). Short forest was present on river alluvium, colluvial fans of large boulders, and valley-side accumulations of unconsolidated avalanche debris. Contiguous with this forest were patches of silver beech scrub. The canopy was lower (2 - 7 m), much more open (30 - 60% cover) and usually contained *Coprosma pseudocuneata,* snow totara (*Podocarpus nivalis*) and *Dracophyllum longifolium*, as well as silver beech.

Juvenile silver beech was well represented in both the tall and short forests, especially in canopy gaps.

Fuchsia-wineberry and fuchsia-broadleaf forests.
Major species were *Fuchsia excorticata*, wineberry (*Aristotelia serrata*) and broadleaf, mostly 6 - 12 m high, with *Hoheria glabrata* frequently present in the canopy. The understorey was open and contained few species: broadleaf, fuchsia, *Pseudowintera colorata* and *Coprosma ciliata w*ere the most common. The ground was often completely covered by a dense thicket of the fern *Polystichum vestitum*.

The proportion of wineberry in this forest apparently decreased with stand age while that of broadleaf increased. Such forest grew on recent deposits of coarse bouldery alluvium where soil nutrients were likely to be higher than in the older, more leached soils which supported silver beech.

Leatherwood - mountain fivefinger scrub (Appendix 5).
Leatherwood (*Brachyglottis rotundifolia*) and mountain fivefinger formed a dense scrub, 2 - 4 m high, which was better developed on bouldery alluvium above the altitudinal limit of silver beech. Similar "subalpine scrub" grew between stands of short beech forest on the very steep north-west facing slopes of the valley. This was the most advanced stage of a succession initiated on stony surfaces by mountain holly (*Olearia ilicifolia* x *arborescens*).

Mountain fivefinger - mountain holly scrub.
This covered most of the alluvial terraces below de Lambert Falls. It was both shorter (2 - 3 m) and less dense than the leatherwood – mountain fivefinger scrub. Composition was varied (Appendix 6) and it appeared to be an earlier stage in succession towards leatherwood-mountain fivefinger scrub. Seedlings of mountain holly were abundant on open stony sites within this community but mountain fivefinger seedlings established at a later stage after the canopy has closed.

Mountain holly - mountain höhere - Hypolepis *scrub and fernland*.
Mountain holly together with mountain hohere (*Hohere lyalli*) and the fern *Hypolepis millefolium* formed a mosaic pattern of scrub (up to 5 m high) and fernland (0.4 m high) covering most of the talus cones and fans along the lower south-western slopes of the valley floor. These slopes appeared more shaded than those supporting other kinds of scrub, and the vegetation was less varied. All three major species formed pure stands in places though mostly they were mixed.

Subalpine scrub
This area, mapped in Fig. 4, was not examined.

Snow totara scrub and Dracophyllum shrublands
Snow totara formed a scrub 0.4 - 1.2 m high and covered the main river terrace down-valley from de Lambert Falls. Snow totara scrub included communities in which shrubs contributed 80% or more of the canopy cover whereas in snow totara shrubland, shrubs contributed < 80% of the canopy cover (Atkinson 1985). The home range of kakapo 1 was located within this vegetation type (see below). A possibly significant site difference between this scrub and the mountain fivefinger - mountain holly scrub was the occasional presence of large boulders 2 - 7 m in diameter. Further details are given in the home range descriptions and Appendix 7.

Blechnum *shrubland*
The fern *Blechnum capense* ("mountain" sp.) was widespread in scrub and shrubland of the valley. On some steep eastern slopes it contributed more canopy cover

Table 2 Birds recorded from the Esperance Valley, February – March 1974. (Key: + = species seen at least once; a = species seen frequently)

Species	Home range 1	Home range 2	Esperance Valley
Bellbird (*Anthornis melanura*)	a	+	a
Blackbird (*Turdus merula*)	+	+	+
Brown creeper (*Finschia novaeseelandiae*)	+	+	+
Chaffinch (*Fringilla coelebs*)	+	+	+
Fantail (*Rhipidura fuliginosa*)	+	+	+
Grey warbler (*Gerygone igata*)	+	+	+
Hedge sparrow (*Prunella modularis*)			+
Kaka (*Nestor meridionalis*)			+
Kakapo (*Strigops habroptilus*)	+ (1)	+ (1)	
Kea (*Nestor notabilis*)		+	+
Kiwi (*Apteryx* sp.)	+		+
Long-tailed cuckoo (*Eudynamis taitensis*)			+
Morepork (*Ninox novaeseelandiae*)		+	+
NZ Falcon (*Falco novaeseelandiae*)			+(1)
NZ Pigeon (*Hemiphaga novaeseelandiae*)	+		
NZ Pipit (*Anthus novaeseelandiae*)			+
Parakeet (*Cyanoramphus* sp.)			+
Redpoll (*Acanthis flammea*)	+		+
Rifleman (*Acanthisitta chloris*)	+		+
Rock wren (*Xenicus gilviventris*)			+
Silvereye (*Zosterops lateralis*)	a	a	a
Yellow breasted tit (*Petroica macrocephala*)	+	+	+
Yellowhead (*Mohoua ochrocephala*)			+

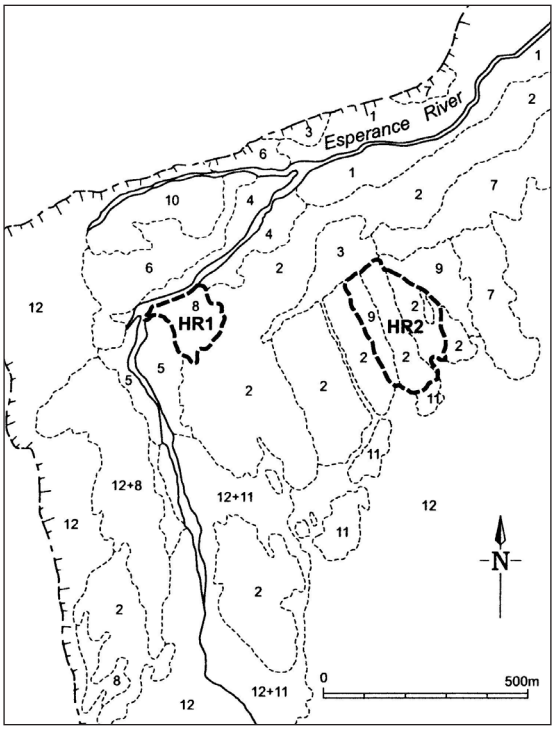

Figure 4 Vegetation map of upper Esperance Valley showing positions of two home ranges of male kakapo found in 1974. Key to symbols: 1 - Tall silver beech forest (*Nothofagus menziesii*); 2 - Short silver beech forest and silver beech scrub (*N.menziesii*); 3 - Fuchsia-wineberry and fuchsia-broadleaf forests (*Fuchsia excorticata, Aristotelia serrata, Griselinia littoralis*); 4 - Leatherwood-mountain fivefinger scrub (*Senecio bennettii, Pseudopanax colensoi* var. *ternatum*); 5 - Mountain fivefinger-mountain holly scrub (*P. colensoi* var. *ternatum, Olearia ilicifolia* x *arborescens*); 6 - Mountain holly-mountain hohere/hypolepis scrub and fernland (*Olearia ilicifolia* x *arborescens, Hoheria glabrata, Hypolepis millefolium*); 7 - Subalpine scrub: not examined; 8 - Snow totara scrub and shrubland (*Podocarpus nivalis*); 9 - Blechnum fern-shrubland (*Blechnum capense* agg.); 10 - *Chionochloa* tussocklands (*Chionochloa rigida, C. oreophylla*); 11 - Mountain flax shrubland (*Phormium cookianum*); 12 - Rockland, mossfield and cliff vegetation.

than any other species. The community was mapped as a shrubland because shrub species, taken together, contributed the largest proportion of the canopy.

Canopy height varied between 0.1 and 1.5 m and, apart from the blechnum, the most characteristic plants are mountain flax (*Phormium cookianum*) and *Dracophyllum longifolium* (see also home range 2).

Chionochloa *tussocklands.*
Chionochloa rigida and *C. oreophylla* covered the higher slopes and ledges of the head basin (1200-1500 m) as well as the upper slopes of the talus cone in the south-western corner of the valley-floor (Appendix 8). Although *C. rigida* was the most widespread tussock grass, the tussocklands were very variable in composition. *C. conspicua* often formed a fringe along river banks and forest edges. The lower slopes of the talus cone, included in this type, were largely mossfields of *Racomitrium lanuginosum*, and other mosses, with numerous tussocks of *Rytidosperma setifolium*.

Mountain flax shrubland
Flax-dominated vegetation was concentrated on the steep eastern slopes of the valley, particularly above the treeline at altitudes of 860 to 900 m.

Rockland, mossfield and cliff vegetation.
Almost all of the very steep valley walls were formed by slopes of massive rock heavily striated by past movements of avalanche debris. During intense rainfalls some slopes became curtains of water leaving crevices in the cliffs as the only stable sites. Species common in these crevices were *C. rigida*, *P. cookianum*, *Dracophyllum uniflorum*, *D. menziesii* and *R. setifolium*.

Birds
Twenty-three species of birds were recorded in the valley during February and March 1974 (Table 2). This included four parrot species and four introduced species. Neither robins (*Petroica australis*) nor weka (*Gallirallus australis*) were recorded but weka were present in the valley during the early 1920s (D.R. Jennings pers. comm. 1974). At least three kiwi (*Apteryx* sp.) were present in the upper half of the valley but their specific status could not be determined. On 13 March a female and male kiwi were calling together at 1300 hrs when the weather was overcast and light intensity low.

Introduced mammals
Possums
During 87 trap-nights (18 - 28 February 1974), two adult and two juvenile possums were caught in kakapo traps set on animal tracks at the margin of home range 1. Three of these animals were caught near the southern boundary of this area. Although the traps remained set until 31 March, no further possums were caught. No possums were caught in kakapo traps set for 120 trap-nights in home range 2 although one animal was killed outside a trap, and fur of a second animal was found in a sprung trap.

Possum droppings were seen in a number of places throughout the valley including several forest areas and the talus fan on the south-western valley floor. Apparent "animal tracks" on this fan had resulted from running water. The incidence of possum droppings was very low in the head basin.

Chamois
Chamois *(Rupicapra rupicapra)* were apparently the only ungulates in the valley at the time. Droppings were found at one place during March 1974 and droppings had been found in the valley on previous occasions (G. Anderson pers. comm.). In years immediately prior to 1974, the New Zealand Forest Service made regular searches for, and shooting of, ungulates in the Milford catchment. Deer (*Cervus elaphus*) were not recorded.

Rats and mice
Two rats were caught during 90 trap-nights on the valley floor in the vicinity of home range 1. One was identified by R. H. Taylor (pers. comm.) as a male kiore and, at that time, this was only the fourth mainland record in the 20th century. The second rat (not collected) was a lactating female ship rat, identified by having five pairs of mammae.

Five mice were caught during 155 trap-nights on the valley floor and a sixth was seen. It was apparent that mice were not restricted to the vicinity of the Esperance Hut.

Stoats
No stoats were caught during a total of 54 trap-nights. A dropping collected from the head basin, associated with the wing of a small passerine, was identified as that of a stoat (C.M.King pers. comm.). Remains identified from the dropping consisted of *c.* 90% rat fur and 10% insect parts. No cats (*Felis catus*) were seen.

Home ranges of kakapo in the Esperance Valley
Feeding signs of a kakapo, referred to as "kakapo 1" (subsequently named Jonathan), were first located on 12 February, approximately 150 m down the valley from the McPherson Hut. Two weeks later, J. Kendrick and D. Merton succeeded in obtaining satisfactory calls of this bird on tape. Initially, the vocal response of this bird to playback of its own calls was immediate and vigorous. With repeated playbacks on the same night, responses became less frequent. Responses always originated from within an area, the boundaries of which appeared to be well defined. However, given that we were in the valley for only seven weeks, it is probable that the actual home ranges of kakapo were significantly larger than the areas evident during our study. Therefore, what we have identified as "home ranges" are probably better described as "core home ranges".

Table 3 Home range 1: Percentage composition of scrub canopy

Species	Transects 1-3 (*n*=150)	Transects 4-7 (*n*=200)	All transects (*n*=350)
Aciphylla horrida	1	1	1
A. takahea	1	1	1
Aristotelia fruticosa	1	1	<1
Astelia sp. *(aff. A. nervosa)*		0.5	<1
Blechnum capense agg. ("mountain" sp.)		0.5	<1
Brachyglottis rotundifolia	5	11	9
Boulders		0.5	<1
Cassinia vauvilliersii	1		1
Chinochloa conspicua	3	3	3
Ch. rigida	3		1
Coprosma cheesemanii	2		1
C. ciliata	2	2	2
C. pseudocuneata	10	8.5	9
C. serrulata	1		<1
Coriaria plumosa	1	2.5	2
Dracophyllum uniflorum	11	3	7
Gaultheria rupestris	4	1	2
G. sp. *(G. depressa var. novae-zelandiae)*	1		<1
Griselinia littoralis		2.5	1
Hebe cockayniana	1	1	1
H. subalpina	7	11	9
Hymenophyllum multifidum		0.5	<1
Myrsine divaricata	1	7	5
Nothofagus menziesii	1		<1
Olearia ilicifolia x O. arborescens	6	8	7
O. moschata	2	3	3
Phormium cookianum		1	1
Podocarpus nivalis	25	23	24
Polystichum vestitum	1	0.5	1
Pseudopanax sp. (Ps. colensoi var. ternatus)	6	7.5	7
Racomitrium lanuginosum	3	0.5	2

Figure 5 The gentle northerly slope of Home Range No. 1 covered by snow totara scrub.

Table 4 Home range 1: Percentage frequency of plants in understorey of snow totara (*Podocarpus nivalis*) scrub.

Species	% frequency at 0-30 cm ht.	% frequency at 30-60 cm ht.
Aciphylla horrida	1	
A. takahea	5	1
Aristotelia fruticosa	1	
Blechnum penna-marina	40	
Brachyglottis rotundifolia	1	1
Carmichaelia grandiflora	1	
Cassinia vauvilliersii	1	3
Celmisia glandulosa	2	
C. petiolata	3	
Chionochloa conspicua	2	3
Ch. rigida	5	11
Coprosma pseudocuneata	1	4
C. serrulata	2	
Dracophyllum uniflorum	10	13
Epilobium sp.	2	
Foliose lichens (Unidentified)	2	
Galium perpusillum	3	
Gaultheria rupestris	13	5
G. sp. *(G. depressa var. novae-zelandiae)*	1	
Halorhagis depressa	5	
Hebe cockayniana		2
H. subalpina		5
Helichrysum filicaule	3	
Hierochloe recurvata		1
Hymenophyllum multifidum	26	1
Lichens (non-foliose)	7	
Liverworts (unidentified)	4	
Lycopodium fastigiatum	1	
Mosses (unidentified)	25	
Muehlenbeckia axillaris	4	1
Myrsine nummularia	1	1
Olearia moschata	1	2
Ourisia macrophylla	2	
Phormium cookianum	1	
Pittosporum crassicaule		1
Podocarpus nivalis	61	44
Polystichum vestitum	1	1
Pratia angulata	1	
Pseudopanax sp. *(Ps. colensoi var. ternatus)*	2	
Rock	1	
Schizeilema nitens	4	
Schoenus pauciflorus	2	1
S. lyallii	3	
Unicinia filiformis	1	
Viola cunninghamii	1	
Wahlenbergia albomarginata	1	

"Kakapo 2" (subsequently named "Jill" but actually a male), was located by playing the same tape-recorded "skrark" calls obtained from kakapo 1. Its vocal response was vigorous and immediate but generally not as vigorous as that of kakapo 1. Frequency of response declined with repeated playback. To the human ear, the calls from both birds were of an aggressive character. They were similar but not identical to the now well-known "skraark" calls of Stewart Island birds (Powlesland *et al.* 1992). However, the Esperance Valley birds, as well as other kakapo subsequently encountered in Fiordland, produced a number of calls that have not been heard from Stewart Island kakapo (Higgins 1999). Spontaneous calls were very infrequent. On one night only, kakapo 2 gave an extended challenging (and to the human ear, hair-raising) call in immediate response to the crashing noise of a large avalanche in the neighbouring Donne Valley.

The nature of the calls described above suggests that both birds were attempting to advertise their whereabouts and defend the areas in which they were located. However, we found no evidence of fighting; radio-tracking of kakapo on Stewart Island has since indicated that feeding areas of different birds sometimes overlap (Powlesland *et al.* 1992). It is also known that kakapo may have booming sites (track-and-bowl systems or "courts"; Merton *et al.* 1984) within their home ranges but we were unable to find courts in the Esperance Valley. For these reasons we have identified the two areas described below as home ranges rather than territories.

We found no evidence of kakapo presence elsewhere in the Esperance Valley in 1974. However, as indicated above, the male bird "Richard Henry" was caught at *c.*1000 m altitude in 1975, high above the confluence of the Esperance and Gulliver rivers and *c.*1.5 km distant from the home ranges described below.

Home range 1

This home range was used by kakapo 1 and was *c.*1.5 km distant from the place where the kakapo "Richard Henry" was located at 1000m altitude, high above the junction of the Esperance and Gulliver Rivers (Fig. 4).

The site was an alluvial terrace of coarse rock debris with scattered large boulders at an altitude of 700 m (Fig. 5). Its slope was 7° and its aspect N-NNE. It was covered in snow totara scrub with short silver beech forest at its margins. The approximate area was only 1.8 ha but, as indicated above, this may only be the "core area" of a larger home-range that might have been recognised had a longer period of study been possible.

The home range covered a gently sloping river terrace on the true right bank of the river. It was well above normal flood levels and on the more sunny side of the valley. No water channels crossed the area but one boundary of the home range was formed by the Esperance River which, at this altitude, had a low flow in summer except during high-intensity rainfalls.

Snow totara scrub of varying composition covered most of this home range (Fig.4). Its average height was 1 m but varied from 0.1 to 3.2 m in height (n = 350 point measurements). Point-intercept measurements (Appendix 2) showed that 90% of the canopy consisted of shrubs with the remaining 10% contributed by grasses, herbs, mosses and ferns. More than half the shrubs (51%) were species with succulent berries, e.g., *Coprosma astonii, C. colensoi, C. pseudocuneata, Gaultheria rupestris, G. depressa, Pseudopanax colensoi*, *P. simplex*, *Coriaria sarmentosa, C. plumosa* (particularly near the river) and *Myrsine divaricata.* The tall tussocks *Chionochloa conspicua and C. rigida* were both scattered through this community. Herbaceous plants were abundant in the ground layer (<0.3 m high).

Judged by the distribution of tracks, droppings, feathers, feeding signs and places from where the bird was heard calling, the central part of the home range was more intensively used. This was an irregular U-shaped area characterised by a significantly lower canopy (height: 0.05 - 0.9 m with a mean of 0.5 m) than the 1 m average of the surrounding scrub. *Dracophyllum uniflorum* was more abundant in this area, and *Brachyglottis rotundifolia* and *Myrsine divaricata* less abundant than in remaining parts of the range (Table 3: Transects 1 - 3 crossed the central intensively-used part of the range whereas transects 4 - 7 traversed less-used parts). The lower canopy in this central area allowed increased light to reach the ground where a distinct herbaceous layer had developed (Table 4). Although present in other parts of the home range, this layer was not as rich in species.

A change from scrub to silver beech forest along eastern and northern margins of the home range was associated with a transition from a gently sloping river terrace to a bouldery fan deposit of moderate slope (Figs. 4, 5). The forest (Appendices 1 - 4) averaged about 7 m in height (range: 6 – 11 m, n = 25 measurements). Canopy trees were mostly 10 to 30 cm dbh. Juvenile broadleaf was very abundant in the understorey and *Coprosma pseudocuneata*, *C. astonii*, *Pseudopanax simplex* and juvenile silver beech were well represented. Konini (*Fuchsia excortica*) was present in the forest margin and in scrub along the riverbank. Mosses made up 24% of the ground cover but juveniles of broadleaf, *Pseudopanax* spp., *C. astonii* as well as *Astelia* sp. (aff. *A. nervosa*), *Blechnum procerum* and *Polystichum vestitum* were common. Patches of *Astelia* extended out from the forest margin into the scrub, particularly in the northern part of the area. Numerous decaying logs lay within the forest and many trees along the southern forest margin had been uprooted. Fungi were abundant.

Distribution of feeding signs, feathers and droppings, as well as observations of the bird's movements at night, indicated that kakapo 1 was not penetrating the forest for any distance greater than 5 m, at least during March. Large lengths of the forest margin showed no evidence of the bird's presence.

Table 5 Home range 2: Percentage composition of shrubland canopy. Site sampled was a very steep valley wall

Species	Transect 1	Transect 2	All transects (*n*=100)
Aciphylla horrida		2	1
Blechnum cepense agg. ("mountain" sp.)	34	26	30
Brachyglottis rotundifolia	2	6	4
Chinochloa conspicua	2	2	2
Ch. rigida	2	8	5
Coprosma colensoi	2		1
C. foetidissima	2		1
C. pseudocuneata	2	2	2
Coriaria plumosa	2	6	4
Dracophyllum longifolium	8	10	9
D. uniflorum		2	1
Gahnia procera	2		1
Gaultheria rupestris	4	10	7
Lachnagrostis sp.		2	1
Litter		2	1
Leptospermum scoparium	4		2
Mosses (unidentified)		4	2
Myrsine divaricata		2	1
Nothofagus menziesii	6	4	5
Olearia arborescens	6	4	5
Phormium cookianum	16		8
Pseudopanax sp. *(Ps. colensoi var. ternatus)*	2	4	3
Rock	2		1
Rytidosperma setifolium		4	2
Schoenus pauciflorus	2		1

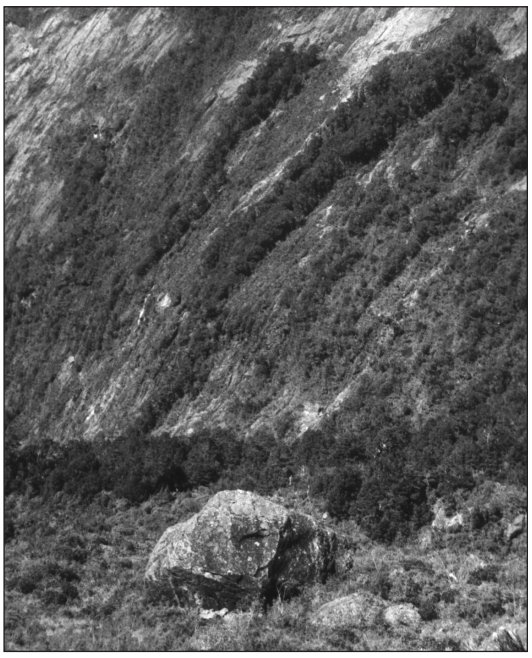

Figure 6 The steep to very steep slopes of Home Range No.2 covered by *Blechnum* fern-shrubland and silver beech forest.

KAKAPO TRACKS: These tracks, 20-35 cm in width, formed a network concentrated in the centre of the home range. Some were well-defined and marked by their moss cover: *Racomitrium lanuginosum* and *Dicranoloma robustum. D. robustum* was definitely chewed by kakapo. Other mosses present were *Bazzania involuta, Breutelia elongata, Dienemen semicryotum, Hypnum cupressiforme* and *Thuidium furfurosum*. Tracks usually passed through low-growing shrubs such as *Gaultheria rupestris*, snow totara and *Dracophyllum uniflorum*, or through patches of plants known to be eaten by kakapo: the sedge *Schoenus pauciflorus* and the speargrass *Aciphylla takahea*. Tussock grasses (*Chionochloa conspicua, C. rigida, Poa colensoi*) were also more common near tracks, the taller species showing kakapo feeding sign on both leaves and seed heads. Where shrubs were taller than 0.4 m, tracks extended beneath the shrub crowns. Many tracks, however, were vague and difficult to follow. In no case were there signs of recent clipping or hedging of plants alongside tracks, as is characteristic of a track and bowl system (or court) in active use by kakapo. In taller vegetation towards the periphery of the home range, tracks either faded out or stopped abruptly. These tracks were also being used by possums, so they may not have originated wholly from kakapo use.

KAKAPO ROOSTS: The northern third of the scrub-covered sector of this home range contained many large boulders beneath which two roosts were found:

(1) A large semi-triangular boulder (2 - 3 m diam.) within scrub of *Coprosma pseudocuneata* and mountain fivefinger, 1 m tall, surrounded by a deep mat of snow totara. The space beneath the boulder was in current use by kakapo 1 (feathers and droppings present) and appeared to have three exits to surrounding vegetation. After very wet weather, this roost was only partly dry.

(2) A large boulder (>3 m diam.) surrounded by *C. pseudocuneata*, *C. ciliata* and *Myrsine divaricata* reaching a height of 1 m. The space beneath this boulder, also in current use by kakapo 1, was open to surrounding vegetation at not less than four places, yet remained completely dry during very wet weather.

Home range 2

This home range was used by kakapo 2 (named "Jill" but later found to be a male). Its core area lay 0.4-0.5 km from home range 1 but differed in being very steep. It was sited on a very steep valley wall mantled with unconsolidated avalanche debris at 800-860 m. altitude, had a general slope of 42 - 45º and faced NW (Figs 4, 6) . The vegetation types were *Blechnum capense* fern - shrubland and short silver beech forest; the two communities growing as alternating stands of vegetation aligned parallel (up and down) with the slope.

This home range, approximately 4 ha in area, lay 0.6 - 0.7 km from home range 1. Very steep slopes, terminating in cliffs above the valley floor, were channelled by actively eroding water-courses. In some places, water passing through these channels had completely removed the mantle of stony debris to leave large expanses of bare rock. Fern - shrubland was associated with shallow soils eroded in this manner whereas the forest was associated with deeper deposits of stony debris.

The fern - shrubland varied in height between 0.3 and 2.0 m with a mean height of 0.7 m. Results from point-intercept transects (Table 5) showed that about 40% of the canopy consisted of shrubs, 30% of the fern *Blechnum capense* aggregate ("mountain species"), and the remainder consisted of herbs, grasses and sedges. After the *Blechnum*, mountain flax (*Phormium cookianum*) was the commonest plant.

Scouring and plucking by sliding ice and snow was evident in the downslope bending of *Chionochloa rigida, Celmisia petiolata* and juvenile silver beech. Root masses were exposed and whole tussock plants had been gauged out or chopped off along the edges of water courses.

Silver beech forest (Appendices 1- 4) varied in height from 21 m in the lower part of the area down to 6 m at the treeline. Canopy trees were mostly in the 20 - 50 cm dbh range with asymmetrical crowns more heavily branched on the downslope side. Many species were present in the understorey with *Pseudopanax simplex*, *Coprosma foetidissima* and *Myrsine divaricata* particularly common. Where the canopy was more open, *Brachyglottis rotundifolia* and juvenile silver beech were present. Southern rata (*Metrosideros umbellata*) was present on the lower slope of the home range but absent from the upper half of the range. The fern *Blechnum procerum* contributed more than 50% of the ground cover. Fallen tree trunks, stumps and loose rocks were numerous on the ground. Foliose lichens were abundant on beech trunks and there was a marked development of mosses on the northern side of these trunks.

KAKAPO TRACKS: No one part of this home range appeared to have received more intensive use than any other. A few tracks were present, particularly in the forest, but they were poorly developed in comparison to those of home range 1.

KAKAPO ROOSTS: Several roosts were found in this home range:

(1). A hole extending 40 cm horizontally beneath the roots of an overturned tree with a forest canopy cover of <10%. The roost contained feathers and droppings. It was fairly open with two entrances between exposed roots that faced N and NNW. Inside the roost the ground was damp after heavy rain.

(2). A hole extending 45 cm horizontally beneath the roots of a live tree with a forest canopy cover of *c.* 50%. The roost contained feathers but no droppings. This hole also had two entrances, at right angles to each other, one facing N and the other NNW. The ground was damp after heavy rain.

(3). A system of two connected cavities beneath roots of an overturned tree. One cavity (*c.* 45 x 45 cm) opened to the north beneath a gap in the forest canopy. A second, and larger cavity, opened from the roof of the first with an entrance facing west. Floors of both cavities were wet after rain. The lower cavity contained fresh droppings and it was from this roost that kakapo 2 was captured.

Breeding activity

No sign of a track-and-bowl system (Henry 1903, Merton *et al.* 1984) was found in either home range and no booming by kakapo was heard in the Esperance and neighbouring valleys during our trip.

Plants eaten by free-living kakapo in the Esperance Valley

Plants browsed by kakapo.

At least nine species of plants had been browsed by kakapo in the Esperance Valley during March 1974. In order of conspicuousness these were:

Schoenus pauciflorus. Leaf tips chewed and compressed into crescent-shaped bundles of chewed fibre left either at the base of the plant or still attached to the leaves. Between 20 and 30 plants of this sedge were present in home range 1 of which three showed definite and abundant signs of browse. No browsed *Schoenus* was found in home range 2 although it was present.

Table 6 Natural foods eaten by kakapo while in captivity in the Esperance Valley.

Type of food eaten	Amount eaten
Leaves:	
Aciphylla takahea	Large amounts
Anisotome haastii	A leaf clipped on one occassion
Asplenium flaccidum	Not touched (eaten subsequently on Maud I.)
Blechnum capense agg. ("mountain" sp.)	Large amounts (stipes eaten on two occassions
B. penna-marina	Eaten on four occasions
Carmichaelia grandiflora	Large amounts sporadically
Celmisia petiolata	Not touched
Chinochloa conspicua	Large amounts
C. rigida	Large amounts
Coriaria phemosa	Moderate amounts
C. sarmentosa	Moderate amounts
Phormium cookianum	Not touched
Poa colensoi	Not touched
Polystichum vestitum	Moderate amounts leaving the stipes untouched
Pseudopanax sp. *(Ps. colensoi var. ternatum)*	Leaves cut on one occasion but not eaten
Schoenus pallciflorus	Large amounts
Roots:	
Aciphylla takahea	Eaten on one occasion
Blechnum capense agg. ("mountain" sp.)	Eaten on three occasions
Polystichum vestitum	Not touched
Fruit:	
Aristotelia fruticosa	Not touched
Astelia sp. *(aff. A. nervosa)*	Large amounts
Coprosma astonii	Eaten on three occasions
C. ciliata	Moderate amounts
C. pseudocuneata	Moderate amounts
C. rugosa	Not touched
Fuchsia excorticata	Eaten on three occasions
Gaultheria sp. *(G. depressa var. novae-zelandiae)*	Large amounts
Hoheria glabrata (green fruit only)	Not touched
Podocarpus nivalis	Not touched
Pseudopanax sp. *(Ps. colensoi var. ternatum)*	Not touched
Seeds:	
Aciphylla takahea	Not touched
Chinochloa conspicua	Eaten on one occasion
Phormium cookianum	Seeds eaten from two pods on one occasion

Aciphylla takahea. The stiff leaves of this plant were chewed a short distance back from their pointed tips which remained attached, hanging by fibres. Although the plant was abundant in home range 1, < 1% were browsed. With both this species and the previous one, kakapo had focused on a few individuals and left the majority untouched.

Dicranoloma robustum. A few patches of this moss had been uprooted and removed (presumably swallowed), particularly on tracks in areas where other feeding sign was present. One instance of "moss chews" was found by C. Smuts-Kennedy (pers. comm.).

Blechnum procerum. Stipes and roots were eaten. About 12 freshly-dug holes were found in home range 2, each of cup size and shape, and all associated with cut fronds of this fern. Roots and stipes had been removed.

Phormium cookianum. Scratches and cuts found on flower stalks were apparently made by kakapo climbing to reach seeds. Kakapo 1 was heard one night climbing and flapping in a flax plant which carried ripe seed. Subsequent observations showed that pods had been torn open and the seeds removed. Similar damage to flax stalks was made by this kakapo when it was subsequently held in a temporary aviary in the valley. Kea also left this feeding sign.

Hierochloe recurvata. Browsed leaves of this uncommon grass were associated with a crescent-shaped chew found on one plant.

Chionochloa rigida and *C. conspicua*. Both species were abundant in both home ranges. The only sign of kakapo browsing were chews on the seed heads of *C. rigida* in the north of home range 1. Both species were chewed by kakapo 1 when in captivity, those of the second species extensively. With fruit abundant at the time of our study, tussock tillers and leaves may have been less important as food. Gray (1977) found tussock grasses to be an important food in the Tutoko, Sinbad and Transit Valleys during 1975-76.

Podocarpus nivalis. Leaf cuticles of snow totara were found in a small sample of kakapo faeces analysed by A. Fitzgerald (pers. comm.).

Carmichaelia grandiflora. The green stems of most plants seen in the valley had been browsed at the tips. Intensity of browsing was greatest adjacent to kakapo tracks and near their roosts. It is probable that this species was eaten by possums and kakapo.

Coriaria plumosa. Leaflets were clipped and stems cut. In the aviary, leaves of this species were stripped of leaflets.

Polystichum vestitum. Cut fronds were seen occasionally in the two home ranges.

Pseudopanax colensoi var. *fiordiense*. Cut stems were seen in a few places.

Natural plant foods eaten by kakapo in captivity in the Esperance Valley

After their capture, kakapo 1 and 2 were held in separate compartments within a temporary aviary (8 x 3 x 1.5 m) a period of four weeks and one week respectively, prior to their transfer to Maud Island. This aviary was built over snow totara scrub in the middle of home range 1. Feeding signs of the birds were recorded for a variety of natural foods offered (Table 6) and compared with feeding sign seen in the field. The table lists only species offered frequently enough to indicate interest by kakapo in them as foods.

Table 7 Foods of kakapo in Fiordland

Type of food	Source of observation
Succulent fruit:	
Astelia sp. aff. A. nervosa	Bell (unpub. 1960), present study.
Coprosma pseudocumeata	Present study.
Coriaria spp.	Henny (1903), Hall-Jones (1960b), Williams (1960), Lavers (unpub. 1967), present study.
Gaultheria sp. (G. depressa var. novae-zelandiae)	Present study.
Griselinia littoralis	Lavers (unpub. 1967).
Myrsine australis	Henry (1903).
Pseudopanax simplex	Present study
Pseudopanax sp. *(P. colensoi var. ternatus)*	Present study
Schefflera digitata	Henry (1897)
Nectar/flowers:	
Metrosideros umbellata	Henry (1903, 1905).
Celmisia petriei	Johnson (unpub. 1979)
Seeds:	
Chinochloa conspicua	Present study
C. rigida	Present study
Phormium cookianum	Bell (unpub. 1960), Lavers (unpub. 1967), present study, Nilsson (unpub. 1974)
Scirpus habrus	Present study.
Leaves:	
Aciphylla takahea	Present study.
A. sp. (not identified)	Lavers (unpub. 1967)
Blechnum procerum	Present study
Carex ternaria agg	Nilsson (unpub. 1974)
Carmichaelia grandiflora	Present study
Carmichaelia sp.	Potts (1873)
Celmisia lanceolata	Johnson (unpub. 1979)
Celmisia sp. (leaf bases)	Bell (unpub.1960)
Chinochloa conspicua	Morrison (unpub. 1962 and pers comm.),
C.rigida	Nilsson (unpub. 1974)
Dicranoloma robustum (moss)	Present study
Gahnia procera	Lavers (unpub. 1967): Sinbad Valley
Hierochloe recurvata	Present study
Hypnum cupressiforme (moss)	Present study
Phormium cookianum	Hall-Jones (1960a,b): Tutoko V. Potts (1873), Henry 1903), Lavers (unpub. 1967)
Podocarpus nivalis	Present study, A.Fitzgerald pers. comm.
Pteridium aquilinum	Von Hugel (1875)
Schoenus pauciflorus	Present study, Nilsson (unpub. 1974)
Roots/rhizomes:	
Blechnum procerum	Present study
Pteridium aquilinum (front tips)	Von Hugel (1875): Te Anau
Tree-ferns (not identified)	Henry (1908): Dusky Sound

Leaves and bark in kakapo droppings

Leaf cuticles of snow totara were found in a small sample of kakapo faeces from Esperance Valley examined by A. Fitzgerald (pers. comm.). This perhaps provides an explanation for why many kakapo tracks and feathers were found in stands of this low-growing tree. Grass seeds were available but none were found in the droppings examined. Henry (1899:139) observed that kakapo could "shell oats like a sparrow", and Gray (1977 - see also Butler 2006) described the kakapo's method of stripping and eating snow tussock seeds.

Bark of pate (*Schefflera digitata*) was present in some faeces, consistent with an observation by Potts (1873) that kakapo eat pate bark. Observations by DVM on Codfish Island have shown subsequently that bark is a normal part of kakapo diet. This includes bark of manuka (*Leptospermum scoparium*), totara (*Podocarpus totara*), southern rata, mountain fivefinger and ribbonwood (*Plagianthus regius*).

Food sources of kakapo in Fiordland

Records of foods eaten by kakapo in Fiordland are summarised in Table 7. Foods eaten by kakapo in captivity are excluded. Observations come mainly from the Milford catchment and are biased towards summer months when field parties have been most active. Kakapo are entirely herbivorous and plants eaten range in growth form from trees to mosses and fungi. Specific food sources include leaves, bark, fern pinnae, rhizomes and ripe sporangia, roots of herbaceous plants, succulent fruit, dry seeds, nectar and tussock-grass tillers which are apparently eaten most frequently in spring.

DISCUSSION

The two home ranges described cover only a small part of a valley where, judged by the distribution of kakapo sign found in earlier years, more birds were once present. However, some conclusions can be drawn from our observations as well as those of other workers.

Habitat selection

Topography and hours of sunshine

The two home ranges contrasted greatly in slope but both were in the sunny half of the valley. Kakapo habitat has been associated with sunny slopes in other parts of Fiordland (Reischek 1884; Melland 1889). The three kakapo "courtship territories" described by Johnson (1976) in Sinbad Gully all had N-NNE aspects. Thirteen kakapo located by Wildlife Service parties in Transit, Tutoko, Gulliver and Poseidon Valleys in the Milford catchment, and at Marrington Peaks, Doubtful Sound between 1974 and 1978 were also in more sunny parts of these valleys.

Vegetation structure and composition

Both home ranges included beech forest margins and this was also the case for kakapo habitats in Sinbad Gully and three of four habitats in the Tutoko Valleys (n = 7 habitats). Johnson (1976) described three "courtship territories" all in ridge-crest silver beech forest. Other home ranges in Fiordland, found subsequent to this study, in the Gulliver (1), Poseidon (2), Transit (4) Valleys and at Doubtful Sound (2) also included beech forest. However, the association with beech forest may not be essential: of five areas where

kakapo feeding sign was found in the Tutoko Valley during the late 1950s and early 1960s, forest was within 100 m of the area in only one case; in two areas the nearest forest was more than 500 m distant (R. Adams pers. comm.).

Both home ranges in the Esperance Valley contained areas of low-growing vegetation (scrub, fernland, tussockland, herbfield) < 1 m high. Scrub immediately beyond home range was *c.* 2.0 m high

Haast (1864) and Potts (1873) mention the presence of low-growing scrub, shrubland, tussockland or open vegetation in areas frequented by kakapo. In Sinbad and Tutoko Valleys, all seven areas used by kakapo in the 1970s included low-growing vegetation < 1 m high (Gray 1977). In Tutoko Valley in the 1960s, all five areas where kakapo were feeding contained some low-growing vegetation, often tussockland < 1 m high (R. Adams pers. comm.). Tracks used by kakapo in low vegetation frequently became vague or disappeared when followed into taller scrub or forest, suggesting that short vegetation was preferred. However, this apparent relationship with vegetation height may have reflected the fact that some favoured food plants, such as *Schoenus pauciflorus, Aciphylla takahea, Coriaria plumosa* and tussock species, are generally restricted to low vegetation. Since birds studied in Fiordland have all been male, it may also reflect a preference by males for the sub-alpine zone (Higgins 1999), which is characterised by lower-growing plant species.

Differences between the kakapo home ranges and other parts of the Esperance Valley

Vegetation of the two home ranges (Tables 3 - 5) and that of other parts of the valley (Appendices 1 - 8) can be compared as potential food sources for kakapo. Plants eaten by kakapo in captivity (Table 6) are included as potential food sources. Observations by other observers of foods eaten by kakapo in Fiordland are given in Table 7. However, it is difficult to assess the importance of food sources identified within the home ranges, given that we now know a kakapo will sometimes travel a kilometre or more to a preferred food source and return to its roost site for the day (Higgins 1999).

Considering potential food for kakapo, the scrub and shrubland data for home range 1 showed little difference between the high-use part of this range and the remainder. Although the mountain fivefinger - mountain holly scrub immediately adjacent to the home range appeared to be a satisfactory food-source, no use of this area was being made by kakapo during February and March 1974. Scrub and shrubland sampled elsewhere in the valley also appeared suitable for kakapo. As discussed below, some areas found had been used by kakapo in the past.

The apparently large differences in foods available within scrub and shrubland of the two home ranges (Tables 3 - 5) illustrates a limitation of the data: sampling covers many areas of vegetation apparently scarcely used by kakapo while small patches of vegetation containing a rich food supply may be under-sampled. During February - March 1974, kakapo 1 could reach patches of *Schoenus pauciflorus* and *Aciphylla takahea*, as well as abundant fruit crops of *Coprosma ciliata*, *C. pseudocuneata* and snow totara within a few metres of its roosts. Similarly, kakapo 2 had made its roost within a few metres of abundant *Blechnum procerum*, *Metrosideros umbellata* in flower (nectar) and fruit of *Astelia* sp. (aff. *A.nervosa*), *Gaultheria* spp. and hybrids, and *Coriaria plumosa*.

Landslides, snow avalanches and rock falls are of frequent occurrence in Fiordland. Seral vegetation develops on slip faces, scoured ground and stony fans that result from these mass-movements. The vegetation of such sites is often rich in shrubs producing succulent fruit as well as rich in fern species eaten by kakapo. It is probable that it was these kinds of vegetation that Henry (1903b) recognised as "kakapo gardens". Johnson (1976) provides a detailed description of such a "garden" in Sinbad Gully. Similar communities are sometimes associated with forest margins, the treeline and recent alluvium on river flats. We suggest that these varied kinds of seral vegetation once comprised the major part of kakapo habitat in Fiordland. The extent to which beech forests were used remains unclear.

Kakapo diet and masting species

A number of native plants, particularly some tree species in New Zealand, produce very heavy crops of fruit in some years, referred to as "mast years". On Stewart and Codfish Islands, kakapo have bred only when rimu (*Dacrydium cupressinum*) has masted (Powlesland *et al.* 1992; Eason *et al.* 2006; Elliott *et al.* 2006; Cockrem 2006). Rimu is not present in the upper Esperance valley or in adjacent valleys at similar altitudes, presumably because these valleys are beyond the altitudinal limit of rimu. Snow totara is not usually recognised as a masting species but its seed production varies greatly from year to year. Whether kakapo can breed in response to abundant fruiting by this species is unknown.

Kakapo habitats in Sinbad Gully (Johnson 1976) also lacked rimu, as well as all other podocarps, including snow totara.

Females may live at lower altitudes than males (Higgins 1999). Where topography has permited, sexes and age -classes have occupied different altitudinal zones e.g., males at the higher altitudes (700–1000 m in Fiordland; 500–750 m on Little Barrier Island), females at lower altitudes (200 – 500 m on Little Barrier Island), and sub-adults at peripheral and lower altitude areas including sea cliffs and the coastal zones on Little Barrier and Codfish Islands (Higgins 1999). Silver beech is frequently the dominant masting species in all but low-altitude parts of Fiordland and it is possible that kakapo bred there in response to its masting.

In identifying the foods of kakapo on Stewart Island, Best (1984) demonstrated how versatile its feeding patterns

can be. The equally wide range of plants and plant parts eaten by kakapo in the Esperance Valley reinforces Best's findings and shows how adaptable kakapo would have been in a New Zealand environment free of mammalian predators.

Reasons for kakapo decline in Fiordland.

The observations discussed above do not suggest that availability of food, or the diversity of food types present, can explain the decline of kakapo in the Gulliver and Esperance Valleys, or in other parts of Fiordland where they were formerly present. The considerable diversity of plants eaten by kakapo, and their ability to derive all of their food requirements during our short study period from within such a small area implies an abundant food resource. Although a potential food competitor, possum, was present, we recorded them to be in very low densities and found no evidence of their effect on potential kakapo foods. Deer, also potential food competitors, were not present. Nor do our data and field observations provide any explanation for the disappearance of female kakapo.

Others (e.g., Butler 1989; Powlesland *et al*. 1992; Higgins 1999) have commented at length on the combination of morphological and behavioural features that make breeding females, eggs, nestlings and fledglings exceedingly vulnerable to introduced mammalian predators, and much more so than males. A breeding population of kakapo survived on Stewart Island into the 1980s in the presence of cats and three species of rats, though it was in steep decline when discovered (Powlesland *et al*. 1992). A key difference between Stewart Island and Fiordland is the absence of stoats and other mustelids from Stewart Island. In the absence of unequivocal evidence of a specific habitat effect, we conclude this difference between Stewart Island and Fiordland to have been crucial. It seems probable that female kakapo had already gone from Fiordland by the early decades of the 20th century, soon after colonization of the region by stoats.

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LITERATURE CITED

Atkinson, I.A.E. 1962. Semi-quantitative measurements of canopy composition as a basis for mapping vegetation. *Proceedings of the New Zealand Ecological Society 9*: 1-8.

Atkinson, I.A.E. 1985. Derivation of mapping units for an ecological survey of Tongariro National Park, North Island, New Zealand. *New Zealand Journal of Botany 23*: 361-378.

Atkinson, I.A.E.; Blaschke, P. 1995. Vegetation. Pp 25-31 *in* Milne, J.D.G.; Clayden, B.; Singleton, P.L.; Wilson, A.D. *Soil description handbook*. DSIR Land Resources, NZ Department of Scientific and Industrial Research.

Best, H.A. 1984. The foods of kakapo on Stewart Island as determined from their feeding sign. *New Zealand Journal of Ecology 7*: 71- 83.

Butler, D.J. 1989. *Quest for the kakapo*. Heinemann Reed, Auckland.

Butler, D.J. 2006. The habitat, food and feeding ecology of kakapo in Fiordland: a synopsis from the unpublished MSc thesis of Richard Gray. *Notornis 53(1)*: 55-79.

Cockrem, J.F. 2006. The timing of breeding in the kakapo (*Strigops habroptilus*). *Notornis 53(1)*: 153-159.

Eason, D.K.; Elliott, G.P.; Harper, G.A.; Moorhouse, R.J. 2006. Breeding biology of kakapo (*Strigops habroptilus*) on offshore island sanctuaries, 1990-2002. *Notornis 53(1)*: 27-36.

Elliott, G.P.; Eason, D.K.; Jansen, P.W.; Merton, D.V.; Harper, G.A.; Moorhouse, R.J. 2006. Productivity of kakapo (*Strigops habroptilus*) on offshore island refuges. *Notornis 53(1)*: 138-142.

Gray, R.S.1977. The kakapo (*Strigops habroptilus,* Gray 1847), its food, feeding and habitat in Fiordland and Maud Island. M.Sc. thesis, Massey University, Palmerston North, New Zealand.

Haast, J. von 1864. Notes on the ground-parrot on New Zealand. *Ibis 6*: 340-346.

Hall-Jones, J. 1960a. Rare Fiordland birds. *Notornis 8*: 191-192.

Hall-Jones, J. 1960b. Kakapo caves. *Notornis 9*: 62.

Henry, R. 1895-1908. Resolution Island reports. *Appendices to the Journals of the New Zealand House of Representatives*. 1895 C.I: 97-102; 1896 C.I:105-107; 1897 C.I:124-129; 1898 C.I:122-126; 1899 C.I:138-141; 1900 C.1: 150-153; 1901 C.I:132-136; 1902 C.I: 84; 1904 C.1:132-137; 1905 H.2:15-16; 1906 H.2:12; 1907 H.2: 2-14; 1908 H.2:17-18.

Henry, R. 1903. *The habits of the flightless birds of New Zealand*. Government Printer, Wellington

Higgins, P.J. (ed.). 1999. *Handbook of Australian, New Zealand and Antarctic birds*. Oxford University Press, Melbourne.

Johnson, P.N.1976. Vegetation associated with kakapo (*Strigops habroptilis* Gray) in Sinbad Gully, Fiordland, New Zealand. *New Zealand Journal of Botany 14*: 151-159.

Melland, E. 1889. Notes on a paper entitled "The takahe in western Otago" by Mr James Park, F.G.S. *Transactions of the New Zealand Institute 22*: 295-300.

Merton, D.V.; Morris, R.B.; Atkinson, I.A.E. 1984. Lek behaviour in a parrot: the kakapo *Strigops habroptilus* of New Zealand. *Ibis 126*: 277-283.

Parsons, M.J.; Douglass, P.; Macmillan, B.H. 1995. *Current names for wild plants in New Zealand*. Manaaki Whenua Press, Landcare Research New Zealand.

Potts, T.H. 1873. Observations on the natural history of the night parrot of New Zealand. *Zoologist 31*: 3621-3624.

Powlesland, R.G.; Lloyd, B.D.; Best, H.A.; Merton, D.V. 1992. Breeding biology of the kakapo (*Strigops habroptilisi* Gray) on Stewart Island, New Zealand. *Ibis 134*: 361-373.

Reischek, A. 1884. Notes on New Zealand ornithology. *Transactions of the New Zealand Institute 17*: 187-198.

Von Hugel, A. 1875. Letter. *Ibis 17*: 389-394.

Williams, G.R. 1960. The birds of the Cleddau River area near Milford Sound, Fiordland. *Notornis 8*: 185-188.

Wood, B.L. 1962. Sheet 22 Wakatipu (1st Ed). "Geological Map of New Zealand 1: 250 000". Department of Scientific and Industrial Research, Wellington, New Zealand.

APPENDICES

The vegetation of the Esperance Valley, FIORDLAND, February – March 1974.

Appendix 1 Percentage composition of forest canopies in the Esperance Valley.

Species	Point analysis of canopies (*n* = 25)				
	Home range 1 700m	Home range 2 800-860m	Head basin 800-850m	Valley floor 550m	Valley mouth 490m
Archeria traversii			4		
Coprosma pseudocuneata			8		
Dracophyllum uniflorum			4		
Gaps in canopy		12	24	4	8
Griselinia littoralis	4			8	
Metrosideros umbellata		4			
Nothofagus menziesii	92	84	56	88	64
Podocarpus nivalis			4		
Pseudopanax sp. *(P. colensoi var. ternatus)*	4				
Weinmannia racemosa					28

Appendix 2 Percentage composition of lower understorey in forests of the Esperance Valley.

Species	Point analyses of lower understories, 0.3-2m (*n* = 25)				
	Home range 1 700m	Home range 2 800-860m	Head basin 800-850m	Valley floor 550m	Valley mouth 490m
Archeria traversii			8		
Astelia sp. *(aff. A. nervosa)*			4		
Blechnum discolor					64
Brachyglottis rotundifolia		12	4		
Chionochloa conspicua	4				
C. rigida			4		
Coprosma astonii	12	8		20	
C. ciliata	8	8			
C. colensoi				16	16
C. foetidissima		20			
C. pseudocuneata	16		16		
Cyathodes juniperina		4			
Dracophyllum uniflorum			4		
Fuchsia excorticata	4				
Gaps in understory	24	8	28	32	4
Griselinia littoralis	8	4		12	
Metrosideros umbellata		4			
Myrsine divaricata	4	16	4		
Nothofagus menziesii	8		4		
Phormium cookianum			4		
Phyllocladus alpinus		4	4		
Polystichum vestitum	4			16	
Pseudopanax linearis		4	4		
Ps. simplex	8	4	4		4
Ps. sp.*(P. colensoi var. ternatus)*		4	4	4	4
Schoenus pauciflorus			4		
Weinmannia racemosa					8
Percentage of species with fleshy fruit:	60	76	36	52	24

Appendix 3 Percentage composition of upper understorey (>2m) in forests of the Esperance Valley.

Species	Point analyses of upper understories (*n* =25)									
	Home range 1 700m		Home range 2 800-860m		Head basin 800-850m		Valley floor 550m		Valley mouth 490m	
	>6m	2-6 m	>6m	2-6 m	>6m	2-6 m	>6m	2-6 m	>6m	2-6 m
Archeria traversii						4				
Brachyglottis rotundifolia				8						
Coprosma ciliata				4						
C. foetidissima										40
C. pseudocuneata				4						
Dracophyllum longifolium						4				
Gaps in understory	92	40	92	40		76	80	68	52	32
Griselinia littoralis	8	20		8			20	12		4
Halocarpus bidwillii						4				
Hoheria lyallii (H. glabrata)								8		
Metrosideros umbellata				8						
Myrsine divaricata		8		4				4		
Northofagus menziesii		32		8		4		8		
Phyllocladus alpinus						4				
Podocarpus hallii				4						
Pseudopanax linearis						4				
Ps. simplex			8	12						4
Weinmannia racemosa									48	20
Percentage of species with fleshy fruit	8	28	8	36		12	20	16		48

Appendix 4 Percentage composition of ground stores in forests of the Esperance Valley.

Species	Point analyses of ground storey, 0 – 0.3m (*n* = 25)				
	Home range 1 700m	Home range 2 800-860m	Head basin 800-850m	Valley floor 550m	Valley mouth 490m
Archeria traversii			4		
Astelia fragrans					4
A. sp. *(aff. A. nervosa)*	12	8	16	8	
Blechnum capense agg. ('mountain' sp.)			8		
B. discolor					28
B. penna - marina				4	
B. procerum	12	52			12
Brachyglottis rotundifolia			4		
Celmisia petiolata			4		
Chionochloa rigida			4		
Coprosma astonii	8	4			
C. colensoi					4
C. foetidissima		4			
Cyathea smithii		8			
Dendroligotrichum dendroides				4	
Dracophyllum menziesii			4		
Gaultheria rupestris		4			
G. sp. *(G. depressa var. novae-zelandiae)*			4		
Griselinia littoralis	12				
Hymenophyllum multifidum	4		4	4	4
Lichens		4			
Litter	8		20	8	32
Mosses (unidentified)	16	4	8	36	
Nothofagus menziesii					4
Phyllocladus alpinus		4			
Podocarpus nivalis	4		16		
Polystichum vestitum	8			20	
Pseudopanax sp. *(Ps. colensoi var. ternatus)*	8	4	4		
Ptychomnium aciculare	8	4		4	12
Rocks				4	
Stones				4	
Uncinia filiformis				4	
Percentage of species with fleshy fruit	44	24	40	8	8

Appendix 5 Percentage canopy composition of leatherwood - mountain fivefinger scrub in the Esperance Valley (both areas, *n = 25).*

Species	Valley floor	Home range 2
Blechnum procerum		12
Brachyglottis rotundifolia	16	20
Carmichaelia grandiflora	4	
Cassinia vauvilliersii	4	
Chinochloa conspicua		8
Ch. flaveseens	12	
Coprosma ciliata	4	4
C. pseudocuneata		8
Cyathea smithii		8
Griselinia littoralis	4	
Hebe subalpina	4	4
Hoheria glabrata	8	
Myrsine divaricata	4	4
Nothofagus menziesii		8
Olearia ilicifolia x O. arborescens	12	12
Phormium cookianum	12	4
Pseudopanax sp. *(Ps. colensoi var. ternatus)*	16	8

Appendix 7 Percentage composition of shrubland canopies in the head basin of the Esperance Valley

Species	Point analysis of canopies	
	Sample 1 (*n*=100)	Sample 2 (*n*=50)
Aciphylla takahea		2
Anisptome haastii	1	
Astelia sp. *aff. A. nervosa*	1	4
Celmisia glandulosa	1	
C. petrei		4
Chinochloa rigida	9	10
Coprosma pumila	1	
Dracophyllum longifolium	2	
D. traversii		2
D. uniflorum	3	38
Gaultheria rupestris		4
Halocarpus bidwillii	4	
Hebe subalpina		2
Lepidothamnus laxifolius	3	
Leptospermum scoparium	1	
Lichens	6	
Litter	4	
Lycopodium scariosum	1	
Moss (unidentified)	17	
Oreobolus pectinatus	4	
Ourisia macrocarpa	1	
Phormium cookianum	1	2
Pittosporum crassicaule	1	
Podocarpus nivalis	8	12
Pseudopanax sp. *(P. colensoi var. ternatus)*		8
Racomitrium lanuginosum		2
Rytidosperma setifolium	1	
Rock	23	
Schoenus pauciflorus	6	10
Soil (bare)	1	

Appendix 6 Percentage canopy composition of mountain fivefinger – mountain holly scrub in the Esperance Valley (*n* = 100).

Species	*Alluvial terrace*
Aristotelia fruticosa	2
Blechnum capense agg. ("mountain" sp.)	1
B. penna-marina	1
Brachyglottis rotundifolia	3
Cassinia vauvilliersii	2
Chionochloa conspicua	8
Ch. rigida	3
Coprosma ciliata	10
C. pseudocuneata	1
C. rugosa	1
C. serrulata	1
Coriaria plumosa	1
Dracophyllum longifolium	1
D. uniflorum	1
Gaultheria rupestris	1
Griselinia littoralis	3
Hebe subalpina	4
Myrsine divaricata	9
Nothofagus menziesii	1
Olearia ilicifolia x O. arborescens	21
Phyllocladus alpinus	1
Podocarpus nivalis	1
Polystichum vestitum	1
Pseudopanax sp. *(Ps. colensoi var. ternatus)*	22

Appendix 8 Percentage composition of tussockland canopies in the Esperance Valley. All samples were made on the large talus cone forming the south-western corner of the valley floor.

Species	Point analyses of canopies (*n* = 25)		
	Sample 1	Sample 2	Sample 3
Anisotome haastii	4	4	
Boulders (>20cm diam.)	4		4
Celmisia sp.	12		
Chionochloa rigida	4	28	4
Ch. oreophylla	16		
Gaultheria rupestris		12	
Hebe subalpina		8	
Helichrysum bellidioides		4	8
Lachnagrostis sp.	8		
Litter	4		
Moss (unidentified)	8	8	24
Poa colensoi	16	4	
Racomitrium lanuginosum		8	16
Rytidosperma setifolium	4	16	36
Schoenus pauciflorus	8	8	
Stones (2-20cm diam.)	4		4
Wahlenbergia albomarginata	8		4