The habitat, food and feeding ecology of kakapo in Fiordland: a synopsis from the unpublished MSc thesis of Richard Gray

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Abstract Gray studied the last natural mainland population of kakapo in Fiordland in the 1970s. Between 1974 and 1977 all 15 male birds located occupied home ranges high on the sides of valleys in areas of diverse vegetation associated with the tree line or avalanche and alluvial fans. Track-and-bowl systems were frequently positioned on the crests of ridges and knolls on well-drained sunny slopes. Studies of feeding sign and of faecal content using cuticle analysis provided detail of kakapo diet, confirming the bird to be an herbivore. About 80 species of plants were eaten in Fiordland. The kakapo bill is adapted to crushing and extracting nutrients and retaining fibre which is expelled as distinctive 'chews'. A preliminary study of the nutrients in kakapo food suggested that the birds selected the most nutritious plant parts and species.

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INTRODUCTION

In the 1970s Richard Gray joined Wildlife Service expeditions to Fiordland to study aspects of the feeding ecology of kakapo at a time when the species was considered to be on the brink of extinction. The findings documented in his MSc thesis (Gray 1977a) represent unrepeatable observations in the final mainland stronghold of the species. He wrote "It is hoped that the collation of this information on foods and feeding will help in furthering the understanding of the kakapo's feeding requirements, a vital factor in preserving the species." This hope is particularly relevant almost 30 years later as the focus of the kakapo recovery programme returns to Fiordland with birds now present on Chalky and Anchor Islands in Dusky Sound and the restoration of Resolution Island about to commence (R. Moorhouse pers. comm.).

Gray also studied kakapo feeding and use of vegetation on Maud Island in the Marlborough Sounds where a small translocated population was held until recently (Eason *et al.* 2006). This information is not reproduced in this paper for the management of kakapo has shifted away from the use of islands dominated by such modified habitats.

STUDY AREA

Milford catchment

The glaciated topography of the Milford catchment and surrounding fiords (Fig.1) probably contributed to the survival of kakapo there. Access for introduced competitors and predators has been hindered by the geographical barriers.

The valleys of the Milford catchment and surrounding region all have the 'U' shaped cross section typical of glaciated valleys. The valley walls are sheer and extensive areas of exposed granite and granidiorite rocks are visible. A valley floor is comprised of avalanche debris and rock falls which are piled along its sides at the bases of the overshadowing peaks. The highest peak in the area is Mt. Tutoko (2770 m) but most peaks range between 1500 and 2100 metres.

Rainfall in the region is high. The nearest climate station is at the head of Milford Sound where the average annual rainfall is 6236mm. Considering the altitudinal difference between the various subalpine kakapo home ranges described and Milford (at sea-level), annual rainfall at such altitudes west of the divide is likely to be in the order of 7000 mm (J.D. Coulter 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 6^{o}C/km of altitude, mean annual temperature (extrapolated from Milford) in the subalpine kakapo home-ranges described would be about 5.5 – 5.9^{o}C. In winter snow covers most subalpine areas for months and little sunshine penetrates into the valleys (Atkinson & Merton 2006).

At the time of Gray's study, silver beech (*Nothofagus menziesii*) was the most abundant canopy species in the vicinity of kakapo home ranges but on avalanche debris fans mixed *Olearia*, *Hoheria* and *Senecio* scrub replaced it. Above bush line, alpine scrub (*Dracophyllum* spp., *Olearia* spp., *Podocarpus nivalis*, and *Senecio bennettii*) and tussock grassland (*Chionochloa crassiuscula* and *C. rigida*) formed the predominant cover.

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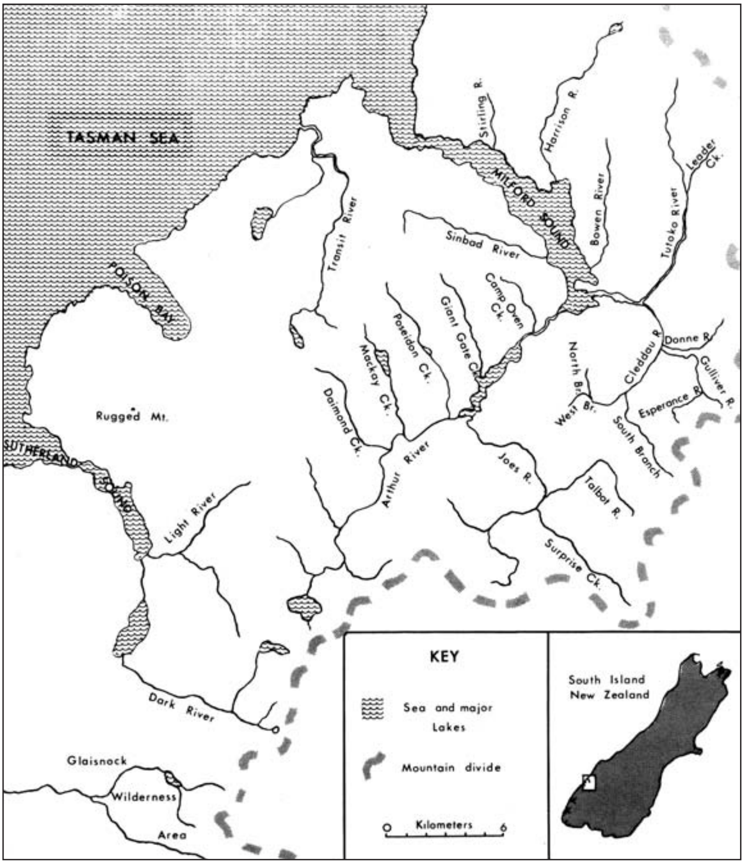


Figure 1 Northern Fiordland showing the principal areas in which kakapo searches were conducted in the 1970s.

Bird life was sparse. The most commonly recorded species in the high altitude forest and scrub were redpolls (*Acanthis flammea*), bellbirds (*Anthornis melanura*), grey warblers (*Gerygone igata*), kea (*Nestor notabilis*), tomtits (*Petroica m. macrocephala*), rock wrens (*Xenicus gilviventris*), and silvereyes (*Zosterops lateralis*). Two other species of parrots regularly reported in the area besides kea and kakapo, were kaka (*Nestor m. meridionalis*) and parakeets (*Cyanoramphus* spp.).

Wildlife Service expeditions trapped rodents or reported rodent faeces on or close to kakapo home ranges, and mustelid droppings were also found throughout this habitat. Ungulates were present in the Milford and Transit catchments but at low densities. In several of the higher-altitude kakapo home ranges, deer (*Cervus* spp.) had not then penetrated and chamois (*Rupicapra rupicapra*) were kept to low numbers with regular shooting by Forest Service personnel. Possums (*Trichosurus vulpecula*), liberated in the Milford Sound area in the 19th century, were slowly spreading throughout the Milford catchment, especially on the warm dry faces which were favoured also by kakapo. No possum sign was evident within the home ranges of kakapo in the Transit Valley, nor in the head basins of the Sinbad and Poseidon Valleys. However such sign was widespread and abundant in the Tutoko, Gulliver and Esperance home ranges.

Frequent expeditions by the Wildlife Service in search of kakapo had been mounted in the Milford catchment area since the late 1950s; 38 expeditions (Wildlife Service files 46/61/1 and 25/3/4) prior to 1974, most of which were into the Tutoko and Sinbad valleys near Milford Sound.

In the 1950s and 1960s, Wildlife Service personnel found that kakapo were restricted to the tributaries of the Cleddau and Arthur rivers, in particular the Tutoko Valley, where feeding sign was found on open flats and debris fans in the upper reaches of this valley (Anderson 1961; P. Morrison pers. comm.). Five kakapo were trapped in the Tutoko Valley in 1961-62 and transported to Mt. Bruce in the Wairarapa where four died soon after but the fifth survived four-and-a-half years. Kakapo sign was also located on the flats and low altitude fans in the West Branch of the Cleddau, the Esperance Valley and the Sinbad Valley. In 1974, kakapo sign had disappeared from all these low altitude sites with the exception of one bird found at the base of Mt. Tutoko (Fig. 1).

In November 1974 a fresh approach to the kakapo conservation program was initiated by D.V. Merton (1975, 1976a,b) and helicopters were used to search the most likely areas still harbouring kakapo. Visits were made to approximately two-thirds of the valleys in the Milford catchment. These included the Stirling, Harrison, Bowen and Sinbad Valleys whose rivers drain directly into Milford Sound; the Cleddau with its eight main tributaries which include the Tutoko, Gulliver and Esperance Valleys; and the Arthur Valley where only four of the eleven valleys were searched by ground parties, one of these being the Poseidon Valley. The search for birds also extended south and west of the Milford catchment into the Poison Bay and Rugged Mountain area north of Sutherland Sound, the Dark and Light Rivers and the Glaisnock Wilderness area (Fig. 1).

Kakapo home ranges

Fifteen kakapo were found during the three-year search programme between November 1974 and February 1977, four in the Transit Valley (Fig. 2) and the remainder in valleys of the Milford catchment. All but one Tutoko Valley bird occupied ridges, benches or avalanche fans high on the sides of the valleys in comparatively inaccessible sites (Figs 3, 4). Feeding sign and droppings of one kakapo were found in the Poseidon Valley in January 1977 (Fig 5) (Buckingham 1977; Gray 1977b). Three kakapo were seen in the Sinbad Valley between January and March 1975 (Fig. 6) (Gray, Merton & Morris 1975; Russ 1975) and subsequent observation of two of these birds continued to February 1977 (Roxburgh 1975; Gray 1977c; R. Morris pers. comm.). Four were located in the Tutoko Valley, one on the valley floor (McFadden 1975; Gray, Merton & Morris 1975), the remaining three on a spur and nearby bench (Figs 3,4), the latter a more gently sloping area on the mountain side 900-1100 m above sea level. The three remaining kakapo, all of which were removed to Maud Island, were located in the Esperance and Gulliver Valleys which, like the Tutoko, are tributaries of the Cleddau River.

METHODS

Describing the vegetation in kakapo home ranges

Profile diagrams

Diagrammatic representations of the vegetation, its structure, comparative height and predominant species, and the slope of the terrain across feeding areas and track and bowl systems were drawn as profile diagrams. A measuring tape was stretched between two points A and B situated 8 - 25 m apart. The species, height and structure of each plant were noted as it crossed the tape. In addition, all species within 50 cm of the tape were recorded.

Point intercept transects

With the knowledge and experience gained from the profile diagrams a more comprehensive study was undertaken in January and February 1977. Plant species were noted as they intercepted a transect line at regular intervals (every 0.5 m or 1.0 m) (Robbins 1962) enabling the percentage cover of plant species to be estimated. Six transects of 100-180 points and one transect of 63 points were undertaken, one in the Tutoko Valley and two in the Transit Valley (data presented in this paper), and two in each of the Poseidon and Sinbad Valleys. Four of these transects passed through combined feeding areas and track-and-bowl systems. The remaining three spanned areas where kakapo feeding sign was observed.

The technique followed that used by Johnson (1976a) in the Sinbad Valley home ranges. At each transect point the presence of plant species comprising the canopy, three tiers (0-30 cm, 30-60 cm and above 60 cm) and the predominant ground cover were recorded. This method demanded a close study of the vegetation within one metre of the ground where species diversity is generally greatest and where kakapo were expected to obtain a large proportion of their diet.

Recording of feeding observations

One kakapo from the Sinbad Valley was captured in March 1975 (Gray, Merton & Morris 1975; Russ 1975), flown to an aviary in the Esperance Valley and held there for several days for filming. Film sequences of the kakapo feeding on *Coprosma rugosa* berries and *Chionochloa conspicua* tillers and seeds were obtained and analysed.

Faecal analysis

Collecting samples

Wildlife Service field parties collected both fresh droppings from track and bowl systems and nearby feeding areas and old faeces from dry roosts, mostly among the exposed roots of beeches or under rock overhangs or shallow caves. Fresh droppings (assumed to be less than 72 hours old) were rare and most samples were of old droppings, some of which were suspected to be possibly 50 years old or more. All were sealed in plastic bags and forwarded to Massey University where they were frozen prior to analysis.

Establishing a plant cuticle reference collection

Plant cuticles of 130 Fiordland plant species from 85 genera were collected, most from kakapo home ranges (provided as Appendix 1 in thesis). A reference collection of microscopic accessory structures including hairs (trichomes), scales, and fern palea was also prepared.

Reference cuticles were prepared by the chromic/nitric acid method (Zyznar & Urness 1969; Dunnet *et al*. 1973) which involved a 50:50 mixture of 2N nitric acid (HNO_3) and a saturated solution of chromium trioxide (CrO_3). The leaves of each species and the petioles, twigs, stipules, inflorescences, exocarp and petals of many were processed in the mixture.

Plant parts were cut into small portions several millimetres in length and left for varying lengths of time (10 minutes - 48 hours) in the acid, depending on the size, thickness and moisture content of the leaf. The cuticle and remaining material was then washed and bottled in FAA (70% alcohol 90pts; glacial acetic acid 5pts; 40% formaldehyde 5pts).

Figure 2 Transit Valley, Fiordland showing locations of four kakapo track-and-bowl systems (arrowed). (photo: R.B. Morris)

Figure 3 Tutoko Valley (Mt. Tarewa spur), Fiordland, the numbered arrows indicating the two locations of track-and-bowl systems of a single male kakapo.

Figure 4 Tutoko High Bench, Tutuko Valley, Fiordland where a track-and-bowl system was established immediately above the numeral 2.

Figure 5 Poseidon Valley, Fiordland showing an alluvial fan that was the principal fedding area within the home range of the last kakapo in the valley.

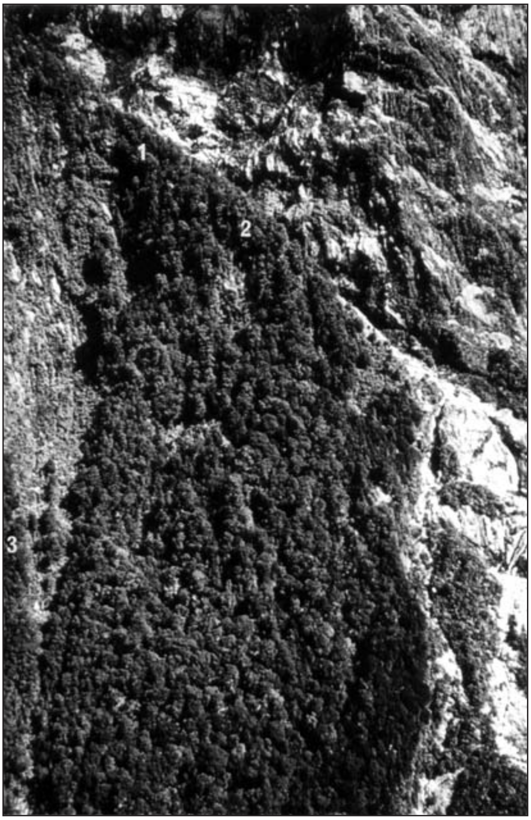


Figure 6 Sinbad Valley, Fiordland, the numerals indicating the general position of three kakapo home ranges. (photo: D.V. Merton)

Cuticles were photographed which proved a useful general guide to the species involved. A chart tabulating plant cuticle characteristics (cell wall thickness, cell and stomata size, shape, segmentation and arrangement) was used to limit the reference cuticles which had to be checked and compared with the unknown cuticles in the droppings. Scale diagrams of trichomes (hairs, scales, palea) and some cuticles (similar to Davies 1959) proved helpful and supplemented the photographs.

Some reference cuticles were mounted in glycerine and the coverslips sealed with nail varnish. However bottled reference cuticles in FAA which could be readily mounted in water, examined and then returned to the preservative, proved more useful.

Preparing samples

Fresh and recent droppings were examined individually, as were old droppings if they had been found singly. In many instances, however, quantities of old droppings were collected from roosts. These were bulked, mixed and then sampled. For analysis work a few typically coiled kakapo droppings were selected (10 or less).

Samples of dry droppings were crumbled into a Petri dish containing water, while moist samples from fresh droppings were whisked in water with tweezers. These preparations were examined under a binocular microscope of magnification 0.7 - 4.0 times. When present, seeds, leaf fragments, large pieces of conductive tissue and other items of interest were removed for later identification. The wet sample was then filtered in a coarse grade filter paper and set aside for chromic/nitric acid treatment.

Faecal samples were macerated in a similar fashion to the leaves according to the following method: wet sample of faecal material placed in watch glass - sufficient acid added to immerse sample - acid left to 'work' at room temperature for up to 20 minutes depending on content and age of dropping - filtration of acid and washing of sample - cuticles and remaining plant material removed from filter paper and preserved.

Examination of cuticles

All material on several slides was examined methodically. The more diverse the sample the more slides examined. If the acid treatment seemed to have been too severe or insufficient for identification more samples were prepared. Identified and suspected cuticles were listed. Unknown cuticles were given a number and a scale sketch drawn for later consideration.

Once the identifiable cuticles and plant cells in the sample had been recorded, an estimation of the contents in the processed dropping was undertaken. Generally several dropping samples were combined and five to eight slides examined. A transect method was used where either 100 or 200 points, depending on the diversity of material, were examined. In each slide an area of medium density was selected. The first 20-30 items to pass under the centre line of the grid scale as the slide was scanned were listed.This enabled an estimate of the percentage total cuticle present, the percentage of individual species, and the amount of fibrous plant matter (Stewart 1967). Before the count was made seeds and massed conductive cells were removed with tweezers and a coverslip positioned over the sample.

Nutrient analysis

Collection of samples

A total of 14 kakapo food species were collected. Where practicable 454 g (1 lb) wet weight samples were obtained from a number of individual plants. Samples were dried in the sun or pressed between newsprint, and then placed in a warm air drier in the laboratory to complete the process. What chemical changes may have taken place between the time of collection and air drying, and whether these may have influenced results, are uncertain. Plant samples, with the exception of *Phormium tenax*, *Agrostis tenius* and *Holcus lanatus*, were collected in kakapo home ranges at a time when the plant species were being eaten by kakapo. Flax and grasses were collected outside the study areas.

Figure 7 Track-and-bowl system of male kakapo at site 1 (Fig. 2) in Transit Valley, Fiordland. A measuring tape traverses the track where vegetation is clipped low by the male kakapo.

Analyses

Methods of analyses followed standard procedures (Horwitz *et al.* 1970). All results were repeated until duplicated samples varied less than 1%.

For moisture content determinations, wet weight of plant matter was recorded immediately following collection and the dry weight after 24 h in an air oven at 58°C. Plant material was then ground and passed through a 1.0mm grid and dried in a vacuum oven at 14 mm Hg and 62°C for 5 h. Loss in weight between fresh wet weight and weight of sample after the second drying was expressed as percentage water.

Crude protein (C.P.) content of samples was determined by the Macro Kjeldahl method. The nitrogen value obtained was multiplied by the standard figure of 6.25 to obtain an estimate of crude protein. For ether extract (E.E.) determinations, fats were extracted by refluxing samples with ethyl alcohol in a Soxhlet apparatus for 14 h.

The loss on ignition (at 580°C for 30 min.) of dried residue remaining after digestion of the sample with 1.25% H_2SO_4 and 1.25% NaOH solutions under specific conditions was defined as crude fibre (C.F.) content. The value obtained approximates the proportion of feed which is indigestible, predominantly celluloses, with the exception of lignin which is included under N.F.E. values as a non-digestible carbohydrate. To determine ash (inorganic component) content, a 5 g (dry weight) sample was incinerated in a muffle furnace at 600°C ± 15°C for 3 h or until a constant weight was obtained.

Nitrogen Free Extract (N.F.E.) determinations provided a measure of the digestible and non-digestible carbohydrate fraction in the food sample and was calculated as follows:

% N.F.E. = 100 - (% H_2O + % C.P. + % E.E. + % C.F. + % Ash). Accumulated errors made this value the least reliable of the six fractions analysed.

KAKAPO HOME RANGES – TOPOGRAPHY AND VEGETATION

Gray (1977a) reported on all the valleys in which kakapo were found in the 1970s and drew 13 profile diagrams of the vegetation of kakapo home ranges. The two valleys studied in most detail, Transit and Tutoko, included 10 profiles; two examples from each valley are reported below and appear representative of all sites described.

Transit Valley

The Transit River runs into the sea 3 km south of the entrance to Milford Sound and extends some 3 km in a south-easterly direction in from the coast before curving sharply to the south south-west penetrating a further 7 km inland (Fig. 1). The low 450 m hills which flank the valley on the coast rapidly rise to 1500 m and overlook a thickly forested valley floor. A large open river flat spreads across the lower reaches of the valley, but further inland continuous forest covers the 0.3 to 0.8 km wide valley floor below the area occupied by the four known kakapo.

A comparatively short razorback ridge abutting the range of mountains on the true right of the Transit Valley, about 8 km from the coast, supported two kakapo. This massive rock buttress reached an altitude of 1130 m at its highest point before dropping to a pass 30 m below and there fusing to the main mountain range.

Two track-and-bowl systems were located on this ridge (sites 1, 2; Fig. 2). The first included seven bowls along 30 m of the ridge crest near the highest point (1100 m) (Fig. 7). The second bowl system began 50 m further down the ridge below the first system and extended along 75 m of the ridge linking 19 bowls. Four bowls in the upper and four in the lower system appeared to be in use during January and February 1976 (Anderson 1976; Veitch 1976a).

A third system was found in the vicinity of a gently sloping but thickly forested ridge 1 km north of ranges

1 and 2 at 680 m.a.s.l. (site 3; Fig. 2) while the fourth, also at 680 m, lay at the base of the rock buttress on which birds 1 and 2 were present (site 4; Fig. 2).

Description of general vegetation

The vegetation of the Transit Valley is briefly described by Wardle *et al.* (1971) who noted the presence of silver beech - rata (*Metrosideros umbellata*) - kamahi (*Weinmannia racemosa*) - mountain beech (*Nothofagus solandri* var. *cliffortioides*) forest and tall *Senecio* scrub. Beech forest (*Nothofagus* spp.) covered most of the valley floor, and where terrain permitted, beech forest extended to the tree line (*c.*1000 m).

In the vicinity of the kakapo home ranges the tree limit was of variable altitude (680-1050 m) because of the steep rugged nature of the topography. Silver beech was the predominant canopy tree at tree line where the association may be classified as 'silver beech - *Archeria* - *Senecio* forest' and 'beech - *Coprosma* forest' (C1 and C2 respectively in Wardle *et al.* 1971). The silver beech - *Coprosma* forest association was present as the tree line forest at low altitude where bluffs restricted higher altitudinal extension of the forest.

Thick *Senecio-Dracophyllum-Olearia* scrub (canopy height average 2 m) occupied much of the steep terrain in areas where silver beech forest was absent below 1050 m. Exposed un-weathered rock faces and avalanche scars were numerous between home ranges 1 and 3. Tussocks, grasses and herbaceous species were common on many of these sites.

Detailed description of home range 1

Map Reference[1]: NZMS1 S112 763104; vegetation: tussock and alpine scrub; site type: prominent rock buttress; altitude: 1100m; slope/aspect: 30° E-W.

From the valley floor 900 m below the track-and-bowl systems of kakapo 1 and 2 (Fig 2), broken tongues of silver beech forest roise to the expected tree line altitude of 1000 m despite the steep terrain. Above the tree line, alpine scrub replaced beech forest wherever the substrate was suitable and encompassed the exposed, near vertical rock faces and rock outcrops which studded the higher reaches of the ridge. Grasses, predominantly *Chionochloa crassiuscula* and *C. rigida*, covered the more gently sloping terrain south of the ridge above bush line and extended up the southern face to occupy small areas of the ridge west amongst the thick scrub.

General composition of alpine scrub: canopy height: 0.01 – 3.5 m; general height:1-2 m.

Four shrub species dominated the canopy on the sunny north face of the ridge, *Coprosma crenulata*, *Halocarpus biforme*, *Dracophyllum longifolium* and *D. uniflorum*. Other common species were *Senecio bennettii*, *Pseudopanax colensoi* var. *ternatum*, *Coprosma crenulata*, *C. astonii*, *Hebe subalpina* and *H. cockayniana*. Flax (*Phormium cookianum*), *Chionochloa rigida* and *Astelia nivicola* played minor roles as canopy species. A discontinuous and sparse understorey was present including *Celmisia lanceolata*, *Anisotome haastii*, *Blechnum capense*, *Gaultheria crassa* and *Coprosma* spp.

The vegetation cover varied on the shady damp southern side with *Dracophyllum menziesii*, *D. fiordense* and *Olearia colensoi* the predominant canopy species. *Dolichoglottis scorzoneroides*, *D. lyallii*, *Anisotome haastii*, *Celmisia ramulosa*, *C. walkeri*, *Astelia nivicola* and large *Chionochloa rigida* clumps were common. *Podocarpus nivalis* was a notable absentee in the area. Along the ridge crest several small areas had been extensively clipped by the kakapo in and around the vicinity of the bowls (Fig. 7).

Profile diagrams

The range 1 profiles (Figs. 8, 9) span parts of the same track-and-bowl system; profile 1 crosses the ridge crest along the line of the tape showing in Fig. 7; profile 2 (Fig. 9) spans a small plateau on the north face of the home range just below the ridge crest. A total of 37 plant species were recorded within 50 cm of the tape along profile 1 and 21 species along a similar distance of profile 2.

Plant transect

Point intercept transect involved two parallel lines across ridge crest; Line 1, 18.5m, line 2, 12.0m, total transect 30.5m, 63 points, points 0.5m apart, direction N-S.

A total of 50 vascular plants were recorded across the transect: woody shrubs 11, grasses 6, herbs and ferns 33. The canopy height ranged to 1 m and canopy composition was: overall cover 94%, bare earth 4.5%, litter 1. 5%, shrubs 14%, grasses 41.5%, herbs and ferns 16.0%, Cryptogams 22.5%.

Major canopy species were *Chionochloa crassiuscula* 27%, *Chionochloa rigida* 14%, *Rhacomitrium* sp. 13%, *Dicranoloma* sp. 6.3%, *Dracophyllum uniflorum* 6.3%. A further 12 species occupied 27% of the points.

At only 13% of the points was cover over 60cm; this was predominantly *C. rigida* which reached about 1 m. Vegetation between 60-30cm covered 19% of the transect points (*C. rigida* 13%, *D. uniflorum* 4.7%, *Olearia colensoi* 1.3%). Vegetation below 30 cm covered 59% of the transect points(*C. crassiuscula* 24%, *D. uniflorum* 8%). A further 10 species occupied 27% of the points. Overall ground cover was 80% with exposed rock 2%, exposed earth 9%, litter 9%, Cryptogams 53%, and *Astelia linearis* 6.0%. A further nine species occupied 21%.

Detailed description of home range 4

Map Reference: NZMS1 S112 763109; vegetation: regenerating scrub and beech forest; site type: base of bluff, old rock falls and alluvium; altitude: 680 m; slope/aspect: 10° E-W.

Home range 4 was situated in an area where the bush line was restricted to a comparatively low altitude (680 m). Bluffs, 300 m high, formed the eastern boundary of the range and determined the limit of beech forest. Presumably,

[1] All map references refer to the imperial grid

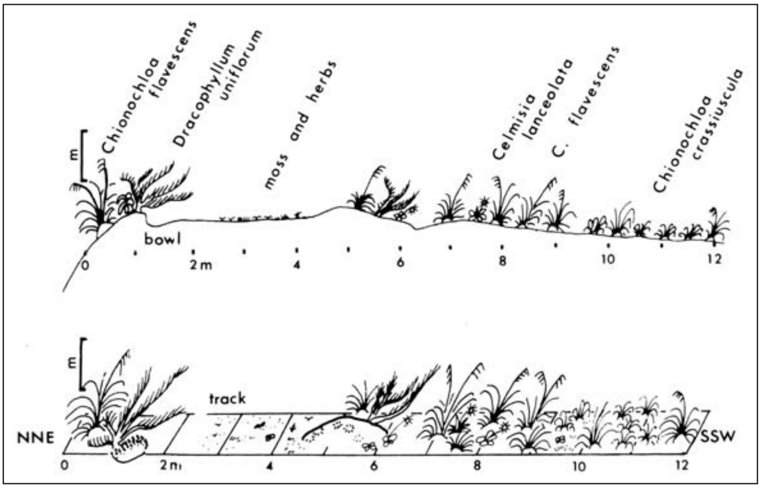


Figure 8 Profile 1. Profile diagram of transect within home range of kakapo at site 1 (Fig. 2) in Transit Valley, Fiordland. The transect follows the measuring tape visible in Fig. 7. Upper profile illustrates vertical scale of vegetation; Lower profile illustrates vegetation within 50 cm of transect line.

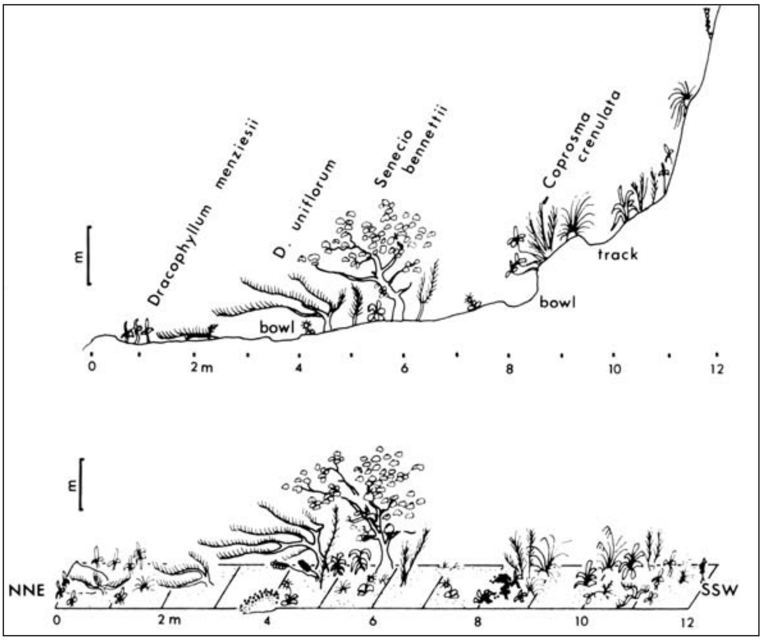


Figure 9 Profile 2. Profile diagram of transect within home range of kakapo at site 1 (Fig. 2) in Transit Valley, Fiordland. Upper profile illustrates vertical scale of vegetation; Lower profile illustrates vegetation within 50 cm of transect line.

past rock falls from these bluffs had destroyed an area of 2 ha and thick *Dracophyllum* scrub and grasses covered this area (Fig. 10). Above the bluffs a small cirque contained a small unnamed lake which probably acts as a buffer to snow avalanches falling from the surrounding higher peaks (Fig. 2). Seepage from the bluffs and water flow following wet weather has cut a small but deep stream bed between the rock face and avalanche debris. The resulting west bank of this stream bed takes on the appearance of a small ridge and it is along this that the track-and-bowl system ran.

Silver beech surrounded the 2 ha area of scrub, except on the eastern side, and formed a continuous cover down the steep slope below the 'garden' area to the valley floor.

Profile diagram

A SE – NW profile (Fig. 11) crossed two tracks maintained by the resident male kakapo.

Plant transect

Point intercept transect through track-and-bowl system and feeding area: transect 50m, 100 points, points 0.5m apart, direction of transect, SE - NW.

A total of 44 vascular plants species were recorded across transect. The canopy height was 0.4 - 2.25 m with a general height of 1 - 1.5 m and canopy composition was: overall cover 99%, rock 1%, shrubs 62%, grasses 21%, herbs and ferns 15%, and Cryptogams 1%.

Figure 10 Home range 4 in Transit Valley, Fiordland. A hide (left centre) was positioned to overlook a track-and-bowl system in the *Dracophyllum* scrub.

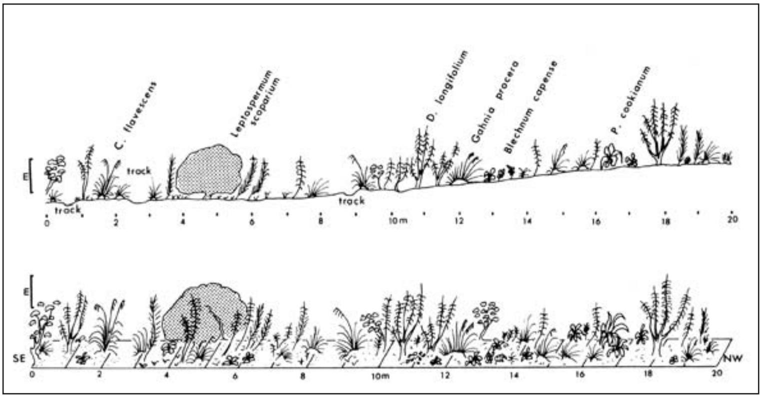


Figure 11 Profile diagram of transect within home range of kakapo at site 4 (Figs. 2, 10) in Transit Valley, Fiordland. Upper profile illustrates vertical scale of vegetation; Lower profile illustrates vegetation within 50 cm of transect line.

Major canopy species included *Dracophyllum longifolium* 27%, *Chionochloa rigida* 15%, *Olearia colensoi* 13%, *Phormium cookianum* 9%, *Pseudopanax colensoi* 7%, *Senecio bennettii* 7%, *Gahnia procera* 6%, *Astelia nivicola* 5%. A further eight species occupied 10%.

Vegetation over 60cm in height provided 69% cover, including *D. longifolium* 23%, *C. rigida* 13%, *P. cookianum* 10%, *O. colensoi* 9%, *S. bennettii* 7% with four other species occupied 7% of the points. Vegetation between 60 - 30cm provided 86% cover including *C. rigida* 16%, *D. longifolium* 13%, *P. cookianum* 13%, *Blechnum procerum* 11%, *Astelia nervosa* 8%, *G. procera* 7%, and another 12 species occupying 19%.Vegetation below 30 cm provided 94% cover including *B. procerum* 28%, *C. rigida* 13%, *A. nervosa* 9%, *Gaultheria crassa* 6%, *P. cookianum* 6%, *Lycopodium scariosum* 5%, and 10 more species occupying 19%.

Overall ground cover was 96% with Cryptogams 46%, *Hymenophyllum* 8%, litter 33%, open rock 4% while a further six species occupied the remaining points.

Tutoko Valley

The Tutoko Valley branches north from the base of the Cleddau Valley and penetrates 10 km into the Darran Mountains (Fig. 1). A small tributary, Leader Creek, flows west into the Tutoko River 5 km up the valley. This creek, and the upper half of the Tutoko Valley, skirt the south and west sides of Mt. Tutoko (2770 m).

One kakapo was found in December 1974 on the moraine and avalanche debris at the foot of Mt. Tutoko, and a year later three were found on a 1.5 km long bench (880 - 1120 m) south of Leader Creek on the sides of Mts. Tarewa, Mahere and Waitiri.

The main ridge of Mt. Tarewa which overlooks the Tutoko-Leader Creek junction was the site of territory 1 (Fig. 3). Two track-and-bowl systems on the south face of this ridge between 1100-1200 m were probably maintained by one kakapo from December 1975 to December 1976. The upper of these two track-and-bowl systems, situated on a small south west sloping terrace above a steep broken rock face, was the highest occupied territory found in Fiordland (1200 m). The terrace was strewn with rock, boulders and monoliths which were surrounded by a low but dense canopy of tussock and alpine scrub. The scrub was dense where sheltered by large rocks but the track-and-bowl system, however, had been excavated on an area where rocks were comparatively small and the vegetation predominantly grasses. The second track-and-bowl system was about 50 m of altitude below the upper system at the base of a steep bluff on the fringe of the silver beech forest.

The track-and-bowl system of the second kakapo on the Tutoko High Bench (Fig. 4) was located above a bluff at 1100m overlooking a lower silver beech-covered section of the Bench beyond and below which lay the Tutoko Valley floor.

A third kakapo occupied a track-and-bowl system 200 m south of the second bird and 50 m of altitude lower (1050 m) on a minor ridge overlooking one of the small creeks crossing the bench. The well-developed tracks were situated in comparatively dense scrub about 50 m above bush line.

Description of general vegetation

Beech trees (*Nothofagus* spp.) comprised the forest on most of the Tutoko Valley floor but were replaced on comparatively recent talus slopes by scrub species. The kakapo territory located in 1974 on the valley floor at the foot of Mt. Tutoko was situated on one such talus slope. On the highest section of this, where the track-and-bowl system was found, grasses, herbs and low shrubs covered the finer shingle substrate amongst the larger rocks and boulders. *Chionochloa rigida* was the predominant grass in the area but other *Chionochloa* species, *Poa colensoi*, *Lachnagrostis* spp. and *Ryhilosperma setifolia* were present. Predominant shrubs include *Carmichaelia grandiflora*, *Coprosma rugosa*, *Coriaria plumosa*, *Gaultheria crassa*, flax and the fern *Blechnum capense* type.

Canopy height was greatest near the Tutoko River but declined from 12 m to less than 3 m in the area surrounding the bowls where species such as *Aristotelia fruticosa*, *Coprosma* spp., *Fuchsia excorticata*, *Griselinia littoralis*, *Hoheria glabrata*, *Myrsine divaricata*, *Olearia arborescens*, *O. ilicifolia* and *O. colensoi* formed a mixed scrub cover.

High altitude silver beech forest formed a broken tree line between 900 - 1150 m on Mt. Tarewa spur and Tutoko High Bench. Above tree line predominant shrubs *Dracophyllum uniflorum*, *Podocarpus nivalis* and *Olearia colensoi* form a patchy alpine scrub canopy amongst *Chionochloa rigida* and *C. crassiuscula*.

Detailed description of home range 1

Map Reference: NZMS1 S113 965165; vegetation: silver beech forest - alpine scrub; site type: prominent spur; altitude: 1075 m; slope/aspect: 20° W (Fig. 3).

Two track-and-bowl systems were used on this ridge, probably by the same bird. The first was situated on the silver beech forest tree line (1075 m) at the base of a rocky bluff where silver beech forest was becoming established on what had been a tussock-covered talus slope. North of the lower track-and-bowl systems, silver beech reached 1150 m in a steep sheltered defile, but scrub and tussock were the predominant canopy species at this altitude. *Olearia colensoi* and *Senecio bennettii* were the main shrubs on the bluffs, but above these around the upper track-and-bowl system, low *Dracophyllum uniflorum*, *Chionochloa rigida* and *C. crassiuscula* predominated.

Plant transect

Point intercept transect across track-and-bowl system 1: 50m, 100 points, points 0.5m apart, direction N-S down slope (Fig.12).

A total of 40 vascular plants were recorded across transect: shrubs 11 species, grasses 4 species, herbs and ferns 25. Canopy height was 0.01 - 0.9m with a general height of *c.*0.5m and canopy composition was overall cover 92%, open rock 7%, litter 1%, shrubs 23%, grasses 49%, herbs and ferns 20%.

Canopy species were *Chionochloa rigida* 30%, *C. crassiuscula* 19%, *Dracophyllum uniflorum* 12%, Moss 7%, *Schoenus pauciflorus* 6%, and *Hebe cockayniana* 5%. Vegetation over 30cm in height provided 44% (*Chionochloa rigida* 23%, *C. crassiuscula* 19%, 4 species the remaining 9%) while that between 30 - 0 cm provided 86% cover (*Dracophyllum uniflorum* 17% *Chionochloa crassiuscula* 15%, *Celmisia walkeri* 10%, *Chionochloa rigida* 9%, *Coprosma cheesemannii* 7%, *S. pauciflorus* 9%, *Olearia moschata* 6%, 6 species the remaining13% of the points).

Ground cover was 75% with Cryptogams 39%, rock 16%, litter 9%,*Hymenophyllum* sp. 12%, *Lycopodium fastigiatum* 7%, *Chionochloa rigida* 6%, and a further six species occupying 11% of the points.

Detailed description of home range 2

Map Reference: NZMS1 S113 967156; vegetation: alpine scrub; site type: bench; altitude: 1000-1050 m; slope/aspect: 5-20° W (Fig.4).

The altitude of the bench corresponded with the expected tree line for northern Fiordland forest (Wardle *et al.* 1971). Here silver beech forest formed a broken bush line, evidence of the variability of altitude, slope and sites prone to flood and avalanche damage. Aspect had a noticeable affect on the vegetation such as along the banks of a stream. On the sunny northern sloping faces the scrub was higher and denser and included such warmth-loving species as flax and *Pseudopanax colensoi*.

The vegetation on the Bench near the kakapo track-and-bowl systems and feeding areas can be grouped into three broad vegetation communities: Firstly, rolling tussock and scrub-covered terrain occupies the higher altitudes where such food plants as *Podocarpus nivalis*,

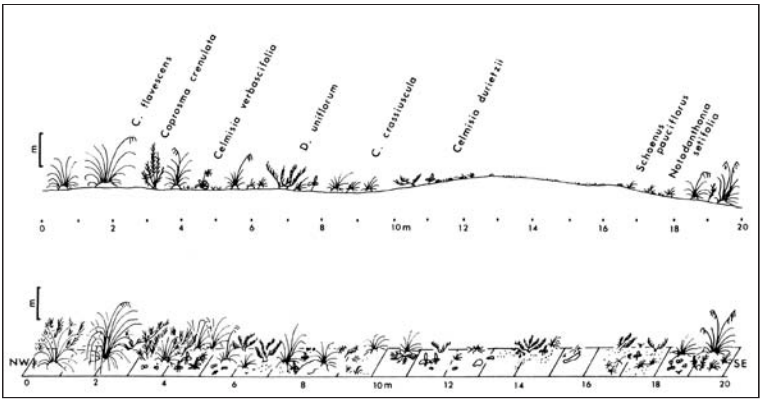


Figure 12 Profile diagram of transect within home range of kakapo at site 1 (Fig. 3) in Tutoko Valley, Fiordland. Upper profile illustrates vertical scale of vegetation; Lower profile illustrates vegetation within 50 cm of transect line.

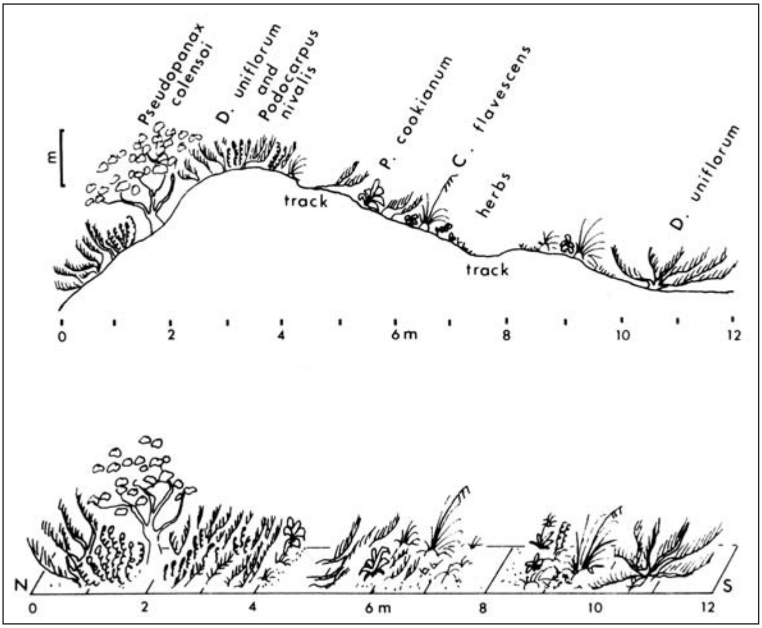


Figure 13 Profile diagram of transect within home range of kakapo at site 2 (Fig. 4) on the Tutoko High Bench, Tutoko Valley, Fiordland. Upper profile illustrates vertical scale of vegetation; Lower profile illustrates vegetation within 50 cm of transect line.

Chionochloa spp., *Aciphylla crenulata* and *Celmisia* spp. were common (Fig. 13); secondly, open rock slabs in the vicinity of the track-and-bowl systems which formed a mosaic with the mixed vegetation of silver beech stands, scrub, tussock and herbs; and thirdly, at lower altitudes, silver beech was an important canopy species.

TRACK-AND-BOWL SYSTEMS AND ROOSTS

Track-and-bowl systems

Most track-and-bowl systems were located on prominent ridge crests, although others had been located previously in unobtrusive sites on avalanche debris and river banks. These 'tracks' had been cleared of vegetation. The male kakapo clipped and gnawed the vegetation with their bills. Ground plants such as *Astelia* spp., grasses and ferns, and low, overhanging branches of various shrub species, up to 1 cm in diameter and exposed roots were thus removed. Tracks up to 1 m wide were cleared, probably over a period of many years. Track ran more-or-less continuously along or close to the ridge crest, curving amongst trees and rocks, and sometimes formed an interlacing network. Tracks up to 250 m long were located (Veitch 1976a).

Kakapo also grubbed away soil and gnawed roots along these tracks, making them conspicuous amongst the surrounding ground cover of moss, fern or litter. Tracks in low scrub or tussock about the vicinity of tree line (approximately 1000 m.a.s.l.), for example, could be seen from the air. The tracks linked a series of 'bowls' or depressions in the ground, the largest of which were about 30 cm deep and 100 cm wide. These depressions were grubbed and scraped out by the kakapo. It was usual for the bowls to be positioned at the base of a tree, a rock or shrub. Kakapo had favourite sites, for example, under dry rock overhangs. Such bowls were usually more extensively excavated, a longer time apparently having been spent on them.

Roosts

As kakapo are nocturnal feeders it was presumed that they roosted during the day. It was uncertain, however, whether they feed every night. Probably in the high rainfall area of Fiordland the birds may have roosted,or at least sheltered, during periods of heavy rain.

Most roost sites were located on dry warm sunny slopes. Old droppings collected for food analysis studies were found in old roost sites under dry rock overhangs and shallow caves. In the Tutoko Valley many small quantities of droppings were collected from comparatively exposed sites under low hanging branches, at the base of trees, especially amongst an exposed root system, and under overhanging fern at the base of dry banks. Generally the bird had perched on a small rock or a branch just off the ground. Such roost sites would afford little protection against the torrential mountain rains. Presumably, such sites might be used in fine weather when the bird could bask in the sun as Henry (1903) reported.

The small number of droppings found, coupled with the numerous roost sites (21 sites were found in one territory in one day's search (Veitch 1976b)) suggest that the birds roosted in the nearest suitable site once they ceased feeding for the night.

Observations by Morris & Russ (1976) in the Tutoko Valley in July and Russ *et al.* (1977) on Stewart Island in July and August support the observation that kakapo are surprisingly mobile and wander considerable distances using many different roost sites for only brief periods. Large accumulations of droppings from some dry caves suggest that they may have been used by several generations of kakapo.

FEEDING SIGN

Introduction

The kakapo is an herbivore. Observations by early observers (Haast 1861, 1864; Potts 1873; Henry 1895-1908; Best 1908; Pascoe 1957) record kakapo feeding on leaves, twigs, bark, nectar, berries, seeds, fern rhizome and fungi. Recent observations (1960-1977) by Wildlife Service expeditions in the Milford and Transit catchments, and faecal analyses (below), have confirmed these early reports of a vegetarian diet.

In Westland and Fiordland, kakapo were reported ranging from sea level to 1200 m (4000 ft) (Lyall 1852; Hector 1863; Reischek 1884, 1930; Henry 1903). Birds have been most frequently associated with grassland habitats (Lyall 1852; Haast 1864; Henry 1903; O'Donoghue 1924; Pascoe 1952) although they range over a wide variety of vegetation types. Henry (1903), whose field experience is unrivalled, reported that during the breeding season kakapo frequented valley floors and land slips where berry-producing trees and shrubs grew. During other times of the year the birds wandered widely. As noted by Atkinson & Williams (1971) kakapo formerly inhabited podocarp forest, beech forest, subalpine scrub and tussock grassland.

Observations between 1961 and 1977 have confirmed the presence of kakapo in beech forest (Lavers 1967; Gray, Merton & Morris 1975; Veitch 1976a, Gray 1977b), subalpine scrub (Atkinson & Merton 1974; Nilsson 1975; Scown 1976; Anderson 1976; Morris 1976), tussock grassland (Scown 1976; Morris 1976; Gray 1977b), avalanche slips and debris fans (Anderson 1961; Roderick 1963; Atkinson & Merton 1974; McFadden 1975; Gray, Merton & Morris 1975; Johnson 1976a), alluvial fans and river terraces (Atkinson & Merton 1974; Gray 1977b), river flats (Anderson 1961; Veitch 1962; Lavers 1967; Cheyne 1969; Russ & Anderson 1977; Russ *et al.* 1977) and in podocarp/broadleaf forest (Russ & Anderson 1977; Russ *et al.* 1977).

Description

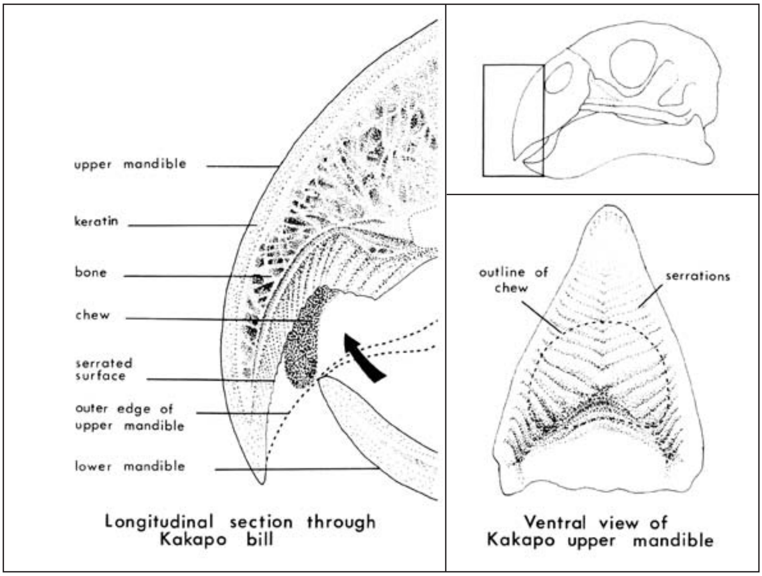
Leaves

The leaves or tillers of 11 grass species were recorded as kakapo foods (Appendix 1). The most frequent feeding sign on the leaves of tussocks and small grasses was the crushed and chewed outer portion of the blade nearest the tip. The chewed fibrous plant tissue remaining was left attached to the damaged blade and resembled a frayed, twisted and tangled hemp twine. Though initially light green in colour (some of the chlorophyll having been removed by the bird) the chewed section of the leaf eventually bleached to a pale yellow or cream. Bleaching occurred within 30 - 48 h if the chewed leaves were exposed to sunlight, but in damp shady sites some green colouration persisted for several months. Chewed portions of leaf blades of *Chionochloa conspicua* as long as 40 cm were collected still attached to the leaf.

The chewing of grass leaves often resulted in the loss of the chewed section from the rest of the tiller. This was invariably the case with the small grasses, such as *Poa colensoi* and *Festuca matthewsii*, but to a lesser extent with the more fibrous *Chionochloa* species. In comparison with insect and deer sign (illustrated in Gray's thesis), the frayed character of the severed blade was characteristic of kakapo. The detached chewed remains of the leaves fed upon by kakapo were scattered amongst the remaining leaves and around the base of the tussock or grass clumps.

The chewed leaves were compressed in the bill to form a tight wad of fibre which is rejected from the bill with the aid of the tongue as a pellet or 'chew' (illustrated in Gray's thesis; see also Best 1984). The formation of 'chews' is a characteristic kakapo feeding habit. Once in the mouth, leaves and other flexible plant matter are compressed against the serrated upper mandible by the lower mandible (Fig. 14). This results in the food being crushed, much like being flattened between a hammer (upper mandible) and anvil (lower mandible). Serrations on the upper mandible probably help secure the chew between successive bites.

Figure 14 Manipulation of plant material in the beak of kakapo and the formation of the extruded pellet or chew.



Henry (1903) suggests that the serrations acted as a file. The crushing of food between the two mandibles enables a portion of the available nutrients to be removed and the more fibrous portions of the food expelled as chews. This means the lignified and presumably indigestible celluloses and hemicelluloses are only consumed in limited quantities while the most readily available plant fractions pass into the crop.

The leaves of *Astelia* sp. (principally *A. nervosa*) were frequently collected with single bites taken out of the lamina, characteristically with the thick lateral vein left attached to the lamina resulting in an 'A' shaped bite. A variety of plants were found sampled with single bites.

Leaves of several dicotyledonous species played an important role in the diet, particularly *Dracophyllum* and *Olearia* species. A variety of seedling shrubs and trees were occasionally sampled but their contribution to the diet was considered minor. The young leaves of native Fiordland *Dracophyllum* species (*D. fiordense*, *D. longifolium*, *D. menziesii* and probably *D. uniflorum*) and *Olearia colensoi* (Fig. 15a,b) were major foods at many sites. Examination of old and recent feeding signs on these species suggest that they are utilised during the spring. Kakapo appeared to either clip the leaves surrounding the base of the young emerging *Dracophyllum* leaves or pluck at the young terminal leaves and chew the fleshy leaf base. On *D. fiordense* the fleshy leaf bases were skilfully removed from the lateral buds. With *Olearia colensoi* the lamina of the young leaf was eaten and the petiole left attached to the shrub (Fig. 15b).

The pinnae of ferns and compound dicotyledonous leaves (e.g., *Anisotome haastii*) were clipped. The fine leaf tips of *A. haastii* appeared to be clipped and swallowed whole. The cut or clipped leaf ends were slightly frayed or comparatively clear cut. Across the larger surfaces of *Blechnum* laminas a fluted edge resulting from several bites was left (see Atkinson & Merton 2006, Fig 7).

Petioles, twigs, fern rachides and bark

Kakapo clipped petioles and twigs of vegetation, and gnawed branches and roots along the tracks which linked their bowls. Observations of kakapo track maintenance in the Transit, Tutoko and Sinbad Valleys (Gray, Merton & Morris 1975), suggested that the clipped or broken petioles, twigs and branches about tracks are tossed haphazardly away and little if any was eaten.

The piths of the petioles of *Anisotome haastii* and the rachides of ferns (*Blechnum capense* and *Histiopteris incisa*) were utilized as foods (Appendix 1). The rachides of *Blechnum* species, more or less circular in cross section, were split by kakapo. Bill indentations, which often occurred at regular intervals down the rachis, suggested that it was crushed, the pith removed and the exterior bark-like tissue left (Fig. 16) The petioles of *A. haastii* were 'pithed' in a similar way.

Roots, rhizomes, stolons, leaf bases and bulbs

Roots, like branches and twigs, were either snapped off or gnawed depending on thickness. Lyall (1852) reported that kakapo dig with their bills for food, and Gray, Merton & Morris (1975) observed kakapo excavating bowls with their bills. The fleshy petiole bases of *Celmisia* species and, to a lesser extent, the swollen bases of *Aciphylla crenultata*, *Astelia nervosa* and the leaf bases of *Chionochloa rigida* and *Gahnia* were taken as food by this method (Fig. 17). Kakapo appeared to clip and chew their way into the fleshy centre rather than pull up the plant or remove the leaves.

Fern rhizomes and the roots of *Brachyglottis revolutus* were reported as being dug up by kakapo (Appendix 1) in the Tutoko Valley. On Stewart Island many square metres of *Lycopodium* were grubbed up by kakapo and the roots chewed, as well as the roots of flax and *Carex adpressa* (Russ & Anderson 1977; Russ *et al.* 1977).

Inflorescence stems

The inflorescence stems of grasses, *Celmisia* species, and flax were pithed in a similar way to the rachides of fern leaves, although, unlike ferns, the woody chews persisted for several months after being fed upon. Specimens were collected with the internode portion of grass stems crushed while in some *Chionochloa rigida* the internodes had been specifically hollowed out. The pith of flax inflorescence stalks was utilised as food from before their emergence from the sheath until the seeds matured.

Flowers, fruits and seeds

Flowers were also eaten by kakapo. Henry (1903) reported rata (*Metrosideros umbellata*) flowers being taken by kakapo and faecal analyses recorded orchid flowers (*Aporostylis bifolia*). Buckingham (1977) collected *Wahlenbergia* plants with the flowers chewed off, possibly taken by kakapo although kea were present in the region.

Fleshy fruits with small seeds (*Coriaria* spp., *Gaultheria* and *Pernettya* spp. and hybrids) were squashed and swallowed with the seeds passing through the gut largely undamaged. Large seeds with tough exocarps or major stone cell components (*Pseudopanax* spp., *Astelia* spp.) also passed through intact. Morris & Russ (1976) found *Astelia* berries with the fleshy mesocarp and some seeds consumed but the remaining seeds and exocarp had been rejected. *Coprosma* seeds were usually cracked and *Podocarpus nivalis* arils fragmented and swallowed.

Seeds of a wide variety of grasses and some *Uncinia* species were stripped and chewed by kakapo. No grass seeds were located in kakapo droppings so they were probably crushed and expelled as 'chews' along with the other flower parts of the grass inflorescence. Examination of flax pods following removal of the seeds by kakapo suggested that the pods were split by crushing, the exocarp broken or torn away, and the seeds removed, crushed and swallowed. Large numbers of flax seed fragments were recovered in droppings.

Droppings

Kakapo droppings varied in size, shape and consistency according to the diet. Potts (1873) noted that kakapo produced faeces of 'vast' size when on a fern diet and although subsequent observations have not associated large droppings necessarily with a fern diet, large coiled droppings up to l0 cm long were collected. The principal characteristic feature of many kakapo droppings was the coiled, spaghetti-like structure and general curved contours. They were usually made up of very fine plant material and had a faint odour.

Figure 15 Kakapo feeding sign on *Dracophyllum fiordense (above)* and *Olearia colensoi (below)*.

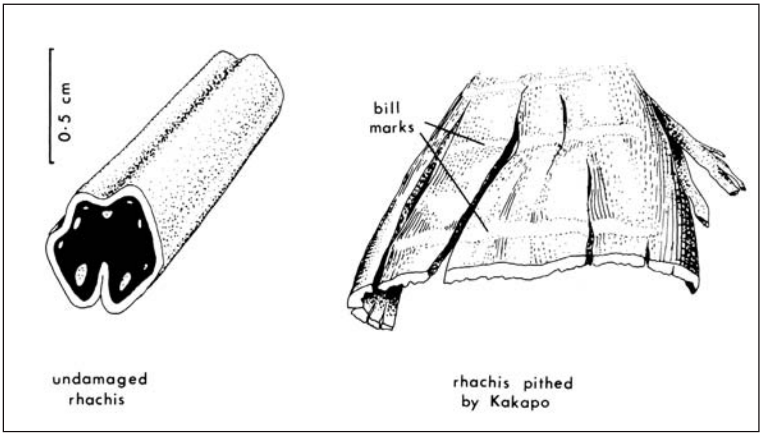


Figure 16 Kakapo feeding sign on the rachis of the fern *Blechnum capense*. The inflorescence stems of grasses, *Celmisia* species, and flax had their pith removed in a similar way.

Figure 17 Kakapo feeding on the swollen base of *Astelia*. (photo: P. Morrison)

FEEDING OBSERVATIONS

Coprosma rugosa drupe

The *Coprosma* drupe appeared to be selected on sight and the bird stretched its neck and head towards the desired food simultaneously opening its bill. The upper mandible is hinged (kinesis) in kakapo as in other parrots enabling movement of both mandibles (Forshaw & Cooper 1973; Smith 1975). With the bill wide open the upper mandibles were then closed and the drupe was delicately held against the upper mandible by means of the lower mandible and then rolled deeper inside the mouth following the curve of the serrated palate (Fig. 14). The tongue then appeared to manipulate the drupe while the lower mandible was lowered, then followed a rapid upward crushing movement. Following this initial crushing action there was minor movement of the lower mandible for about 10 sec as if a rasping or crushing action was in progress.

According to Forshaw & Cooper (1973) this method of manipulation and crushing of seeds and fruits is typical of many parrot species.

Chionochloa seed

Analysis of a filmed feeding sequence showed the kakapo grasped cut inflorescence stalks of *Chionochloa conspicua* in its left foot while its right clasped the branch on which it perched. The bird lowered its neck and head and selected one or two inflorescence stems and held them lightly in its bill below the seed head (position A, Fig. 18). The bird then rapidly raised its head in a sweeping arc slipping its bill along the inflorescence stem and over the seed head.

Seed stripping by the bill involved two stages: first, a rapid movement, (22 frames at 25 f/sec.) followed by a brief pause at position B (Fig. 18) before the head was then raised further and the neck stretched to position C. (Fig. 18). The entire sweeping upward movement of the head lasted just under 2 sec (43 frames at 25 f/sec.) before the head returned to position B and a rapid mastication began with the tip of the inflorescence stalk still in the mouth. The mastication continued for nearly 2 sec (47 frames at 25 f/sec.) before the inflorescence was rapidly pulled out and a chew expelled. Chewing continued for another 1.5 sec after which the head was lowered to take another inflorescence and a similar process repeated.

Uncinia sp. seeds were stripped in a similar way (R. Morris pers.comm.).

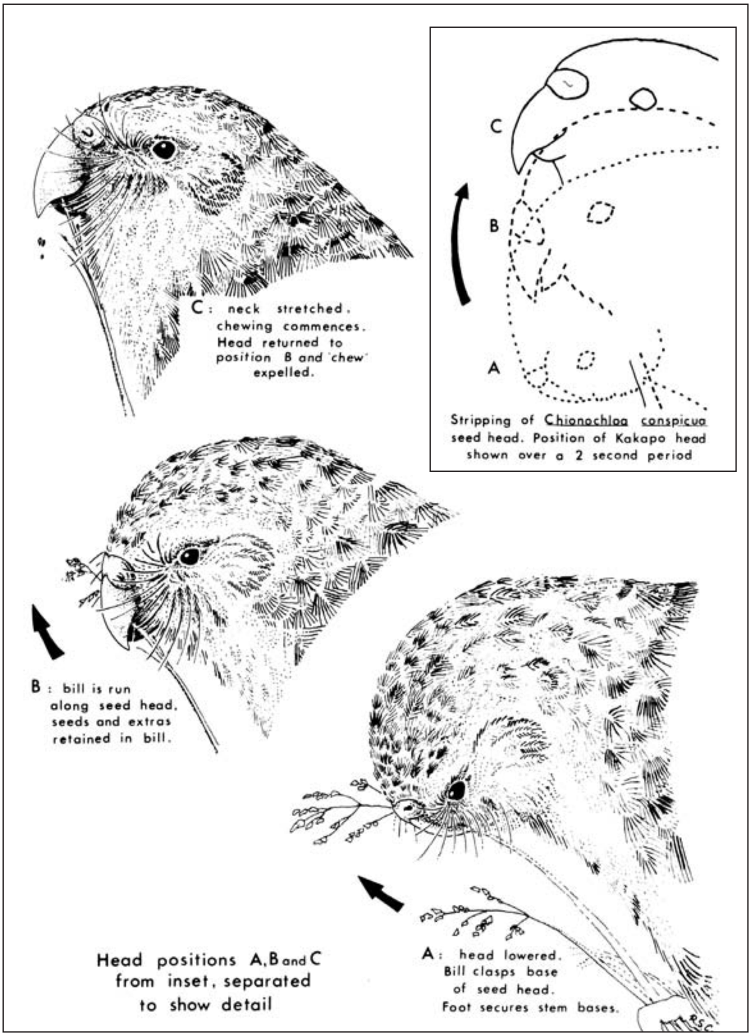


Figure 18 Kakapo stripping seed from a *Chionocloa conspicua* inflorescence (drawn from a filmed feeding sequence).

FAECAL ANALYSIS

Gray undertook an extensive analysis of over 350 old and fresh kakapo droppings collected from 42 locations within 11 valleys in Fiordland. Most fresh droppings were collected from his principal study site on the Tutoko High Bench in Tutoko Valley in 1976 (Figs. 4, 13). An unspecified number of droppings were collected on Maud Island in 1975 and 1976 and their contents examined and reported on in his thesis also. To complement his Fiordland analyses, Gray also examined 23 kea droppings (not reported here).

Plant cuticles

A wide variety of leaves and other plant tissues were eaten. Leaves eaten included those of 24 different genera of trees, shrubs, ferns, herbs and grasses (Appendix 2). The cuticles occurring most frequently were of ferns which were present in droppings from all 11 locations; *Blechnum* spp. were the most common. Grass cuticle was recorded in droppings from six valleys, *Anisotome haastii* (a herb) from six areas, and *Dracophyllum* spp. (a subalpine shrub) from five areas. There was no indication that kakapo ate anything other than plants.

The percentage composition of droppings, in terms of plant conducting tissue, cuticle and other vegetable matter (Appendix 3) indicated ferns, *Anisotome haastii*, *Podocarpus nivalis*, and grasses to comprise the bulk of the food. A high proportion of conducting tissue was present in faeces; this is not unexpected as 'pithed' flower inflorescence stems (of flax, *Senecio* and *Celmisia* spp.), bases, nodes of grasses, rhizomes and stems of fern, and petioles of shrubs were common feeding sign in all kakapo feeding areas.

There were five contrasts between faecal content and field observations:

1. *Podocarpus nivalis* occurred regularly in droppings on the Tutoko High Bench but it was absent in the flora further west.

2. *Anisotome haastii* was recorded more frequently in the Transit Valley droppings than in those from the Tutoko High Bench. The regular occurrence of *Anisotome haastii* in droppings from the Tutoko Valley (13 out of 19 groups) and other valleys was more frequent than field observations had suggested.
3. Feeding sign on leaves of silver beech, *Gaultheria* spp. and *Hebe* spp. had not been recorded previously for kakapo in the wild.
4. High occurrence of *Hymenophyllum* spp. in droppings from Caswell Sound and Tutoko High Bench indicated that this was a food plant. However, low occurrence in droppings from elsewhere suggested it was an unimportant in those areas.
5. Grass species and *Aciphylla* cuticle occurred less frequently than might have been expected from field observations and feeding sign. This was probably due to the fibrous structure of these plants and the kakapo's characteristic method of expelling as chews such fibre and much associated leaf cuticle.

Seeds

In over 500 droppings examined from Fiordland, seeds were present in *c.*50 droppings (Appendix 4). This was in marked contrast to 23 kea droppings collected in the same area all of which contained seeds.

The absence of grass seeds (*Chionochloa* spp., *Poa* spp., *Ryhilosperma* sp.) in kakapo faeces was unexpected in view of field observations. For example, kakapo had been observed stripping and chewing inflorescences of grasses, and many hundreds of grass seed heads have been found stripped by kakapo. The absence of seeds in faeces, therefore, may be the result of the seeds being either expelled with the chews or being damaged and ground so finely that they were unidentifiable.

Kakapo are capable of crushing large seeds. Flax seeds and *Podocarpus nivalis* arils were invariably crushed and ground; *Coprosma* seeds found in faeces were frequently cracked, as occasionally were *Astelia* seeds, although generally *Astelia*, *Cyathodes juniperina* and *Pseudopanax* spp. and smaller seeds such as *Coriaria* spp. and *Gaultheria*/*Pernettya* spp. were passed with the exocarp intact. The endocarp of many seeds appear to be available for digestion by kakapo.

Coprosma and *Astelia* seeds were abundant in one fresh dropping collected in late March 1976 on the Tutoko High Bench. Fresh droppings collected in the same vicinity in June 1976 (Morris & Russ 1976) also contained large numbers of *Coprosma* and *Astelia* seeds. It seemed that *Coprosma* and *Astelia* fruits were important as winter foods.

NUTRIENT CONTENT OF KAKAPO FOOD

Some kakapo food plants were collected, mostly between December 1975 and February 1976, for nutrient content analyses. The selection of species was based on the diet surmised from field observations in the lower Tutoko, Gulliver/Esperance, and Sinbad Valley kakapo home ranges. Subsequent feeding observations and faecal analyses indicated the choice of plant species was not as representative as was originally thought.

The nutritional values of different kakapo foods are presented in Table 1.

Nitrogen (crude protein/6.25) and ash percentages for *Chionochloa conspicua* were within the range of percentage figures of four other *Chionochloa* species presented by Connor *et al.* (1970). The two *Olearia* species (*O. colensoi* and *O. ilicifolia)* had higher moisture content in the petioles and consequently a lower nutrient concentration there than the leaves. *Olearia colensoi* was more abundant in the Fiordland kakapo home ranges than *O. ilicifolia*. The leaves of the former were eaten by kakapo in the Tutoko, Transit, Sinbad and Poseidon Valleys. Little feeding sign had been found on *O. ilicifolia* but this may be due to its scarcity or absence in many of the kakapo areas, since its high nutrient content suggests it would be an excellent food.

The fruits of *Coriaria plumosa* and the pith of *Phormium tenax* had the highest moisture content of the species analysed. In proportion to other nutrients, nitrogen-free extracts were high, particularly in *C. plumosa*.

Crude protein values were highest in the *Chionochloa* seed heads, and ether extracts likewise were high. The green pods and seeds of *P. tenax* also had high ether extract values while the leaves of *O. ilicifolia* had exceptionally high ether extract levels in comparison with all other species analysed.

The highest nitorogen-free extract values were present in the more fibrous plant fractions such as *Chionochloa* leaves and seed heads. These high proportions were probably due to non-digestible carbohydrates such as lignin. Likewise crude fibre percentages were highest in these fibrous plant fractions as was the ash content.

The analysed plant fractions reported are not necessarily all consumed by kakapo. For all the species listed, a proportion of the plant contents were extracted to compare 'chewed' and 'un-chewed' leaf samples (Table 2). In all the chewed samples there was a greater proportion of crude fibre which suggested that little is consumed. All other nutrient levels in the chews were lower with the exception of some nitrogen-free extract levels indicating that they may have been used by kakapo. As the nitrogen-free value included non-digestible carbohydrates, such as lignin, much of this was probably left by the bird in the fibrous conducting tissue that was expelled in the chew.

The levels of crude protein, ether extract, and ash were generally markedly lower in the chews. Between 8 - 54% of the crude protein (average 26%), 30 - 83% of the ether extract (average 56%), and 22 - 80% (average 56%) of the ash content was removed from the five species of chews reported in Table 2.

Table 1 Nutrient content of selected kakapo food plants in Fiordland. (NFE = nitrogen-free extract)

	Part tested	% Water	% Crude protein	% Ether extract	% NFE	% Crude fibre	% Ash
Aciphylla crenulata	Leaf	86.40	1.25	0.20	6.63	4.38	1.14
Chionochloa conspicua	Leaf	62.58	2.28	0.70	19.67	12.89	1.88
C. rigida	Seedhead	51.76	5.28	1.33	28.51	11.26	1.86
Coriaria plumosa	Fruit	96.39	0.45	0.28	2.32	0.46	0.10
Olearia colensoi	Petiole	89.57	0.94	0.28	4.90	3.37	0.94
O. colensoi	Leaf	86.04	1.53	0.42	6.61	4.51	0.89
O. ilicifolia	Leaf	75.20	2.73	1.36	12.49	6.86	1.36
O. ilicifolia	Petiole/twig	86.95	1.41	0.62	6.30	3.76	0.90
Phormium cookianum	Inflor'ence	96.30	0.05	0.02	1.64	1.78	0.21
P. tenax	Green pod	87.29	1.51	0.95	5.09	4.46	0.70
Schoenus pauciflorus	Leaf	78.12	1.67	0.53	11.67	6.77	1.24

Table 2 Nutrient content (% dry wt.) of chewed and non-chewed parts of some kakapo foods in Fiordland. (NFE = nitrogen-free extract; * Maximum % (dry weight) consumed by kakapo (green leaf wt. – chewed leaf wt.)).

	Part tested	% Crude protein	% Ether extract	% NFE	% Crude fibre	% Ash
Aciphylla crenulata	Green leaf	9.21	1.45	48.25	32.19	8.90
	Chewed leaf	4.21	0.99	36.94	57.05	0.81
	Max. % consum.*	5.00	0.46	11.31		7.09
Chionochloa conspicua	Green leaf	6.10	1.87	52.32	34.68	5.03
	Chewed leaf	4.36	1.14	52.18	40.38	1.94
	Max. % consum.	1.74	0.73	0.14		3.09
Phormium cookianum	Green leaf	5.47	2.13	41.26	46.94	4.20
	Chewed leaf	4.98	0.52	35.51	58.20	0.79
	Max. % consum.	0.49	1.16	5.75		3.41
Schoenus pauciflorus	Green leaf	7.63	2.40	53.20	31.12	5.65
	Chewed leaf	6.34	0.33	49.01	41.00	3.32
	Max. % consum.	1.29	2.07	4.19		2.33

DISCUSSION

Kakapo diet

The observations of kakapo feeding sign and the analyses of faecal material have confirmed the reports of early New Zealand ornithologists, that the kakapo is an herbivore (Lyall 1852; Haast 1864; Potts 1873; Reischek 1884, 1930; Buller 1888, 1905; Henry 1903; Best 1908; O'Donoghue 1924). These data reveal the diversity of vegetation comprising kakapo diet, both in the number of species eaten and in the portion of the plant eaten.

Too few comparative figures are available to explain the field observations of the apparently haphazard selection by kakapo of plant species and individual plants within a species. Nevertheless, a similar pattern of the distribution of observed feeding sign occurred repeatedly in kakapo feeding areas. Firstly, in any one home range during a particular period, a limited number of plant species (one plus), abundant or not, were found to have been eaten by kakapo to the exclusion of other species in the locality. Secondly, the individual plants of any one of these preferred species within any localized area were not all eaten to the same extent. Some plants were extensively damaged through the bird's feeding methods, other individuals had only one or two leaves sampled, while the remainder were untouched.

The same plant species were not necessarily eaten in each home range, though feeding sign on some species, notably the terminal buds of *Dracophyllum* sp., *Olearia colensoi* leaves, and the leaves of some *Chionochloa* species, did occur widely in Fiordland. The selection of species was, in part, the result of plant distribution as affected by altitude and geographical location, but this does not explain why some species in two home ranges were taken by one kakapo and not another. For example, in the Sinbad Valley, *Astelia* was taken by one bird where in previous years it had not been utilised as a food.

The nutritional content of the plants may offer an explanation. A comparison of *Olearia colensoi* and *O. ilicifolia* (Table 1) indicated a variation in nutrient content between leaf lamina and petiole. An additional explanation may be a behavioural one: the preference or avoidance of a particular species of plant may depend on previous experience with such plants and an individual's 'taste' preference.

The results suggest possible explanations for the selective nature of the kakapo's grazing and possible reasons for the selection of particular species and parts of them. In a broader context, availability of nutrients may explain distribution patterns. The relationship between plant nutrients and kakapo feeding is an area for further investigation.

Location of kakapo home ranges in relation to vegetation and food

Kakapo in Fiordland occupied a variety of plant communities. Eight of the 15 kakapo located between 1974 and 1977 were found near the tree line, 1000 - 1200 m.a.s.l. Five kakapo maintained track-and-bowl systems at lower altitudes (300 - 700 m.a.s.l.) where steep rocky terrain prevented the silver beech forest from extending to higher altitudes. One of two kakapo occupied the valley floor in the head basin of the Esperance Valley and the other bird, in territory 2 in the Sinbad Valley, occupied a track-and-bowl system in low silver beech forest below a higher-located bird. The positions of these home ranges enabled them to graze through silver beech forest, detritus fans, alpine scrub and tussock grassland, all generally within close proximity to one another. Feeding sign had been located in all these areas but the greatest altitudinal range of any one bird, as far as can be judged, was some 525m in the Poseidon Valley (Buckingham 1977; Gray 1977b).

It is not clear what combination of factors influenced these birds in their choice of sites for their track-and-bowl systems. However, altitude, directional aspect, acoustical properties of the site, the preference or need for audio or social contact, and food sources could all have influenced their decisions. From the food viewpoint, many birds were able to utilise the diverse floras associated with the tree line and with avalanche and alluvial fans.

Diversity of plant communities about the tree line

Over 200 species of plants were recorded in the silver beech forest, alpine scrub and tussock grassland around tree line on the Tutoko High Bench (P. Johnson pers.comm.). The leaves and seed heads of tussocks and small grasses were available along with herbs found in such grassland habitats. For example, *Celmisia* spp., *Astelia nivicola*, *A. nervosa*, *Gunnera monoica* and *Aporostylis bifolia* were chewed or recovered in droppings. Generally, common alpine scrub species regularly eaten by kakapo include *Dracophyllum* spp., *Olearia colensoi*, and, of more restricted distribution, *Podocarpus nivalis*. These scrub species in the kakapo territories were generally <2 m high. Being a skilled climber, kakapo were capable of reaching the terminal buds and leaves.

The silver beech forest in these localities appeared important in providing cover and protection during winter as snow can hinder movement of a flightless bird. Movement would have been much easier under a beech canopy because of a discontinuous cover of snow. Thus kakapo could move comparatively freely in the forest and make excursions into the scrub and tussock areas.

It was expected that berry-bearing plants of the alpine scrub (*P. nivalis*, *Coprosma* spp., *Gaultheria* spp., and *Fernettya* spp.) and avalanche detritus fans (*Myrsine* spp., *Aristotelia* spp., *Coriaria* spp.) would provide a major fraction of the winter diet since *Coprosma*, *Astelia* and *Podocarpus nivalis* shrubs retain their berries through the winter. These three species had been found in quantity in a few fresh droppings from the Tutoko High Bench (Morris & Russ 1976). On the other hand, examination of the bulk (500+) of the droppings revealed that, in general, seed numbers were low (Appendix 4); less than 50 contained seeds. Faecal analyses did not reveal grass seeds taken by kakapo as these were crushed and expelled as chews, so data in Appendix 4 underestimated the importance of seeds to kakapo.

Diversity of plant communities of avalanche and alluvial fans

Avalanche detritus and alluvial fans were often at lower altitude sites (300 - 700 m.a.s.l.), such as in some home ranges in the Transit, Sinbad, Tutoko, Poseidon and Esperance Valleys. In Fiordland rainfall is high and soils are rapidly leached but these fans may provide fresh substrate for early scrub communities such as grasses, herbs and shrubs. Since a site influences the nutrient content of vegetation such areas may be important. Furthermore, areas at the base of rock faces near track-and-bowl systems may be enriched by nutrients leached from the faces above.

There is limited published data on the vegetation of alluvial fans in Fiordland. Cockayne (1928), Poole (1951) and Holloway (1954) report on the *Hoheria* and *Aristotelia* scrub canopy on avalanche detritus slopes. Mark *et al.* (1964) and Johnson (1976b) provide detailed accounts of two detritus fans at Lake Thompson near Lake Te Anau. On the first fan, 15 years old, *Aristotelia serrata* was the only canopy tree. On the second fan, 49 years old, *Fuchsia excorticata* was predominant and *Carpodetus serratus* of secondary importance.

Johnson (1976a) described the avalanche detritus fan in the kakapo home range in the Sinbad Valley head and commented on the greater floristic complexity of this fan (98 species) in comparison with those at Lake Thompson (47 species). Ian Atkinson (pers.comm.) recorded 102 species in the *Podocarpus nivalis* scrub and surrounding silver beech forest of a kakapo home range on a river terrace of the Esperance River (see Atkinson & Merton 2006).

CONCLUDING REMARKS

Richard Gray's study of kakapo in its last mainland refuge provides an unrepeatable first-hand account of birds persisting in an extreme environment. Their foraging behaviour and bill morphology allowed them to make selective and effective use of the wide variety of plant species present while their selection, as year-round habitat, of debris fans and other microcosms of high floristic diversity provides a rare, last glimpse of how this bird may have survived during those long Pleistocene glacial times.

Modern kakapo conservation now concentrates on low southern and Fiordland islands, selected partly for the presence of rimu (*Dacrydium cupressinum*) and other mast-fruiting podocarps considered necessary to fuel kakapo breeding. It is timely, however, to be reminded that kakapo also lived in vegetation less than a metre high and near the timber line. Dramatic and demanding sites like the Tutoko High Bench may have been forced on kakapo as their last mainland refuges, but they nevertheless emphasise that this most remarkable of all parrots is a species of considerable adaptability. Thus, defining "kakapo habitat requirements" is not a task to be based on modern examples alone. Hopefully, by the publication of this synoptic version, Richard Gray's thesis will enter the required reading lists of all those responsible for, or contributing to, modern kakapo management.

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APPENDICES

Appendix 1 Foods of kakapo in Fiordland. Gray (1977a, Table 2) provides references and sources for these observations. Key: Bt – branches and twigs; Fl – flowers; Fr – fruit, berries and drupes; Is – inflorescence stems; L – leaves; Lb – leaf bases; Lc – leaves clipped only; P – petioles; Rh – rhizomes; Ro – roots; Sb – stem bases; Se – seeds; Sh – seed heads.

Food species	Part eaten	Food species	Part eaten
Acaena sp.	L	*D. uniflorum*	Tb
Aciphylla (*crenulata ?*)	L	*Festuca matthewsii*	L
A. takahea	L	*Fuschia excorticata*	Fl, Fr
Anisotime haastii	L, Lb, P	*Gahnia procera*	Lb
Aporostylis bifolia	Fl	*Gaultheria crassa*	L
Asplenium bulbiferum	L	*G. depressa*	Fr
Astelia nervosa	L, Fr	*G. macrostigma*	Fr
A. nivicola var. *nivicola*	L	*G. rupestris*	L
Blechnum capense	L, Rh	*Gunnera monoica*	L
B. penna-marina	L	*Hebe* (*macrantha ?*)	L
Brachioglottis revolutus	Ro	*H. subalpina*	L
Caltha novae-zelandiae	L	*Hierochloe cuprea*	Sh
Carex coriacea	L	*H. recurvata*	L
Carex sp.	L	*H. redolens*	Sh
Carmichaelia grandiflora	Sb	*Histiopteris incisa*	L
Carmichaelia sp.	L	*Hymenophyllum multifidum*	L
Carpha alpina	L	*Juncus gregiflorus*	L
Celmisia coriacea	L, Is	*Leptopteris superba*	Lc
C. holosericea	L, Is	*Metrosideros umbellata*	Fl
C. lanceolata	L	Moss spp.	L
C. petriei	L, Lb	*Myrsine australis*	Fr
C. verbascifolia	L, Is	*Myrsine* sp.	P
Chionochloa conspicua	L, Sh	*Nothofagus menziesii*	L
C. crassiuscula	L	*Ryhilosperma setifolia*	L, Se
C. rigida	L, Is, Sh	*Olearia colensoi* var. *argentea*	L, Tb
C. ovata	L	*O. ilicifolia* x *arborescens*	Bt
C. pallens	L	*Phormium cookianum*	L, Is
Coprosma astonii	L, Bt, Fr	*Poa cockayniana*	L, Sh
C. parviflora	Fr	*P. colensoi*	L, Sh
C. pseudocuneata	Se	*Podocarpus nivalis*	L, Se
C. rugosa	Fr	*Polystichum vestitum*	Lc
Cordyline indivisa	L	*Pseudopanax colensoi var. ternatum*	L, Fr
Cordyline sp.	L	*P. simplex*	Fr
Coriara plumose	Fr	*Rubus cissoides*	L, P
C. sarmentosa	L, Fr	*Schefflera digitata*	Fr, Bt
Cyathodes juniperina	Fr	*Schoenus pauciflorus*	L
Dolichoglottis scorzoneroides	Lb, Sb	*Scirpus habrus*	Fr
Dracophyllum fiordense	Lb, Tb	*Senecio bennettii*	L, Bt
D. longifolium	L, Tb	*Uncinia* spp.	L, Se
D. menziesii	Tb		

Appendix 2 Plants identified from cuticle remains in kakapo faeces from Fiordland. Sampled locations: CS – Caswell Sound; DV – Donne Valley; GV – Gulliver Valley; HV – Harrison valley; PB – Poison Bay; PV – Poseidon Valley; SV – Sinbad Valley; SCk – Surprise Creek; TV – Takahe Valley; TrV – Transit Valley; TuV – Tutoko Valley.

Sample location	CS	DV	GV	HV	PB	P V	S V	SCk	T V	TrV	TuV
No. faeces analysed	c.6	16	20	10	5	20	73	25	10	35	120
Leaf cuticles											
Acaena sp.				+							+
Aciphylla crenulata											
Anisotome haastii					+	+	+	+		+	+
Aristotelia fruticosa							?				?
Astelia sp.						+	+			+	+
Carex sp.			+					?		+	
Celmisia sp.										+	+
Chionocloa sp.			+								+
Coprosma sp.							+				
Diploglottis scorzoneroides											?
Dracophyllum sp.					+	+	+			+	+
D. menziesii							+			+	+
D. uniflorum										+	
Fern	+	+	+	+	+	+	+	+	+	+	+
Asplenium sp.							+	?			
Blechnum sp.		+	+	+	+	+	+	+		+	+
Polystichum sp.		+		+			+			+	
Gaultheria sp.					+					+	+
Grass species		+	+	+			+		+	+	+
Gunnera monoica							+				+
Hebe (*macrantha ?*)					+						
H. subalpina				+			+			+	
Hymenophyllum sp.	+	?		?			?	?	?	?	+
H. multifidum	+									?	+
Nothofagus menziesii		?				+	+	?	?	+	+
Moss		?	?				?				?
Olearia colensoi							+				
Phormium cookianum						+					
Podocarpus nivalis			+								+
Pseudopanax colensoi		+									?
Rubus cissoides										+	
Cuticles other than leaves											
Aporostylis bifolia (flower)											+
Astelia sp. (exocarp)											+
Astelia sp. (scales)			+							+	+
Caltha novae-zelandiae (leaf hairs)											+
Coprosma sp. (exocarp)											+
Coprosma sp. (petiole)							+				
Cyathodes juniperina (exocarp)										+	
Cyathodes juniperina (bract)										+	
Gaultheria sp. (petiole)				?			?				
Nothofagus menziesii (petiole)				?			?				
Myrsine sp. (petiole)							+				
Podocarpus nivalis (aril)											+
Exocarp (unknown)				+		+	+			+	
Petiole (unknown)	+			+			+				+
Pollen sacs (unknown)											+
Tomentum hairs (unknown)			+	+			+				+

Appendix 3 Percentage species content of kakapo faeces from Fiordland. Over 350 droppings from 42 localities were examined, each location yielding 1-20 droppings. Geographic areas (no. of localities within) from which samples were collected were: Caswell Sound (1); Donne Valley (2); Gulliver Valley (6); Harrison Valley (1); Poison Bay (1); Poseidon Valley (1); Sinbad Valley (4); Stirling Valley (1); Surprise Creek (2); Transit Valley (3); Takahe valley (1); Lower Tutoko Valley (1); Tutoko High Bench Dec. 1975 (4); Tutoko High Bench Jan. 1976 (3); Tutoko High Bench Feb. 1976 (2); Tutoko High Bench Mar. 1976 (4); Tutoko High Bench 1977 (5).

Plant cuticles and other content of faeces	Number of areas in which present (max. 42)	Mean % (range) cuticle content, if present
Aciphylla crenulata	2	1 (1 - 2)
Anisotome haastii	20	12 (1 – 20)
Astelia spp.	5	2 (1 – 9)
Carex spp.	4	8 (1 – 24)
Celmisia spp.	3	2 (1 – 3)
Coprosma sp. (exocarp)	2	2 (1 – 3)
Dracophyllum spp.	8	6 (1 – 15)
Fern spp.	31	8 (1 – 32)
Gaultheria spp.	3	5 (1 – 9)
Grass spp.	15	3 (1 – 9)
Gunnera monoica	1	2 (2)
Hebe spp.	3	2 (1 – 4)
Hymenophyllum spp.	12	8 (1 – 41)
Moss	5	1 (1)
Nothofagus menziesii	6	14 (3 – 31)
Olearia colensoi	2	1 (1 – 2)
Phormium cookianum	1	1 (1)
Podocarpus nivalis	15	14 (1 – 48)
Pseudopanax colensoi	1	8 (8)
Unknown cuticles	36	8 (1 – 37)
Miscellaneous conducting tissue	42	62 (29 – 97)
Fern palea	20	4 (1 – 14)
Fern annulus rings	5	4 (1 – 11)
Astelia scales	6	2 (1 – 7)
Exocarp	3	2 (1 – 6)
Petiole	9	2 (1 – 7)
Tomentum	8	10 (1 – 22)
Trichomes	10	2 (1 – 7)
Seed fragments	1	3 (3)

Appendix 4 Seeds in kakapo faeces from Fiordland. Sampled locations: GV – Gulliver Valley; PV – Poseidon Valley; SV – Sinbad Valley; SCk – Surprise Creek; TrV – Transit Valley; TuV – Tutoko Valley; EV – Esperance Valley. CrS = Seeds split or crushed. No seeds were found in faeces from Caswell Sound (*n* = 12), Donne Valley (16), Harrison Valley (*c*.50), Poison Bay (*c*.5), and Takahe Valley (*c*.10). Key: a = 1 faece; b = 2-4 faeces; c = 5-10 faeces; d = 25-30 faeces; p = present (I. Atkinson pers. comm.); + = occasionally; ++ = often; +++ = typically

Sample location	GV	PV	SV	SCk	TrV	TuV	EV	CrS
No. faeces analysed	32	*c*.20	*c*.70	*c*.25	*c*.80	*c*.190		
No. faeces with seeds	*c*.2	*c*.4	*c*.3	*c*.2	10	*c*.25		
Astelia spp. (*nervosa*, *nivicola?*)		a	a	a	a	b		+
Coprosma spp. (*astonii*, *ciliata*, *pumila?*)		a	b	b		b	p	++
Coriaria spp. (*plumosa*, *sarmentosa?*)		b	b			a		
Cyathodes juniperina					b			
Gaultheria spp. (*G. antipoda*, *G. depressa*, *G. macrostigma* and hybrids			a		b	b	p	
Phormium cookianum			a		a	c		+++
Podocarpus nivalis	b					d	p	+++
Pseudopanax colensoi var. *ternatum*		a	?	a	a	b	p	
P. simplex					a		p	
Uncinia sp.		a						
Unknown sp.						a		++