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THE FOODS OF KAKAPO ON STEW ART ISLAND AS DETERMINED FROM THEIR FEEDING SIGN

Summary: The diet and feeding methods of kakapo *(Strigops habroptilus)* on Stewart Island, southern New Zealand, were studied by examining sign left by the birds. Most feeding sign was found on herbs, ferns, and shrubs, especially on new and developing growth such as leaves, bark, fruits and seeds, as well as the subterranean portions. The species on which most kakapo sign was found were *Lycopodium ramulosum,* L. *fastigiatum, Schizaea fistulosa* var. *australis, Blechnum minus, B. procerum, Cyathodes juniperina, Dracophyllum longifolium, Olea ria wlensoi, Thelymitra venosa, Oreobolus strictus, Gahnia procera* and *Carex appressa*. Though all (but *Oreobolus* and *Gahnia)* were fed on frequently throughout the year, variations in the use of different parts of plants occurred both seasonally and annually. The nature of the feeding sign indicated that kakapo are versatile feeders with highly variable feeding patterns, and many foods are taken opportunistically. This flexible feeding pattern allows kakapo to utilise a broad spectrum of seasonal foods which may only be available for short periods or on intermittent years.

Keywords: Kakapo; Strigops habroptilus; Cacatuidae; food; feeding sign; feeding patterns; Stewart Island.

Introduction

The kakapo *(Strigops habroptilus,* Gray 1845) is a flightless, ground-dwelling parrot endemic to New Zealand. Presently, it is endangered, occurring only in Fiordland (where less than a dozen birds are known; D. V. Merton, pers. comm.), on Little Barrier Island (onto which 22 birds were released in 1982) and on Stewart Island, where it was rediscovered in January 1977, and where studies to determine ways of conserving the species are being conducted.

Kakapo are difficult animals to study because of their nocturnal habit, cryptic colouration and, except when males are present on their track and bowl systems in booming seasons (Merton 1975), their secretive behaviour. Without the use of suitably trained dogs they are virtually undetectable (Henry, 1903).

This study of the foods and feeding habits of kakapo was carried out on Stewart Island between June 1977 and April 1980 on trips of 3-8 weeks duration in summer, autumn, winter and spring, at a time when the use of dogs to find kakapo was not permitted. The only source of information on kakapo foods was the feeding sign and droppings left by the birds. *

Some information on kakapo foods and feeding habits on Stewart Island is contained in Wildlife Service expedition reports (file WIL 25/4/19) and in brief published accounts (Russ, 1978; Best, 1979). Gray (1977) reported on the feeding sign of kakapo in Fiordland, on Maud Island (on which 9 birds were temporarily held) and on Stewart Island. Further information is given by Williams (1956), who reviewed the pre-1950s literature, Reid (1969) and Merton (1975).

* Subsequent to this investigation, dogs were used, kakapo captured and fitted with radio-transmitters and their movements monitored (Best, 1982).

Study Area

The study area lies at the south-east end of Tin Range, Stewart Island (Fig. 1). From the indented rocky shoreline the land rises steeply to 100 m in

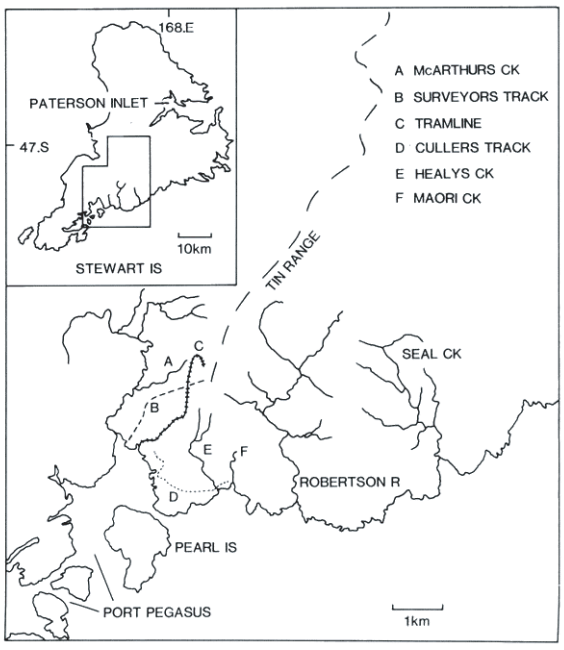


Figure 1: *Southern Stewart Island showing the location of the study area and place names used in text.*

altitude and then climbs gradually to the base of Tin Range 4 km inland. The hinterland is characterised by gently rolling hills dissected by a maze of irregular and intricate stream courses. Granite outcrops are scattered throughout the study area, but tend to be more concentrated at the base of the eastern side of Tin Range. The crest of Tin Range rises abruptly to 500-600 m . a.s.1. and extends north-eastwards.

Vegetation

The vegetation of the study area is a complex of forest, scrub, heath and moor land. Wind, altitude, watertable, fires and mining activities have influenced the vegetation structure and composition (Wilson, 1979). Seven broad vegetation types can be recognised (plant names after Wilson, 1982):

(1) *Coastal scrub* - A narrow (< 50 m) belt of woody vegetation immediately adjacent to the coast but penetrating further inland on exposed sites, such as headlands. The tight, umbrella-like canopy is dominated by *Olearia angustifolia* and *Senecio reinoldii*.

(2) *Podocarp-hardwood forest* - Moderately open canopy up to 20 m high comprising mainly rimu *(Dacrydium cupressinum),* miro *(Podocarpus ferrugineus),* rata *(Metrosideros umbellata)* and kamahi *(Weinmannia racemosa)*. Occurs predominantly within 300-500 m of the coast, but is found inland along the main river courses and in pockets in sheltered places.

(3) *Manuka scrub* - Established on burnt areas and encompassing a variety of sites ranging from those which manuka *(Leptospermum scoparium)* is just beginning to colonise, to dense pole stands 6-7 m high. Areas dominated by manuka are mainly well-drained with variable understorey density, the understorey being least developed where manuka forms dense stands and a uniform closed canopy. On these latter sites manuka forms a monoculture and the ground is carpeted in litter several centimetres deep. Understorey development increases as the canopy thins out and in some of the taller manuka stands die-back of poles has provided an open canopy under which podocarp-hardwood forest regeneration and/or dense groves of *Gahnia procera* sedge occur on favourable sites (e.g. drier areas on ridges, knobs or hillocks, especially if facing north and sheltered from the wind).

(4) *Yellow silver pine scrub* - Vegetation 1-3 m high, predominantly of yellow silver pine *(Dacrydium intermedium)* and manuka, with leatherwood *(Olearia colensoi),* rata, rimu, kamahi, flax *(Phormium cookianum)* and *Gahnia*. On more sheltered sites, occasional emergents of rimu or rata up to 8 m high are present. The canopy is mainly open to partly-closed, though dense thickets occur locally. This scrub is found most often on elevated exposed ground such as small tablelands and broad, gently sloping ridge crests below 300 m a.s.1.

(5) *Swampy flats* - Typically clad in low vegetation and scattered shrubs. The major ground cover comprises sparse to dense carpets of jointed rush *(Empodisma minus)* and umbrella fern *(Gleichenia dicarpa),* though as ground cover declines, mosses and lichen become more prevalent. Bare peat occurs intermittently, usually marking the location of ephemeral ponds and seepages. Flax is found mainly alongside water but some plants are scattered about on higher ground. The sedge *Carex appressa* is distributed locally adjacent to water courses and in some places completely covers shallow drains. Although stands of manuka are scattered over lower-lying ground, it becomes more prevalent as drainage Improves.

(6) *Subalpine scrub* - 3-5 m high decreasing to 1 m high at the altitudinal limit of the scrub's range. Typically this vegetation type has a tight, wind-stunted canopy of leatherwood (dominant species), rata, *Dracophyllum longifolium,* yellow silver pine, Hall's totara *(Podocarpus hallii)* and manuka. Subalpine scrub is found most commonly on the flanks of the Tin Range above 200 m a.s.l.

(7) *Alpine tops* - Fell-field with wind-sculptured shrubbery amongst the shelter of rocks; ground springy underfoot, often waterlogged except around rock or if the ground slopes appreciably. The turf comprises mosses, club moss *(Lycopodium ramulosum),* comb sedge *(Oreobolus strictus)* tussocks *(Chionochloa pungens,* and other *Chionochloa* spp), mountain daisy *(Celmisia polyvena), Senecio bellidioides* and other herbs.

Climate

The climate is maritime; mild to cool, high humidity, cloudy with frequent rainy intervals. It is often windy, predominantly from the NW, W, or SW. Although the ground and the vegetation may be soaked frequently by showers, on exposed areas the moisture held in the foliage can be shaken free in a few hours and the ground surface can dry appreciably in a short time.

Modification of vegetation by man
The study area is one of the more man-modified areas of Stewart Island. A major activity was tin mining, from the 1880s to 1940s (Howard, 1940; Sansom, 1982). Locally, adits were driven, a tramline, surveyor's track and packhorse tracks were laid down and small sluicing and water-cannon operations were established to strip off the peat mantle to expose alluvial deposits and granite bedrock. Such activities, however, were of minor consequence compared to the fires which were lit periodically to assist prospecting, and which have modified the vegetation over more than 15 km^2 of countryside between Tin Range and the catchments of Healys Creek and Robertson River (Fig. 1).

Methods

Feeding sign was found by walking slowly through an area, looking for evidence that vegetation had been recently cropped, chewed, grubbed up or otherwise disturbed. If no sign was apparent, specific attention was paid to the ferns *Schizaea fistulosa* var. *australis, Blechnum minus* and *Blechnum procerum,* the orchid *Thelymitra venosa* and the shrubs *Olearia colensoi* and *Dracophyllum longifolium,* as these appeared to be favoured plants, and often feeding sign on other species was associated with feeding sign on these. Searches were concentrated along the edges and under the canopy of low scrub, at vegetation transition zones, around the margins and on top of granite outcrops, beside streams, and near ridge crests, flanks and faces of differing aspect throughout the study area.

Identity of feeding sign
Kakapo feeding sign can be confused with that left by deer *(Odocoileus virginianus),* possums *(Trichosurus vulpecula),* or rats *(Rattus exulans, R. rattus* and *R. norvegicus).* Confusion with deer sign was probably rare and restricted mainly to podocarp-hardwood forest areas of Robertson River and Healys Creek. Except for occasional deer in these areas, most were restricted to coastal forest.

Confusion with possum and rat sign was probably greater, for Gray (1977) noted that, at times, possum and rat sign on some plants could not be distinguished from that made by kakapo. Possums and rats are widespread throughout the study area.

Because of possible confusion in identifying the species responsible for leaving feeding sign, vegetation thought to have been taken by kakapo was examined very carefully. Grubbing, the formation of 'chews' (expectorated, crescent-shaped, masticated plant material; see Gray (1977) for details) and chewing of leaves or defoliation of limbs too frail to bear the weight of possums were considered signs of kakapo feeding. Where distinctive kakapo sign was not evident, feeding sign on a plant was attributed to kakapo only when (a) the material was adjacent to definite kakapo sign or droppings, and (b) there was absence of sign from other browsing animals.

Aging of feeding sign
As little of the kakapo feeding sign was of known age, estimates of age had to be made for assessing changes of diet with season. Trials simulating kakapo feeding sign were carried out on several plant species in January 1979. The basal portions of *Astelia linearis* (a herb), *Schizaea* (fern) and *Thelymitra* (orchid) were dug up using a small spoon. *Olearia colensoi* leaves were clipped, buds nipped and some new growth stripped down to the bare sapwood. Some pinnae of *Blechnum* (fern) were clipped. Examination of this simulated sign at regular intervals showed, unfortunately, that aging was neither well-defined nor consistent.

Grubbed up *Astelia linearis* appeared little different after a day or a few weeks on the sites tested. Some *Schizaea* grubbings appeared 'old' within days, as litter had fallen into them, or spider webs had been set across the depressions; other grubbings appeared 'fresh' even after a week or two. With *Olearia* and *Blechnum* it was not possible to determine whether foliage had been cut one week or two weeks before. However, when the bark on *Olearia* twigs was stripped to expose the new sapwood, the wood's pale green shade and moist texture were retained for a few days but by the end of a week the tip of the new sapwood had darkened appreciably. Grubbed *Thelymitra* orchids proved to be the best indicators of the age of feeding sign because the succulent, stalk-like leaves wilted after being cut. In exposed sites wilting was pronounced in a day, whereas in damper, sheltered sites it took several days.

Aging of sign was dependent on weather as well as the microclimate of the site, especially its exposure to sun and wind, and the moisture content of the air (for canopy material) or ground beneath (for ground plants).

In the field only sign which appeared fresh was

recorded. This would include sign judged conservatively to be less than a month old, though in many instances the material was probably only a day or two old.

Results

A list of plants found eaten by kakapo on Stewart Island is given in Table 1. For each of the 25 plant species involved, the parts eaten, the frequency with which this was taken and the seasonal occurrence of feeding sign found are given. The list does not include plants or parts of plants damaged by kakapo involved principally in non-feeding activities such as maintenance of track and bowl systems by male birds. Twenty-three of the food species were identified primarily from feeding sign, and two, *Cyathodes juniperina* seeds and *Cyathodes empetrifolia* leaves, from examination of droppings.

Feeding Sign

1. Roots and rhizomes

Kakapo obtained the rhizomes of *Lycopodium, Schizaea, Pteridium, Blechnum,* and roots of *Phormium, Thelymitra, Carpha* and *Carex* by grubbing, a feeding method which created small excavations (1 x 2 - 4 x 4 cm) in the ground, often distributed patchily over an area of several square metres. Grubbing for rhizomes of *Lycopodium,* which formed large mats, typically covered areas of 1-2 m2 but, in one instance extended over an area of 25 m^2.

In very fresh grubbings bill impressions were

Table 1: *List of kakapo foods on Stewart Island as determined by feeding sign.*

Species	Parts eaten	Relative abundance of sign
Club moss		
Lycopodium ramulosum	R	F (all year)
Lycopodium fastigiatum	R	F (all year)
†Moss		
Dicranoloma robustum	R	R (all year)
Ferns		
Schizaea fistulosa var. *australis*	R	F (all year)
Ctenopteris heterophylla	Ra	Oc (sum)
**Pteridium esculentum*	R	Oc (sum)
**Blechnum minus*	R, Ra, P	F, F, F (all year)
†*Blechnum procerum*	R, Ra, P	F, F, F (all year)
Woody plants		
†*Podocarpus hallii*	Le	Oc (win)
**Pseudopanax colensoi*	Lt	Oc (spr, sum)
**Cyathodes juniperina*	Fr	F (all year, in droppings)
†*Cyathodes empetrifolia*	Le	F (spr, sum, in droppings)
**Dracophyllum longifolium*	Lt, Lb, B	F, F, F (all year)
**Olearia colensoi*	Le, Lt, Pe, B, Ba	F, F, F, F, F (all year)
†*Coprosma colensoi*	Le, Ba	Oc (spr, sum, aut)
Herbs and grass-like plants		
†*Celmisia polyvena*	Lb	R (spr, sum)
†*Astelia linearis*	Lb	R (sum)
**Phormium cookianum*	R, Lt, Fs, Fr	Oc (sum-win), Oc (sum), F (sum), Oc (late sum)
†*Juncus planiflorus*	Lt	Oc (sum)
Centrolepis ciliata	R	Oc (sum)
Thelymitra venosa	Le, Lt, R, Bu	F, F, F, F, (all year)
Oreobolus strictus	R, Lb	F (sum, aut), Oc (sum, aut)
**Carpha alpina*	Lt	Oc (spr-aut)
**Gahnia procera*	Lb, Lt, S	F (aut-spr), F (aut-spr), F (sum-aut)
†*Carex appressa*	Le, Lb, Lt, R	F, F, F, F, (aut-win)

KEY: Parts eaten: B = leaf buds, Ba = bark, Bu = bulbs, Lb = leaf base, Le = leaf entire, Lt = leaf tip, Pe = petiole base, R = roots, or rhizomes, Ra = rachis, S = seeds, Fr = fruit, P = pinna, Fs = flower stalk.
Relative abundance: F = frequent, R = rare, Oc = occasional, less than 10 records.
* = same species eaten by kakapo in Fiordland, on Maud Island or at Mt Bruce Native Bird Reserve (see Gray, 1977).
† = same genera eaten by kakapo in Fiordland, on Maud Island or at Mt Bruce Native Bird Reserve (see Gray, 1977).

clearly visible at the worked face of the excavated area (Fig. 2a, b). The rhizomes were broken commonly into 1-2 cm lengths, which had been crushed, presumably to squeeze out the starchy contents within. Other plant species were sometimes dug up during grubbing but did not appear to have been fed on and neither did the aerial portions of the food plants being grubbed. Balls of peat about 1 cm in diameter, scooped by the bill, were often found in the grubbed area.

Feeding on *Schizaea* rhizomes comprised biting or slicing through the stipe at, or just below ground level leaving either a slight trace on the ground, or scoops about 1 cm deep and 1 cm wide x 2 cm long. Sometimes a divot was removed in the process and placed to one side (Fig. 3a, b) with the stipes still intact, though more commonly the aerial portions of the plant lay separately on the ground (Fig. 3c). The sign

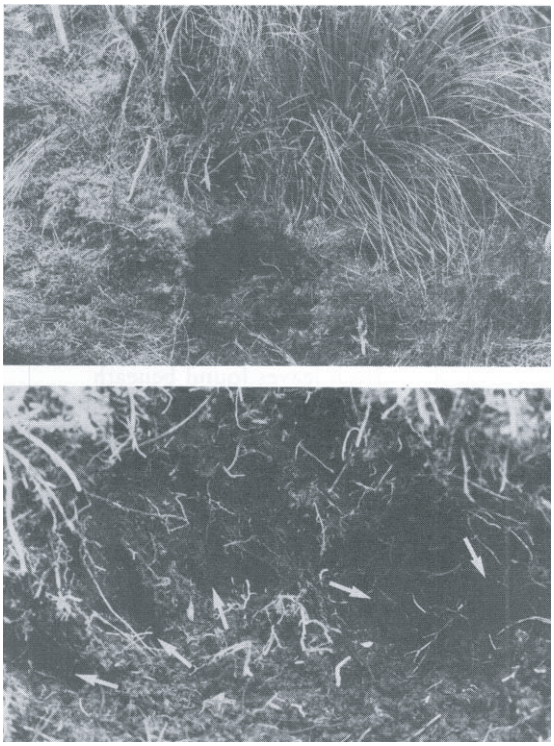


Figure 2: *A. Grubbing for* Lycopodium *rhizomes near the base of a* Gahnia procera *sedge. B. View of grubbed face. Note bill impressions in the peat wall (arrows) and the broken sections of rhizomes and roots.*

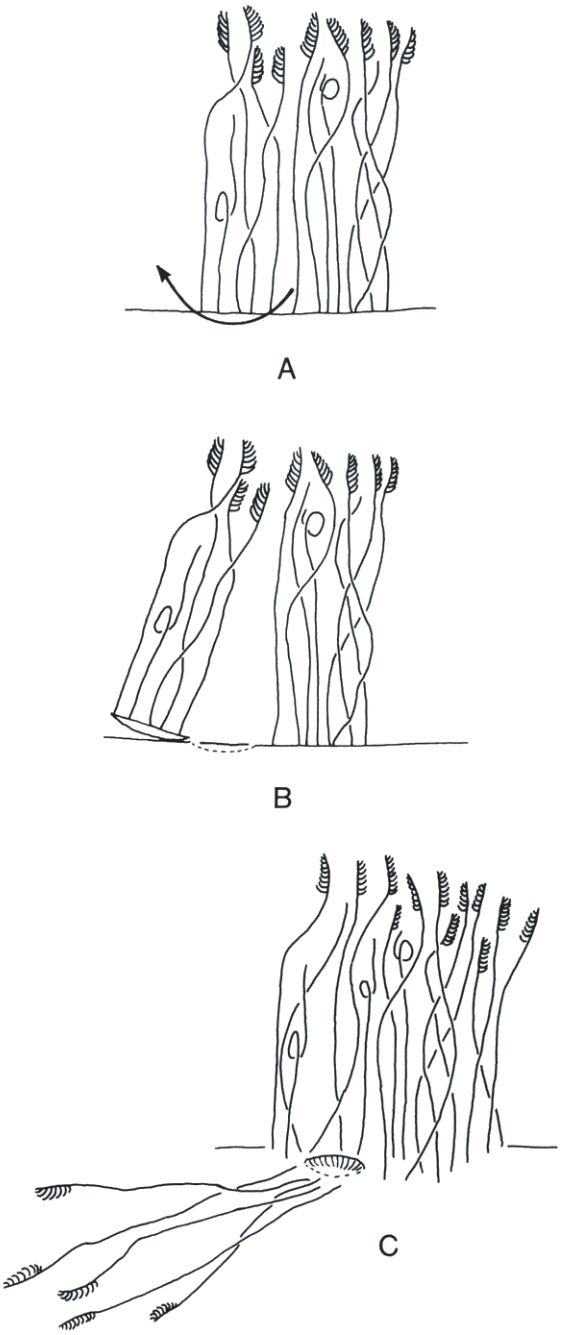


Figure 3: *Feeding sign on* Schizaea fistulosa. *A. grubbing motion; B. divot of turf with intact* Schizaea; *C. felled* Schizaea *beside grubbing.*

was not conspicuous but at times formed one of the main feeding signs in a locality.

Grubbing was used also when kakapo fed on *Celmisia, Astelia* and *Oreobolus;* this was not to feed on the roots of these plants but to gain access to the apical areas of their leaves which were located at the bases of the plants.

2. Material plucked from the ground or parent plant

Kakapo plucked material from the ground when feeding on *Dicranoloma, Oreobolus, Centrolepis, Astelia* and *Celmisia,* all of which form mats on the ground. Sign on *Dicranoloma* moss was rare and consisted usually of a few tufts of foliage pulled out of the ground.

Oreobolus was fed on by a bird either pulling, wrenching or grubbing pieces out of the parent material. Feeding sign was noted only on the bases of the plants just above the roots and formed a very small portion of the material pulled up. The discarded green portions were left intact and sometimes trailed a strand or two of root material (Fig. 4). Kakapo feeding sign on *Centrolepis* was similar to that on *Oreobolus*.

When *Celmisia* and *Astelia* were eaten leaves were pulled off individually and the bases chewed; a single lateral bite through the plant's core was used to remove the apical region at the base of the leaf rosette, whilst the rest of the plant remained undisturbed in the ground; and the innermost rosette of leaves was taken from the plant and the bases of the detached leaves chewed up.

Usually only one or two *Celmisia* or *Astelia* were fed on at a site, but on one occasion, at an area carpeted densely in *Celmisia,* plants along a 40 m line of travel were torn up and strewn about and chews were found amongst the leaves of undisturbed plants.

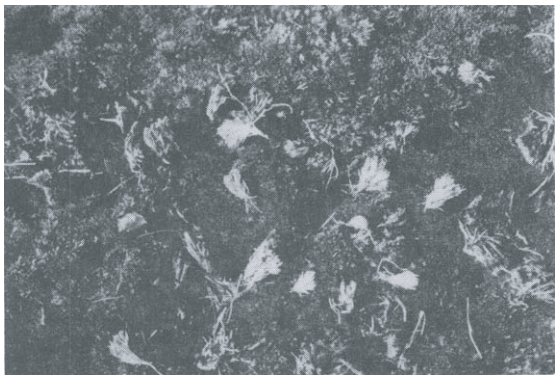


Figure 4: *Grubbed* Oreobolus strictus *portions on* Oreobolus *and* Dicranoloma *turf.*

3. Basal stems

Basal stems were sliced through just above ground level. This feeding method was noted on the ferns *Ctenopteris, Pteridium* and *Blechnum* and on the ground orchid *Thelymitra*. In all cases the cut was oblique and the opposing sides of the stem were pinched in at the edge of the cut. When this mode of feeding was used on ferns, no other parts of the plants were taken - the aerial portions were left on the ground untouched. For *Thelymitra* the entire leaf above the cut section was taken and, in one example, 61 of 83 orchid plant leaves in an area of 50 x 100 cm were trimmed.

4. Leaves, tillers and pinnae

(a) *Blechnum* ferns. Feeding sign was found much more frequently on *B. minus* fronds than on *B. procerum* fronds. Usually, the pinnae were clipped partly or entirely from the rachis (Fig. 5a). Alternatively, pieces were nibbled from the margins of a pinna (Fig. 5b, c) leaving scalloped markings, the edges of which were slightly ragged (insect damage, in contrast, had clean-cut, irregular edges, Fig. 5d).

(b) Leaf tips of Halls totara, *Dracophyllum,* flax, *Juncus, Carpha, Gahnia,* and *Carex*. The leaf tips were chewed leaving the mangled connective fibres on the plant for several weeks or even months (Fig. 6).

(c) Petioles, leaf bases and tiller bases. Examination of fresh leaves found beneath *Olearia* shrubs revealed that 2-3 mm of the petiole base had been nipped off, leaving short, protruding strands of connecting tissue (Fig. 7a, b, c). Kakapo probably held each detached leaf in one foot while feeding on the petiole base. On one instance, 113 of 135 freshly-detached leaves found under one small shrub, had had their petiole bases removed.

The bases of detached leaves/tillers of *Dracophyllum, Gahnia* and *Carex* were chewed and discarded to litter the ground. On browsed *Gahnia* and *Carex* tiller bases the juicy portions were removed by mastication and the fibrous connective tissue was left in a matted condition still attached to the remainder of the severed tiller. At times when feeding sign was concentrated on just a few plants, each had a flattened appearance indicating that the bird had

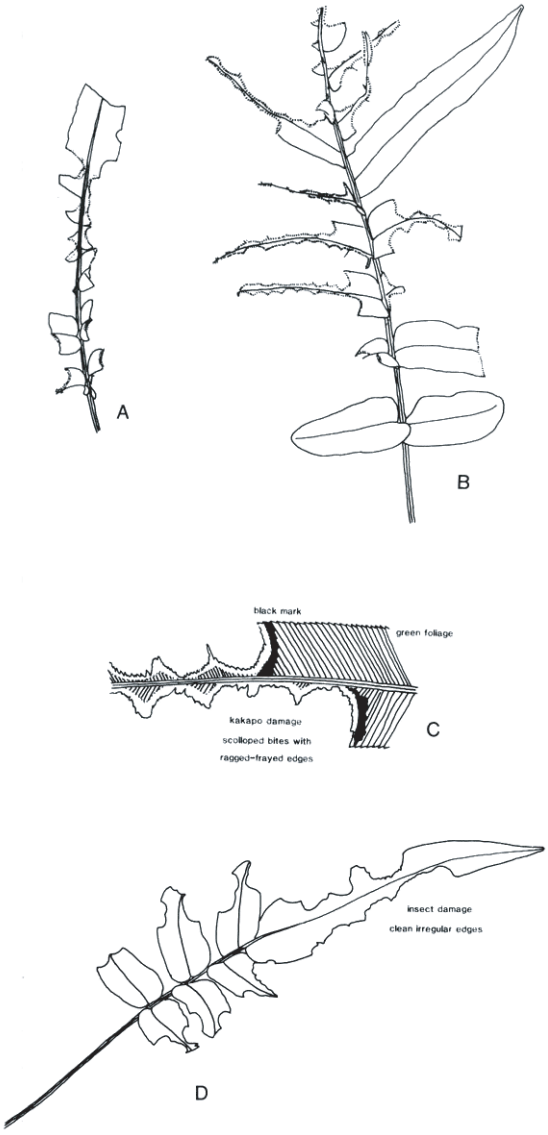


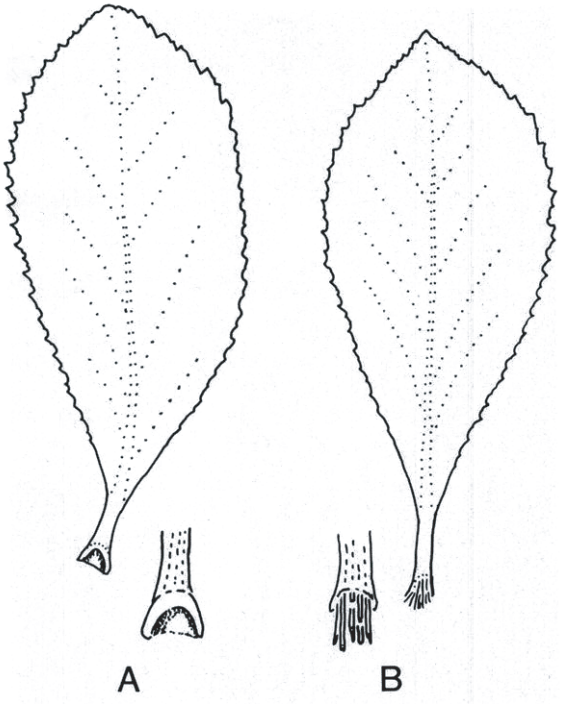
Figure 5: *Feeding sign on Blechnumfronds. A. pinnae clipped entirely (kakapo); B. pinnae nibbled either side of the midribs (kakapo);* C. *close up of kakapo feeding sign on fern pinna. Note scalloped bite marks, ragged edges to bites and zone of paler (dead) vegetation fringing the bites. A black area on the margin of the intact areas of the pinna is frequently associated with such feeding sign.* D. *insect feeding sign on* Blechnum *pinnae - clean edged, irregular patterned feeding damage is characteristic.*

Figure 6: *Kakapo feeding sign on* Dracophyllum longifolium. *The mid portions of leaves have been chewed and the light green mangled connective fibres have bleached to pale straw within a week.*

been standing on the crown of the tussock-like plants.

(d) Leaf buds. *Dracophyllum* and *Olearia* leaf buds were either eaten entirely, (Fig. 8) or a clean bite was taken out of the side to obtain the innermost new growth.

(e) Entire leaves On *Pseudopanax* and *Olearia* leaves feeding sign was most evident on new growth. In some instances a few bites had been taken from the margins of the leaves, while at other times nearly all the leaf was eaten, leaving the basal portion and the petiole attached to the plant (Fig. 9 a, b). Alternatively, on *Olearia* the youngest leaf shoots in an opening leaf bud were plucked out neatly, and a small tunnel in the foliage rosettes was the only indication that



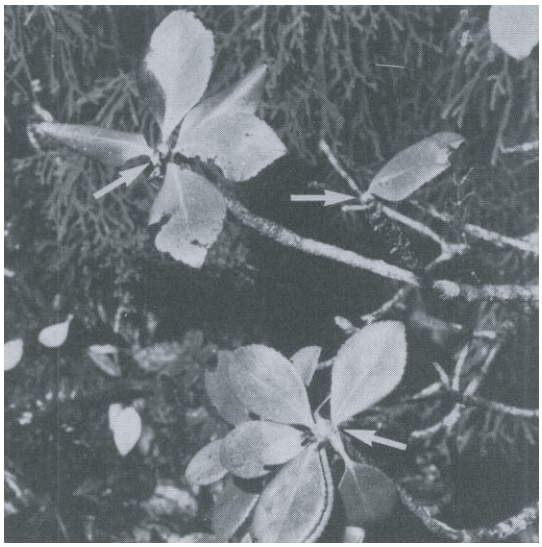


Figure 7: *Petioles of* Olearia colensoi. *A. typical petiole base when leaf pulled off tree; B. petiole base after being fed on by kakapo;* C. *photograph of* Olearia *shrub showing branch tips where kakapo has been feeding on petiole bases (see arrows).*

feeding had occurred. Chews were noticeable, especially when kakapo had been feeding recently on *Olearia* leaves (Fig. 9b); often many chews were caught up in the tight canopy where the bird had been feeding.

5. Bark

Feeding on bark was seen only on new growth of *Olearia* twigs and most often the entire leafy material at the tip of the twig had been removed also. Sign ranged from pieces of bark being nibbled off in small patches through to all of the new growth bark being stripped back to the previous season's growth. Strands of bark were left hanging or were removed entirely (Fig. 10a). Sprouting of new buds was apparent on some twig tips that had been stripped months previously (Fig. 10b).

6. Flower stalks and heads

Flax flower stalks were fed on when the stalks were fully grown but still succulent. On a few plants a kakapo had mouthed the stems along sections 5-25 cm above the ground, leaving numerous crescent-shaped bill incisions in the skin of the stems, as if tasting the material. On other plants, 10-30 cm sections at the stem base had been removed leaving a hollowed stem covered with many bite marks. Within a few days the chewed stems had dried out.

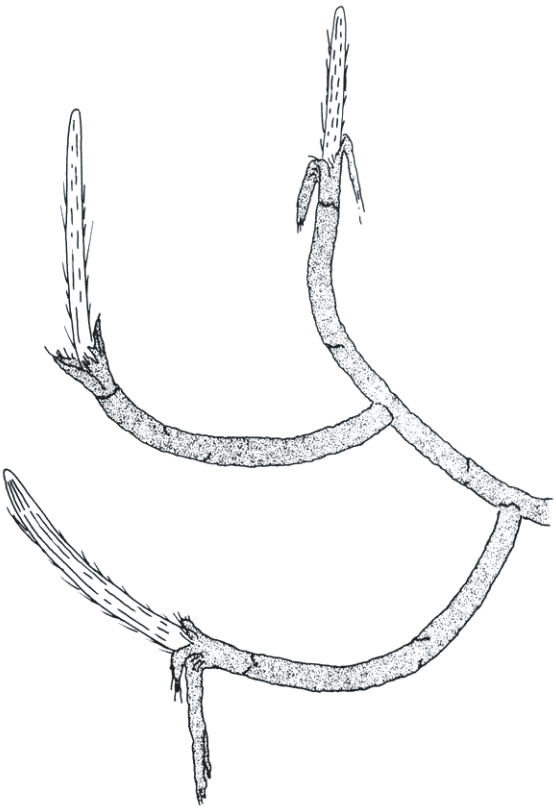
Figure 8: Olearia colensoi - *kakapo feeding sign on leaf bud. Black spot at tip of branch marks pit remaining after a bud has been removed. Adjacent leaf buds have not been disturbed.*

Figure 9: Olearia colensoi - *kakapo feeding sign on leaves A. photograph of leaf cluster from which some leaves have been fed on (see arrows); B. photograph of a section of canopy that kakapo has fed on. Arrows mark eaten leaves (L), 'chews' (C), and denuded branch tips (D).*

Evidence of kakapo feeding on flax seed heads was as follows. Ripe seed heads were found on the ground, still attached to their stalks with either pieces bitten out of them, or covered in distinctive bill imprints where a bird had manipulated them. As with the flower stalks, the seed heads had been fed on when they had turned black but had not dried out. The bird must have climbed each 1-1.2 m high stalk to cut the seed heads down.

7. Seeds

The presence of neat piles of clipped lengths of *Gahnia* seed heads, arranged with the stems in parallel rows, was considered to be evidence of kakapo feeding. The stems had been cut cleanly and obliquely. and the seedless husks were undisturbed (this could be duplicated only by



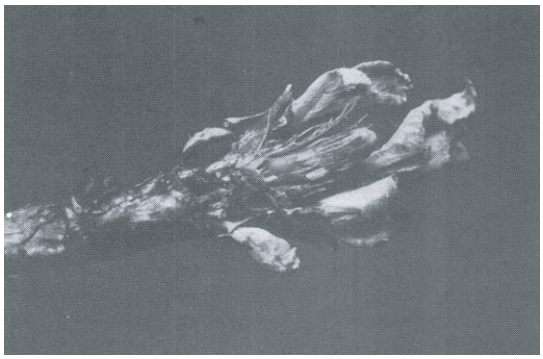


Figure 10: Olearia colensoi - *A. drawing of branch tip stripped by kakapo. All the foliage and some of the new growth bark has been removed (cf with virtually intact leaf cluster at end of branch in Figure* 8); *B. photograph of new growth foliage sprouting at end of a denuded branch tip.*

pinching the seeds at their point of attachment). The arrangement of cut material indicated that a bird had stood in one place while snipping off seed heads. Probably each cut length of seed head was held by a foot until the seeds were removed, after which the stem was dropped.

Sign which was attributed to rats feeding on *Gahnia* seed heads differed from that described above in that the edges of cut sections of stems were ragged, the seed husks were sometimes gnawed through, the majority of seeds on a cut stem had not been removed, and the stems were not piled in parallel rows beside the parent *Gahnia*.

Gahnia seeds were found in droppings of kakapo, as also were seeds of *Cyathodes juniperina*.

Seasonal variation in diet

Kakapo diet, as revealed from feeding sign, changed seasonally. The data on seasonal use of foods on Table 1 are a composite of several year's observation. For any particular season variations occurred in the relative abundance of feeding sign; for example, in 1978 feeding sign on *Dracophyllum longifolium* leaves was found to be common only in winter and spring, but in 1979 this sign was found readily throughout the year.

The plants taken most frequently throughout the year were *Lycopodium ramulosum,* L. *fastigiatum, Schizaea fistulosa, Blechnum minus, B. procerum, Cyathodes juniperina, Dracophyllum longifolium, Olearia colensoi* and *Thelymitra venosa*. Feeding on *Lycopodium* and *Blechnum* rhizomes, *Thelymitra* roots and bulbs and *Olearia* petioles was more common in late autumn-early spring than in the warmer months of the year, while feeding on pinnae of *Blechnum,* the leaf buds of *Dracophyllum,* the leaf buds, new leaves and new bark of *Olearia* and leaves of *Thelymitra* was more apparent in spring-summer-autumn. Generally, in spring and summer through into autumn feeding sign tended to be concentrated mainly on new growth and developing foliage while from late autumn to early spring most feeding sign was on subterranean parts of plants. *Cyathodes juniperina* fruits were present all year and seeds were found in kakapo droppings at any time of the year.

At certain times of year parts of other food species were taken frequently. These were the leaves of *Cyathodes empetrifolia* (summer), *Gahnia procera* (autumn-winter-spring) - especially in autumn 1979 and *Carex appressa* (autumn-winter), and in some years the seeds of *Gahnia* (late summer-autumn) and *Phormium cookianum* (late summer-early autumn), roots of *Phormium* (late summer-early autumn) and flower stalks of *Phormium* (mid summer).

Phormium cookianum produces flowers and seeds in summer, but irregularly and during flowering-seeding years feeding sign on these items was concentrated locally.

General feeding pattern

The distribution of feeding sign suggested that the main feeding pattern was one of discontinuous light browsing, such as would result if a bird were sampling foods whilst on the move. Often one piece of feeding sign led to another a few metres further on, with no one particular species being favoured. Individual plants of the same species were often treated differently, e.g. on *Olearia* shrubs there may have been intensive feeding on the leaf tips at one place, the petiole bases at another, and emergent leaves further on. In some cases, for example when feeding on *Carex,* some individual plants were clipped almost to ground level while adjacent plants were undisturbed. On occasions, birds appeared to have gone to considerable trouble to feed on individual *Carex* plants, clambering over some to feed heavily on others.

From time to time kakapo left conspicuous evidence of their feeding activities. On these occasions areas from 10 x 10 m up to 50 x 100 m were fed on heavily, a variety of foods taken and numerous droppings left (over 30 droppings at two such areas). Sign of concentrated feeding activity occurred mostly in manuka and yellow silver pine scrub.

The methods used by kakapo to obtain food were a mixture of the neat and the untidy. Nipping of *Olearia* and *Dracophyllum* leaf buds was clean and precise, whereas extensive grubbing for *Lycopodium* rhizomes appeared to have been done energetically, leaving a mangled heap of plant remains. The two contrasting methods were used when feeding on the same species e.g., *Celmisia* leaves were typically plucked one by one or the plant core cut through neatly, yet at times entire plants were uprooted.

Though kakapo may spend much of their time on the ground it is evident that they have considerable climbing skills (see also Henry, 1903; Gray, 1977). On many occasions I found feeding sign at the branch tips of shrubs,

especially on *Dracophyllum longifolium* and *Olearia colensoi*. While some of the lower branches may have been accessible from the ground, in most cases birds would have had to climb the shrubs to reach the shoots and leaves concerned.

Distribution of feeding sign
No kakapo sign was seen in coastal scrub or podocarp-hardwood forest within about 200 m of the sea in the coastal parts of the study area visited (principally Healys Creek and Maori Creek catchments but with occasional sorties along the old Culler's track). Inland, kakapo feeding sign was distributed widely through to the crest of Tin Range, including the western flank of the range northward to at least McArthurs Creek.

Most of the kakapo sign found in the study area was in yellow silver pine scrub and man uk a scrub, with very little sign being noted in inland podocarp-hardwood forest, swampy flats (except on *Carex*) and subalpine scrub or on the alpine tops. Kakapo feeding sign was not distributed evenly in manuka scrub and yellow pine scrub. Sign tended to be most common on drier, elevated sites such as hillocks, ridges, tablelands, mounds, outcrops and knobs. On such sites the open-canopy, woody vegetation, from 1-5 m high, sometimes graded through to more dispersed cover with shrubbery dotted about. The canopy gaps allowed the penetration of light and heat to the ground while the woody vegetation dissipated the wind.

The ground storey was open, comprising typically a mosaic of lichens, mosses, *Lycopodium, Schizaea, Pteridium, Thelymitra, Astelia, Cyathodes empetrifolia, Carpha, Oreobolus* and scattered litter, with flax, *Dracophyllum,* five-finger, *Gahnia, Cyathodes juniperina,* and *Olearia* as understorey plants. The herb species fed on by kakapo and the feeding sign on them declined markedly as close-set ground vegetation (e.g. dense groves of *Gahnia,* carpets of jointed rush and umbrella fern, or where podocarp-hardwood regeneration formed low thickets) occupied progressively greater areas. Such close-set ground vegetation tended to choke out many of the kakapo's preferred food species, stayed damp (especially during the winter) and may have been more difficult for kakapo to move through. Likewise, very little sign of kakapo was found in closed-canopy, pole stands of manuka as dense litter covered the ground, and there was a lack of understorey or ground plants for birds to browse.

Discussion

Kakapo diet on Stewart Island: comparison with other studies
Generally, the foods of kakapo on Stewart Island reported in this account are similar to those described by Gray (1977) for Fiordland, Maud Island and Mt Bruce Native Bird Reserve. That is, feeding sign was found most often on herbs, ferns and shrubs, though fruits and seeds from trees were taken when in season. The parts of plants most sought after were either subterranean or new growth such as leaves, bark and fruits-seeds. These parts of the food plants probably contained the highest nutrient levels.

Some of the kakapo foods on Stewart Island identified in my study were of the same species (9 of 25 species) or genera (17 of 21) listed by Gray (1977) (Table 1). Plants reported to have been fed on only from Stewart Island are *Lycopodium, Schizaea, Ctenopteris, Centrolepis, Thelymitra, Oreobolus, Dacrydium, Podocarpus*. Though these species are all present in Fiordland, not all may have occurred in the particular kakapo areas studied by Gray (1977). Of the above Stewart Island foods, *Schizaea, Centrolepis,* and *Oreobolus* seem to be strange choices because only minor portions of these small plants are taken and the energy gain per plant fed on would not seem to be great.

Other differences in feeding were apparent between studies and areas. Kamahi stems and petioles were reported by Gray (1977) to be one of the four favourite foods of captive birds at Mt Bruce Native Bird Reserve, but no feeding sign on this plant was noted in Fiordland (Gray 1977) nor on Stewart Island. *Gaultheria antipoda* fruits were common in one or two droppings from one valley in Fiordland but not from other valleys (Gray, 1977); on Stewart Island no record of kakapo taking this plant was obtained in my study.

Validity of feeding sign for diet assessment
The use of feeding sign produced a bias when assessing the diet of kakapo as conspicuous forms of sign were more likely to be found than less conspicuous ones. In some cases feeding by kakapo on certain berries and fruits and on the foliage of small leaved plants could only be

confirmed by identification of fragments in the droppings. Sign of feeding on such items was very difficult to detect on the plants concerned and even then may not have been attributable solely to kakapo.

Likewise a bias may have occurred when determining the vegetation types kakapo preferred to feed in. Discovery of most of the feeding sign in manuka scrub and yellow silver pine scrub may have arisen because sign was more obvious in these two habitats than elsewhere. In manuka scrub and yellow silver pine scrub the majority of the plants eaten were less than 2 m high and thus within close range of human vision. The ground was generally not concealed from view and droppings were relatively easy to find.

By contrast plants in podocarp-hardwood forest were distributed over a vertical range of 15-20 m and feeding sign above human eye level was not likely to be seen unless exhaustive searches were made using binoculars. Also, the understorey plants in the forest tended to be less concentrated than in manuka scrub or in yellow silver pine scrub and thus, feeding sign on these plants would be more dispersed. Thirdly, it was more difficult to find droppings in podocarp-hardwood forest, as any that fell more than a metre or tWo disintegrated on hitting the ground or may have been hidden in groves of *Blechrum discolor* which covered large areas of the forest floor.

Subalpine scrub was the most difficult of the vegetation types to search because of the close-set, tangled nature of the trees, the uneveness of the ground, the deep moss, prostrate trunks and outcrops of rock. As *Olearia colensoi* and *Dracophyllum longifolium* (which are frequently taken by kakapo) are dominant species in subalpine scrub, the birds probably use this habitat more often than indicated from the amount of sign I found.

The level of kakapo sign found on the alpine tops indicated that birds fed infrequently in this vegetation type. However, I suspect that, as with subalpine scrub, kakapo fed on the alpine tops more often as this vegetation type contained a range of food species similar to that taken by kakapo in Fiordland (Gray, 1977), especially adjacent to the subalpine scrub, and in the more sheltered places.

The paucity of feeding sign and droppings found on swampy flats (except in the vicinity of *Carex appressa*) probably reflected a genuine low use of this habitat for feeding by kakapo. Swampy flats were easy to search for feeding sign and the majority of feeding sign and droppings was seen on the better drained fringes of swampy flats (where the main food species became more plentiful) rather than centrally.

Conclusions on kakapo habits based on their feeding sign

The habits of kakapo inferred from my observations of their feeding sign agreed with those of Gray (1977) for Fiordland and Maud Island in that:

1. the preponderance of sparse feeding sign over large areas suggested that birds were solitary and ranged widely at night.
2. The variety of plant species eaten, the parts of plants taken, and the methods used to obtain their foods, showed that kakapo were versatile feeders.
3. Feeding patterns were variable, and often inconsistent, even in areas of similar habitat at the same time, suggesting that individual birds might have had their own preferences. This inconsistency of feeding pattern was even more noticeable when short-lived foods of sporadic occurrence (e.g. flax flower stalks) for the foods concerned may be gorged upon in only one or two small areas and left untouched elsewhere.
4. Feeding sign tended to be more concentrated on ridge crests and well-drained, sunny slopes, for at these places the variety of plant life was greater generally and more concentrated than on surrounding sites.
5. Kakapo are nocturnal feeders, but they may also feed or move about in the daytime.
6. The birds are skilled climbers and can scale vertical trees and limbs quite readily, and move into the crowns and outermost branches of trees at least 15 m high.
7. The type of feeding sign left, and thus the feeding technique used by the birds on Stewart Island, is similar to that in Fiordland.
8. Of a plant species fed on in a small area it was often found that, while some specimens were cropped heavily, others were browsed lightly or undisturbed.

Final comments

Because of the difficulty of finding sign that was attributable solely to kakapo, the list of foods in Table 1 is likely to represent only a fraction of those taken by the birds on Stewart Island. Use of dogs and radio-telemetry subsequent to this study has given a large data base on the locations and

feeding ranges of individual kakapo and thus searches for feeding sign can be directed to where birds have been.

Another factor limiting the list of kakapo foods on Stewart Island was that my study was for a relatively short term. A much better picture of the response of kakapo to the spectrum of foods available to them would arise from a study of 10 years or more. This is because some foods, such as the flowers, fruit and seeds of podocarps, hardwoods and tussocks have irregular cycles of abundance. A 10-year study would have a better chance of covering the sequence of 'boom and bust' for these plants. Although kakapo may feed very little on such plants for intervals of two or three years, they may be of major significance to the birds during times of high production. One kakapo activity likely to be prompted by a sudden production of high energy food is breeding, for kakapo do not nest every year, and as only the female tends to the young (Best, 1982) she must find plentiful supplies of foods for four-five months within walking distance of the nest for herself and her young.

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