Science Directorate, Department of Conservation, P.O. Box 10420, Wellington, New Zealand

THE FOODS, FORAGING BEHAVIOUR AND HABITAT USE OF NORTH ISLAND KOKAKO IN PUKETI STATE FOREST, NORTHLAND

Summary: The foraging behaviour, diet and habitat use of North Island kokako *(Callaeas cinerea wilsoni)* were studied in Puketi State Forest from October 1981 to August 1982. Kokako fed mainly from branches and twigs of canopy and upper-understorey plants. Although 68 different foods were eaten, only eight contributed more than 5% to the observed diet in any season. The diet consisted of fruit (44%), unknown foods (18%), leaves (15%), epiphytes (11%), invertebrates (8%), buds (2%), flowers (l%) and nectar (1%). The use of these food-types varied seasonally. Fruit consumption was high in summer, autumn and winter, and invertebrates were taken mainly in spring. Kokako ate leaves, including those of epiphytes, most often in winter and least often in summer. When epiphytes, lianes and invertebrates are included with their host trees, kokako obtained most food from shrub hardwoods (54%). Use of the other vegetation types for food WfiS as fopows: tree hardwoods (30%); podocarps (14%); ground-storey plants (1%); and tree ferns (1%). Kokako fed mainly between the crown foliage of canopy trees and 3 m from the ground, where shrub hardwoods and much of the foliage of tree hardwoods and epiphytes predominated.

Keywords: North Island kokako; *Callaeas cinerea wilsoni;* Puketi State Forest; foraging behaviour; diet; habitat use; song post.

Introduction

The North Island kokako *(Callaeas cinerea wilsoni)* is a member of the endemic family of New Zealand wattlebirds, Callaeidae. It is sedentary and territorial throughout the year, long-lived (c. 20 years) and may pair for life (Hay, 1981). The subspecies is classified in the New Zealand Red Data Book as vulnerable to extinction (Williams and Given, 1981). During early European settlement the North Island kokako was distributed as dense populations in scattered localities (Buller, 1892), but since the turn of the century it showed a marked reduction in range and numbers (Lavers, 1978). Populations are now restricted mainly to the central North Island forests (Lavers, 1978; O'Donnell, 1984), but small isolated populations occur in the Hunua Range (St Paul and McKenzie, 1974), Coromandel Range (Hughes, 1981), on Great Barrier Island (Ogle, 1981) and in Northland (Ogle, 1982).

Kokako have had a restricted distribution in European times (Lavers, 1978) but in some places were 'comparatively plentiful' (Buller, 1888). Surveys in Northland between December 1977 and January 1979 located kokako only in Puketi State Forest, and near the boundary of the contiguous Waipoua and Mataraua State Forests (Ogle, 1982). In 1981 a kokako was seen near the Kauri Sanctuary of Omahuta State Forest (M.J. Daniel, pers. comm.), which adjoins on to Puketi State Forest.

Before 1979, kokako were thought to be rare in Puketi State Forest (Halkett, 1980), but surveys in that year (Anderson, 1979; Hay, 1979) revealed a population of at least 70 kokako, mainly inhabiting the relatively unmodified mixed kauri-podocarp-hardwood associations. Another survey in November 1982 found 100 kokako in Puketi State Forest (Anderson, 1984), making it the densest population, representating 10-14% of known individuals (H.A. Best, pers. comm.). The New Zealand Forest Service suspended kauri logging in Puketi State Forest in March 1980 to enable a study to be made by the Wildlife Service of the habitat requirements of kokako.

The present paper describes the foods, foraging behaviour, and habitat use of kokako in Puketi State Forest based on observations carried out between October 1981 and August 1982.

Study Area

Puketi State Forest (35º13 'S, 173º44' E), Northland, (henceforth referred to as Puketi) is situated midway between the Hokianga and Whangaroa Harbours (Fig. 1). It covers 8066 ha and, with Omahuta State Forest (6472 ha) to the west and the Manginangina Scenic Reserve (93 ha) on part of its eastern boundary, forms a continuous tract of native forest extending 19 km. Puketi ranges in altitude from 50 to 550 m a.s.l., and

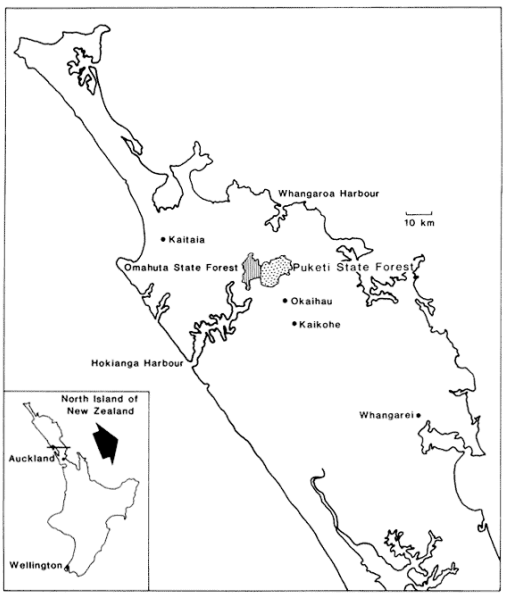

Figure 1: *Location of Puketi State Forest in the North Island of New Zealand.*

much of the land is steeply dissected. The Waipapa River flows westward through the centre of the forest, draining most of it.

Climate

The climate of Puketi is wet and very warm in summer, and very wet and mild in winter (Garnier, 1950). The prevailing wind is from the south-west, with occasional strong gales and heavy rains from the east or north-east (N.Z. Meteorological Service, 1983). Rainfall in the forest during 1949-74 (station A53282) averaged 2575 mm per annum, with about 130 mm per month in summer and about 280 mm per month in winter. Temperatures have not been recorded in the forest, but at nearby Kaikohe (station A53482) the mean annual temperature during 1973-82 was 14.7∞C. Monthly mean temperatures were highest in February (19.2∞C) and lowest in July (1O.6∞C).

Logging history

Logging has occurred in Puketi since 1860 and much of the forest cover has been modified. Large scale removal of kauri began about 1870 and continued intermittently until about 1925 (Halkett, 1980). Generally, logging was carried out at the periphery of the forest and usually only the best and most accessible trees were removed.

Logging under Forest Service supervision began in 1952 in the northern portion of the forest. Mainly rimu *(Dacrydium cupressinum)* was felled, with kauri being taken as it was encountered. Selective logging of kauri began in 1962, often in pockets where millable trees were available, while the surrounding forest was left untouched. Because of the long-term and piecemeal nature of the logging, it is often difficult to distinguish unmodified from modified forest, except where recent logging has occurred.

Vegetation types

Puketi contains a mosaic of vegetation types resulting from the steeply-dissected topography, the patchwork nature of the logging and the subsequent succession at the logged sites. The commonly recognisable vegetation types are:

1. Kauri - occurring as stands of various sizes, mainly on ridge tops, sometimes forming an interlocking canopy. Its upperstorey consists largely of tawari *(Ixerba brexioides);* the understorey is mainly *Gahnia* spp., *Astelia* spp., *Alseuosmia macrophylla, Dracophyllum latifolium* and *Cyathodes fasciculata.*
2. Kauri-podocarp-hardwood - found widely throughout Puketi, occurring at all altitudes and on most aspects. The canopy consists mainly of hardwoods, particularly tawa *(Beilschmiedia tawa),* taraire *(B. tarairi)* and kohekohe *(Dysoxylum spectabile),* with kauri, podocarps *(Dacrycarpus dacrydiodes, Dacrydium cupressinum, Phyllocladus trichomanoides, Podocarpus ferrugineus* and *P. totara)* and northern rata *(Metrosideros robusta)* being infrequent and mainly occurring as emergents. The composition of the under- and ground-storeys is diverse, although sparse in some areas. Common understorey species are putaputaweta *(Carpodetus serratus),* raurekau *(Coprosma grandifolia),* hangehange *(Geniostoma rupestre),* pigeonwood *(Hedycarya arborea),* mahoe *(Melicytus macrophyllus* and *M. ramiflorus),* mapou *Myrsine australis),* heketata *(Olearia rani),* five finger *(Pseudopanax arboreus)* and the nikau palm *(Rhopalostylis sapida).* Epiphytes are generally abundant on canopy and emergent species, particularly on podocarps and *Beilschmiedia* species.

3. Hardwood - this forest type occurs naturally in gullies and on steep faces, but is also found in logged areas. The dominant canopy species are taraire, tawa, kohekohe, puriri *(Vitex lucens),* rewarewa *(Knightia excelsa),* northern rata and towai *(Weinmannia silvicola).* The understorey composition of this forest type is similar to that of kauri-podocarp-hardwood forest, but with more podocarp and kauri seedlings in some areas.
4. Secondary forest and shrubland - present on land that was clearfelled and burnt. Depending on the soil type, degree of exposure and time since they were logged and burnt, such areas are covered mainly by *Gahnia* spp., hangehange, lawyer *(Rubus* spp.), gorse *(Ulex europaeus),* manuka *(Leptospermum scoparium),* towai and rewarewa.

Mammals

Pigs *(Sus scrota)* are present throughout the forest. In the vicinity of the Mokau and Mangahorehore Ridges browsing on the lower understorey shrubs by feral cattle *(Bos taurus)* is evident. Goats *(Capra hircus)* are present about the Pirau and Pukatea Ridges and as a result of their browsing few palatable plants remain in the lower understorey and ground-storey of some stream catchments. Possums *(Trichosurus vulpecula)* were rust noticed in the forest in the early 1970's and by 1982 had spread throughout (J. Beachman, pers. comm.). On three occasions when taped kokako calls were played to elicit calls from kokako, a stoat *(Mustela erminea)* was attracted to the sound.

Birds

The forest has a diverse avifauna, with nine endemic, II native and 13 introduced species seen in or over the forest during the study. The large proportion of introduced species in Puketi probably results from the effects of introduced mammalian browsers and the habitat disturbance caused by the long history of logging (Moynihan, 1980; see Diamond and Veitch, 1981).

Methods

Observations

Kokako activities and habitat use were studied using the methods developed by Hay (1981). Individuals or pairs were followed and their position and major activity during a to second period were recorded on a tape recorder at one minute intervals (an observation). Each observation included the following:

1. Time.
2. Bird height and canopy height (m) estimated by eye. Above the initial height class of 0.0 to 3.0 m, the estimates of the heights are grouped into 5-metre height classes.
3. Species of plant the bird was on and, if it was a liane or epiphyte, the host plant species as well:
4. Bird station was categorised as: *emergent,* trees with crowns above the canopy; *canopy,* the top storey of the tree crowns, generally unshaded; *upper understorey,* consisting of shaded plant crowns greater than two metres high; *lower understorey,* of shrubs, tree ferns, etc, 0.3-2.0 m high; *ground-storey,* of plants with growing points situated less than 0.3 m above the ground, together with the litter (Atkinson, 1966).
5. Type of perch - crown foliage, twig (:s; 15 mm diameter), branch (15-75 mm diameter): limb (≥75 mm diameter), trunk and ground.
6. Food type and species - bud, leaf, flower, fruit, nectar, epiphyte, invertebrate, unknown.
7. Class and species of the food source - podocarp (members of the family Podocarpaceae), tree hardwood (species capable of forming canopy forest 12-20 m in height), shrub hardwood (species rarely attaining more than 12 m in height and often present as understorey species (Leathwick, Hay and Fitzgerald, 1983», tree fern, liane, epiphyte, invertebrate and unknown.

The data were obtained during four field-trips: 27 October - 13 November 1981 (spring); 19 January - 4 February 1982 (summer); 14 - 29 April 1982 (autumn); and 20 July - 1 August 1982 (winter). Although none of the Puketi birds were individually identifiable, observations of colour-banded birds elsewhere (Hay, 1981) and of a particularly confiding bird in Puketi, indicate that kokako are highly territorial and sedentary. During the study 19 kokako were followed and observed, seven being solitary and 12 in pairs. Of the 4956 observations made, 73.3% were of solitary birds (Table 1).

Table 1: *Number of observations of solitary and paired kokako in Puketi State Forest during each field-trip and in total*

Field-trip	Number of observations		
	Solitary	Paired	Total
Nov. 81	917	-	917
Jan. 82	1089	307	1316
Apr. 82	953	739	1692
Jul. 82	675	276	951
Total	3634	1322	4956

Because of the difficulty of locating kokako, other than during the early morning when they often sang from prominent perches, birds were attracted to the observer or encouraged to call by playing a tape recording of mew calls or song. Birds were located in this manner on 56% of the 57 occasions they were followed. Alterations to their behaviour caused by these activities seemed to be short-lived, and I am convinced that all observations made were of natural behaviour. In addition, because the average length of each sighting lasted 90 minutes (range: 11-229) (Table 2), any transitory observer influence on the bird's behaviour would have affected only a very small proportion of the activity records.

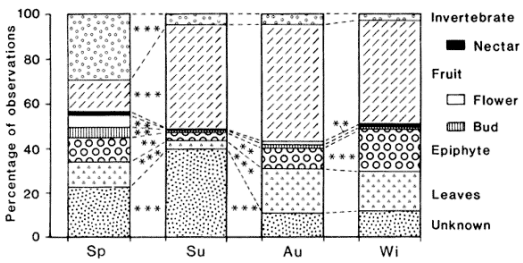

Figure 2: *Seasonal* use *of seven food types and unknown items by North Island kokako* in *Puketi State Forest. The asterisks denote significant differences between adjacent samples:*.=p<0.05, **=p<0.01, ***=p<0.001.*

Results

Over the four seasons 4956 observations were made and on 32% of these kokako were feeding (handling and eating food, but not searching for it). The analysis of these feeding observations is described here.

Time spent feeding

Kokako fed for a similar proportion of time in spring (25%) and summer (23%), but significantly more in autumn (35%) and winter (45%) (p<0.001). Even though there was less time available, they spent more of the daylight hours feeding in winter than during other seasons.

Diet and food types

Kokako had a varied diet. They were seen feeding on 68 different foods (Appendix I), only eight of which contributed more than 5% to the observed diet in any season. Seasonal changes in the types of food eaten by kokako are shown in Figure 2. In spring, 29% of the feeding observations were of birds eating sixpenny scale insect *(Ctenochiton viridis)*. Invertebrates comprised less than 5% of the diet for the rest of the year. Other frequently eaten foods in spring were the fruit of pigeon wood , mapou and fivefinger. However, kokako fed less on fruit and more on buds, flowers and nectar in spring than during the other seasons (Fig. 2).

In summer, autumn and winter fruit made up nearly half the diet (46-52%), but only 14% in spring (p < 0.001). Fruit of lawyer *(Rubus* spp.) was the food most frequently eaten in summer, but toropapa *(Alseuosmia macrophylla),* raurekau, mingimingi *(Cyathodes fasciculata)* and tanekaha *(Phyllocladus trichomanoides)* fruits were commonly eaten. Fewer leaves were eaten in summer than at other times (p<0.001).

In autumn the major component of the diet was fruit (52%), slightly more being eaten then than during summer (48%) and winter (46%) (Fig. 2). The order of preference of fruit in autumn was raurekau, totara *(Podocarpus totara),* tanekaha, nikau, *Collospermum* spp., and mapou. Also, kokako took more leaves (p<0.001) and epiphytes (p<0.01) then than in summer. The most frequently eaten leaves were those of raurekau and heketara. Most epiphytes eaten were unidentified (70%). However, of those which could be identified *(Asplenium flaccidum, Dendrobium cunninghami, Earina autumnalis* and *E.*

Table 2: *Mean number of observations per observation period of kokako each field-trip and* in *total at Puketi State Forest*

Field-trip	Number of kokako followed	Number of observation periods	Mean number of observations per observation period	SD	Range
Nov. 81	4	10	91.7	63.6	21-188
Jan. 82	10	16	87.3	73.3	11-229
Apr. 82	17	21	80.6	46.6	23-186
Jul. 82	9	10	95.1	71.5	33-224
Total	19	57	87.0	61.0	11-229

mucronata), leaves were eaten in 75% of the 36 occasions.

The diet changed less from autumn to winter than from spring to summer or summer to autumn. More epiphytes ($p < 0.001$) and nectar ($p < 0.01$), but fewer flowers ($p < 0.01$), were eaten in winter than in autumn. The food most frequently eaten in winter was lancewood *(Pseudopanax crassifolius)* fruit, constituting 28% of the diet. The only other fruit frequently taken in winter was that of mapou. Commonly-eaten leaves were those of *Clematis paniculata,* raurekau and heketara.

Overall, kokako fed most on fruit (44%), followed by leaves (15%), epiphytes (11 %), invertebrates (8%) and buds (2%), with flowers and nectar contributing 1 % each to the diet. Unidentified foods made up 18% of the diet. When invertebrates are attributed to the host plant species, the three plant species contributing most food to kokako were raurekau (11 % of 1514 feeding observations), fivefinger (10%) and lancewood (9%). Kokako fed in kauri trees on six occasions in spring (3) and summer (3), representing only 0.4% of all feeding observations; on three of those occasions the birds fed on epiphytes.

Food class

To determine the relative importance to kokako of the six vegetation classes as sources of food, the various foods were categorised according to the vegetation classes from which they were derived, with additional classes for invertebrate and unknown foods. In spring, no podocarp foods were eaten, but foods from the other classes were well represented (Fig. 3), particularly invertebrates (29%) and shrub hardwoods (25%). During summer, foods from lianes and podocarps were more numerous in the diet than in spring ($p < 0.001$, but fewer tree hardwood foods were taken in summer than in spring ($p < 0.01$). Although fewer epiphytes were taken in summer ($p < 0.001$), many of the foods classed as unknown were possibly epiphytes (Fig. 3).

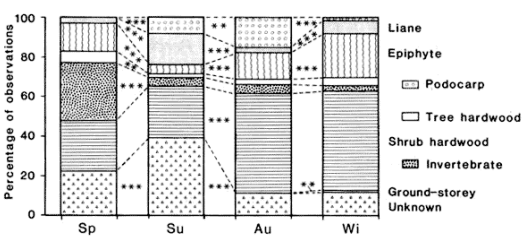

Figure 3: *Seasonal use of seven food classes as sources of food and unknown foods by North Island kokako in Puketi State Forest. The asterisks indicate significance levels as in Figure* 2.

In autumn the proportion of foods taken by kokako from both podocarps ($p < 0.01$) and shrub hardwoods ($p < 0.001$) doubled compared with summer; shrub hardwoods made up 50% of the diet. Associated with this were reductions in usage of lianes and unknown foods ($p < 0.001$). In winter, the shrub hardwood component of the diet remained at 50%. However, the consumption of podocarp foods decreased ($p < 0.001$) and the use of epiphytes ($p < 0.001$) and lianes ($p < 0.001$) increased.

Much of the kokako food was derived from shrub hardwoods (42%); other vegetation classes in descending order of importance as food sources were epiphytes (15%), invertebrates (8%), podocarps (8%), lianes (6%) and tree hardwoods (3%). Unknown foods made up 18% of the diet.

The relative importance of shrub hardwoods, tree hardwoods and podocarps as food sources for kokako is more accurately portrayed when epiphytes, lianes and invertebrates are included with their host trees (Fig. 4). Unknown foods are attributed to the vegetation class in which the bird was perched when feeding, except when feeding on the ground. Grouped in this way the proportion of feeding observations in shrub hardwoods increases slightly from 42 to 54%, because most invertebrates (87% of 199) came from shrub hardwoods. Fivefinger was the most frequent source of invertebrates for kokako from shrub hardwoods (75% of 89), specifically larvae in dead twigs and sixpenny scale insects. However, more notable is the increased proportion of food derived from the podocarp and the hardwood vegetation classes. Food from podocarps increased from 8 to 14% and food from tree hardwoods from 3 to 30%; 75% of 306 observations of epiphytes and lianes eaten were from tree hardwoods. Taraire (36%), towai (25%), kohekohe (18%) and tawa (10%) were the main tree hardwood hosts of the epiphytes and lianes on which kokako fed.

The main seasonal change in the use by kokako of the various vegetation classes occurred between spring and summer. In autumn, winter and spring kokako fed for about 58% of their feeding time in shrub hardwoods, compared with 35% in summer ($p < 0.001$) (Fig. 4). This resulted partly because few invertebrates (most of which came from the shrub hardwood class) were eaten in summer (Fig. 3). A major component of the diet in summer was lawyer

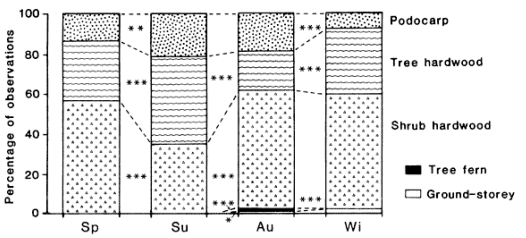

Figure 4: *Seasonal relative importance to North Island kokako in Puketi State Forest of food items from five vegetation classes. Invertebrates, epiphytes, lianes and unknown foods are included with their host trees. Asterisks indicate significance levels as in Figure* 2.

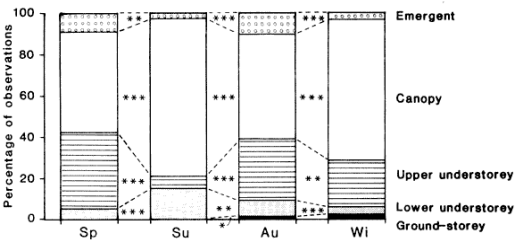

Figure 5: *Seasonal use of five forest storeys for feeding by North Island kokako in Puketi State Forest. Asterisks indicate significance levels as in Figure* 2.

fruit (Appendix I) borne on vines growing through the canopy of tree hardwoods.

In autumn, kokako fed less in tree hardwoods than previously ($p < 0.001$) because lawyer fruiting had finished. Instead, they fed mainly on the fruit and leaves of shrub hardwoods (Fig. 4, Appendix I). By winter, kokako fed little in podocarps because podocarp fruit was scarce. The increased feeding in tree hardwoods in winter ($p<0.001$ (Fig. 4) resulted because the birds fed more on epiphytes (Fig. 3), which were most abundant on tree hardwoods.

None of the foods taken by kokako moving over tree-fern fronds or the ground were identified. When on the fronds kokako seemed to search for invertebrates on the undersurfaces, but while on the ground they appeared to feed on the fruit of plants such as *Nertera* spp.

In total, 54% of the feeding observations were of kokako taking food directly or indirectly (as a host tree) from shrub hardwoods, 30% from tree hardwoods, 14% from podocarps, 1 % from ground-storey plants, and 1 % from tree ferns.

Feeding stations

Kokako fed mainly in the canopy (60%) and upper understorey (25%). The lower understorey (8%), emergent trees (6%) and the ground (1%) were used less frequently. The kokako's use of these feeding stations changed seasonally (Fig. 5). They fed in emergents for 9% of time in spring and autumn and for 3% in summer and winter ($p<0.001$). Kokako used the canopy most in summer (77%) and winter (68%), and least in spring (49%) and autumn (51%). Whilst they fed for only 5% of time in the upper understorey in summer, their use of this station was consistently high for the remainder of the year (23-37%). The use of the lower understorey varied from 3% in winter to 15% in summer. Kokako were seldom seen feeding on the ground in autumn and winter, and never during the other seasons.

Feeding perches

In general, there was little seasonal variation in the use of perch types by feeding kokako (Fig. 6). Of note is the increased use of crown foliage in summer, and of limbs and trunks in autumn. Overall, most feeding was carried out from branches (57%) or twigs (33%).

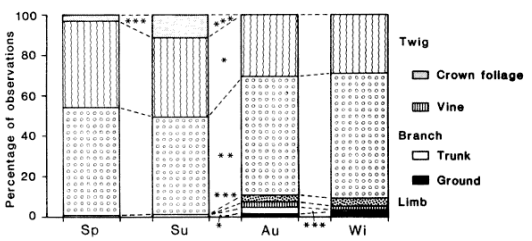

Figure 6: *Seasonal use of types of feeding perches by North Island kokako in Puketi State Forest. Perch categories vine and limb in spring, and vine in summer were recorded as branches. The asterisks denote significance levels as in Figure* 2.

Height of feeding

In spring, autumn and winter kokako rarely fed in emergent trees and confined most of their feeding to the crown foliage of the canopy and below (Fig. 7). Kokako fed most frequently in the 3-18 m height range and infrequently below 3 m. By contrast, in summer they fed more in emergent trees at 18-23 m above ground, and less in the 3-8 m, height class.

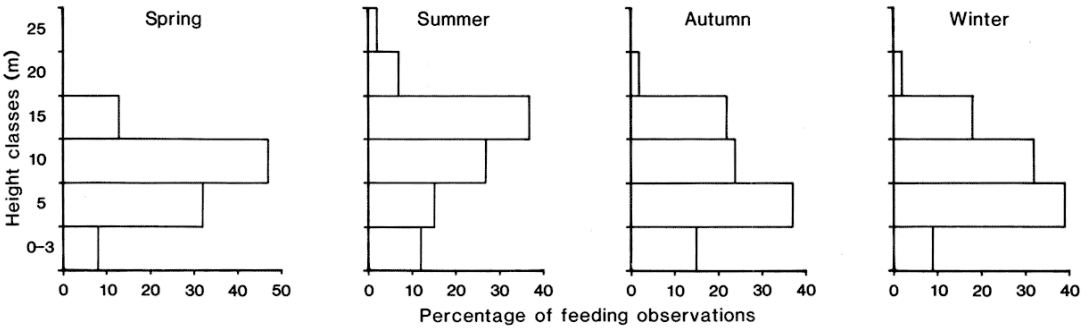

Figure 7: *Seasonal use of six height-classes by feeding North Island kokako in Puketi State Forest. Heights above 3 m to the nearest 5 m.*

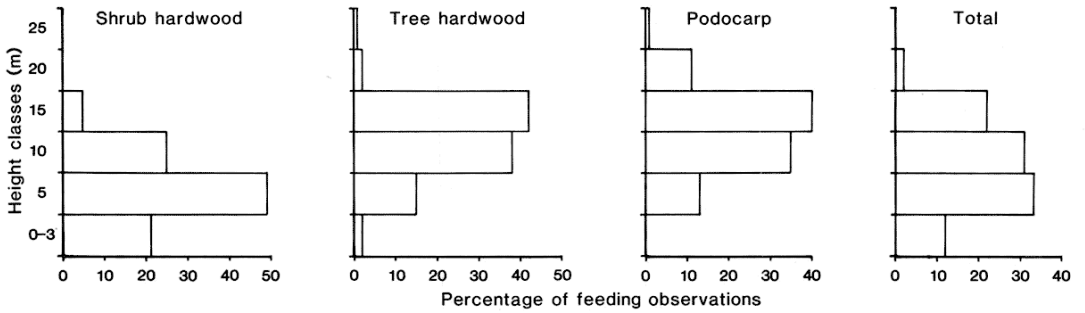

Figure 8: *Use of six height-classes within three vegetation types and in total by feeding North Island kokako in Puketi State Forest. Heights above* 3 *m to the nearest* 5 *m.*

Most shrub hardwoods were less than 12 m high and feeding kokako spent 70% of time in the first two height classes (Fig. 8). They seldom fed above 13 m even when the opportunity existed. In tree hardwoods they fed mostly in the 8-18 m range (80%). In podocarps kokako fed mainly between eight and 18 metres (75%), with no feeding below three metres. The decline in feeding above 18 m was more gradual in podocarps than in tree hardwoods (Fig. 8). Combining all feeding height data, 86% of feeding took place in the 3-18 m range.

Kokako usually sang from the tops of trees, these trees being emergent (68%, n= 511) or canopy species. Kauri and totara were the species most commonly used as song posts (Table 3).

Discussion

Foods

North Island kokako in Puketi were omnivorous, as has been noted of the subspecies elsewhere by Buller (1888), M'Lean (1912) and Hay (1981). Sixty-eight different foods were seen to be eaten during the 12 month period of this study. Similarly, at Rotoehu State Forest, Mapara State Forest and Pureora State Forest over a 33 month period Leathwick *et al.* (1983) found that kokako ate 41, 54 and 77 different foods respectively. Thirty-six foods were common to the diets of kokako in the central North Island and at Puketi.

The proportion of the diet derived from each of

Table 3: *Number of observations of singing kokako in Puketi State Forest on various tree species in November* 1981 *and January, April and July* 1982 *(field-trips) and in total, and the proportion of observations for each tree species*

	Number of Observations					
Tree species	Nov. 81	Jan. 82	Apr. 82	Jul. 82	Total	% of total
Agathis austra/is	29	107	26	24	186	36.4
Podocarpus totara/halli	33	14	15	-	62	12.1
Metrosideros robusta	14	20	20	6	60	11.7
Weinmannia silvicola	20	10	15	6	51	10.0
Podocarpus ferrugineus/spicatus	29	-	11	1	41	8.0
Dacrydium cupressinum	4	11	8	11	34	6.7
Beilschmiedia tarairi	6	1	5	5	17	3.3
Knightia excelsa	-	-	16	-	16	3.1
Ackama rosaefolia	-	-	13	-	13	2.5
Phyllocladus trichomanoides	-	5	6	-	11	2.2
Leptospermum scoparium	-	8	-	-	8	1.6
Elaeocarpus dentatus	2	-	3	-	5	1.0
Persoonia toru	1	-	3	-	4	0.8
Dysoxylum spectabile	-	-	2	-	2	0.4
Pseudopanax arboreus	1	-	-	-	I	0.2
Total	139	176	143	53	511	100.0

the seven food-types was similar for kokako in Puketi and the central North Island (Leathwick *et al.,* 1983). At Puketi fruit formed 44% of the diet, leaves (including those of epiphytes) 27% and invertebrates 8%. In general, the seasonal use of the various food-types by kokako at the two localities was also similar. Fruit use was high in summer and autumn at both localities, but in winter was higher at Puketi. At the three central North Island study areas the availability of each of the food types was determined and it was demonstrated that changes in fruit use by kokako reflected fruit availability (Hay, 1981). Taraire, tawa and podocarps were common canopy species in Puketi, but they fruited poorly during the study and consequently little of their fruit was eaten. In years of heavy fruit production these species are likely to be important food sources for kokako.

If the seasonal totals for epiphytes (of which mainly leaves were eaten) and leaves eaten by kokako at Puketi are combined (Fig. 2), leaf consumption was highest in winter (37% of the diet). Similarly, Hay (1981) found that kokako of the central North Island ate leaves predominantly in winter and spring. Young leaves were preferred but old leaves were frequently seen being eaten, particularly those of raurekau. Also, St Paul (1966) observed kokako at Moumoukai eating old leaves of several species. The New Zealand pigeon *(Hemiphaga novaeseelandiae)* at Pelorus Bridge, Marlborough, has been seen to eat the old leaves of three *Coprosma* species, particularly *C. rotundifolia* (M.N. Clout, pers. comm.). The regular inclusion of old leaf material in the kokako diet warrants an investigation into the nutrient qualities and digestibility of these leaves compared with those of young leaves.

Invertebrates formed a major portion of the kokako diet in spring at Puketi and in summer in the central North Island (Hay, 1981). At both localities the sixpenny scale insect was the predominant species eaten. This insect is sessile and so readily available to the kokako, a bird with poor powers of flight. High densities of the sixpenny scale insect may be an important rich source of protein to kokako for egg development and as a food for nestlings.

Much of the food eaten by kokako in Puketi (Fig. 3) and in the central North Island (Hay, 1981) was from epiphytes and shrub hardwoods. Hay (1981) and Leathwick (1981) showed that these vegetation classes and lianes were eaten by kokako more often than would be expected from their abundance. In Puketi and in the central North Island (Hay, 1981) kokako obtained little food directly from the canopy and emergent storeys, which were dominated by podocarps and tree hardwoods. However, the true importance of these vegetation classes becomes apparent when food from their epiphytes and lianes is incIuded (Hay, 1981; Fig. 4, this study). By combining the epiphyte and liane feeding observations with those of their host vegetation classes, Hay showed that podocarps and the tree hardwoods were used approximately in proportion to their abundance. Both studies found that shrub hardwoods provided most food for kokako, either as plant material or invertebrate.

The importance to kokako of each vegetation class cannot be assessed just from the amount of food obtained from each in one year; the seasonal requirements of the birds and the differing abundance of many foods between years must be taken into account. For example, in Pureora State Forest Hay (1981) found that fruit of matai *(Podocarpus spicatus)* comprised 4% and 40% of the kokako diet in successive autumns. Therefore, it seems that kokako need a wide diversity of flora in their territories to ensure an adequate supply of food each year; a particular food may be readily available one year but not the next.

Foraging behaviour

The seasonal foraging pattern of kokako in Puketi (Fig. 5) largely reflected the availability of the predominant foods and where these foods were in the forest strata. Because the diet varies seasonally (Hay, 1981; this study) and annually (Hay, 1981), the seasonal use of foraging stations can be expected to differ annually.

Kokako often feed by holding the food in one foot, parrot-fashion, resting that leg on a branch and bending the head down to the foot to eat (Buller, 1888; Oliver, 1955; Hay, 1984). To do this kokako need a stable platform. This explains why, even though more food was obtained from twigs than branches, branches were used more than twigs as perches when eating food (Fig. 6). Kokako were rarely seen feeding on the ground (0.4% of 4956 observations). The same was recorded by Hay (1981) for kokako in Pureora State Forest (0.2%). When on the ground they also moved about and bathed in pools. It is possible that my presence sometimes may have deterred birds from descending to the ground. However, my observations appeared to have no effect on their above-ground activities.

Habitat use

In spring most feeding took place below the canopy (Fig. 7) because the kokako were foraging mainly in shrub hardwoods (most less than 12 m) for sixpenny scale insects and for epiphytes on tree hardwoods. Since tree hardwoods form much of the canopy and most epiphytes occur on such trees below their crown foliage, kokako feeding on epiphytes were invariably below the canopy. By comparison, the birds' increased use of the canopy in summer resulted mainly from their feeding on lawyer fruit, which were present in the crown foliage of tree hardwoods. The increased feeding in vegetation higher than 18 m occurred because ripe fruit of miro and tanekaha were available. Also, the presence of toropapa and mingimingi fruit resulted in the kokako feeding more often in the 0-3 m height class in summer than in spring. In autumn and winter kokako fed mainly below the canopy. In autumn kokako fed largely on the fruit and leaves of *Coprosma grandifolia* and *Pseudopanax* species (shrub hardwoods). Although some tanekaha and totara fruit were taken in autumn (Appendix I), the birds did not feed frequently above the canopy because the trees fed in were canopy specimens rather than emergents. Much of the food eaten in winter comprised the leaves and fruit of epiphytes and shrub hardwoods, in particular lancewood fruit.

Overall, kokako fed mainly below the canopy in the 3-13 m height range, this being where the crowns of shrub hardwoods, much of the foliage of tree hardwoods (canopy-forming species) and epiphytes were situated. Although kokako occasionally fed in the upper branches of emergents, no emergent podocarps fruited heavily enough to encourage the birds to feed frequently above the canopy.

The height-class graphs for use of these three vegetation types at Puketi (Fig. 8) and at Pureora State Forest (Hay, 1981, Figure 3.19) are very similar, even though the Pureora results include the data for all activities and not just feeding. From profiles of the occurrence of foliage in the height classes, Hay (1981) showed that the use of the foliage by kokako was generally consistent with its distribution, i.e. there was no preference evident.

Kokako nearly always sing from prominent perches (Hughes, 1981; Hay, 1981; this study). Kauri was the most preferred song-post species in Puketi because it was usually the tallest species available and occurred mainly on ridge tops. Such a song post gave the bird a panoramic view of much of its territory and often much of those of its neighbours. Prominent song posts are important to kokako as they enable them to hear and countersing with neighbours (Hughes, 1981) which may be several hundred metres distance. For a species with limited flight capabilities and a large territory, song and suitable song posts are important for maintaining the territory.

While the results of this study suggest that kauri is not a major food of kokako, either directly or as a host to invertebrates, lianes or epiphytes eaten by the birds, selective logging of kauri may eliminate a significant proportion of shrub hardwoods as a result of associated logging activities. This vegetation class is a major source of food for kokako in Puketi State Forest throughout the year (Fig. 6).

A matter of concern with regard to the kokako population in Puketi is the recent spread of possums throughout the forest. Leathwick *et al*. (1983) concluded that because the diets of possums and kokako overlap considerably, the decline of kokako in the North Island was caused, in part, by habitat degradation resulting from possum browsing. Since kokako at Puketi obtained much of their food from species also favoured by possums (Leathwick *et al*., 1983), the recent establishment of possums in Puketi could jeopardise the long-term survival of kokako there. As kokako are long-lived (c. 20 years; Hay, 1981), it may be many years before population surveys of kokako can detect adverse changes due to possums unless the breeding success of kokako is also studied.

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Appendix I: *The observed diet of kokako at Puketi State Forest seasonally and in total. Food categories are leaf (L), bud (B), flower (F), nectar (N), fruit (D) and invertebrates (I). *Foods seen to be eated by North Island kokako in three central North Island forests (Leath wick* et aI., *1983). Bracketed figures are totals for species.*

		Percent use				
Species	Category	Spring Nov. 81	Summer Jan. 82	Autumn Apr. 82	Winter Jul. 82	Total
Alseuosmia macrophylla	L		1.20			0.20
	D		3.60			0.59
			(4.80)			(0.79)
Asplenium flaccidum	L*			1.03	0.68	0.59
Beilschmiedia tawa	D*		0.40			0.07
B. tarairi	B	2.50	0.40			0.46
Carpodetus serratus	L*			1.20		0.46
Clematis paniculata	L*	2.08			4.31	1.59
Collospermum spp.	D			3.43	0.45	1.45
Coprosma grandifolia	L*	2.92		5.15	4.76	3.83
	B			1.37		0.53
	F*			0.69		0.26
	D*		6.80	12.36	0.91	6.14
				(19.57)	(5.67)	(10.76)
C. spathulata	D			0.34	1.81	0.66
Cordyline banksii	D			0.17		0.07
Ctenochiton viridis	I*	29.17	4.40			5.35
Cyathodes fasciculata	B	2.50				0.40
	D	0.42	6.80			1.19
		(2.92)				(1.59)
Dacrycarpus dacrydioides	D*			0.86		0.33
Dendrobium cunninghami	L			0.86		0.33
	F		0.40			0.07
						(0.40)
Dysoxylum spectabile	D*			0.69		0.26
Earina autumnalis	L*	1.25		0.34	0.23	0.40
	F			0.34		0.13
				(0.68)		(0.53)
E. mucronata	L*	2.50		0.17		0.46
	B				1.36	0.40
						(0.86)
Elaeocarpus dentatus	L*				0.23	0.07
	D*				0.23	0.07
					(0.46)	(0.14)
Freycinetia baueriana ssp. *banksii*	F	2.50				0.40
	D			0.34	1.59	0.59
						(0.99)
Griselinia lucida	L*	2.08			0.68	0.53
	B	1.25				0.20
		(3.33)				(0.73)
Hedycarya arborea	D*	7.08				1.12

Species	Category	Percent use Spring Nov. 81	Summer Jan. 82	Autumn Apr. 82	Winter Jul. 82	Total
Knightia excelsa	F*	0.83				0.13
	N	1.67				0.26
	Pod*			1.20	2.72	1.25
		(2.50)				(1.64)
Leaf roller	I*			0.17		0.07
Liothula omnivorus	I*			0.17	2.49	0.79
Melicytus macrophyllus	L			1.03		0.40
	D		2.00	2.06		1.12
				(3.09)		(1.52)
M. ramiflorus	L*			0.34		0.13
Mida salicifolia	D		0.80			0.13
Moss spp.	Capsule*	2.08		0.34	1.59	0.92
Myrsine australis	L	0.42		0.34		0.20
	D*	2.92	0.40	2.92	3.63	2.71
		(3.34)		(3.26)		(2.91)
M. salicina	D	0.42		0.17		0.13
Olearia rani	L			4.63	4.08	2.97
Phyllocladus trichomanoides	D		7.60	4.63		3.04
Phymatodes diversifolium	L*				0.68	0.20
Pittosporum cornifolium	D				0.23	0.07
P. tenuifolium	L			0.51	2.04	0.79
	D				0.45	0.13
					(2.49)	(0.92)
Podocarpus ferrugineus	D*		0.40	1.54	1.36	1.06
P. totara	D*			9.44		3.63
Pseudopanax arboreus	L*	2.08	1.20	2.06	2.04	1.92
	D*	3.33	1.20	2.74	1.13	2.11
		(5.41)	(2.40)	(4.80)	(3.17)	(4.03)
P. crassifolius	D*			2.57	28.35	9.25
P. edgerleyi	L*	0.83				0.13
	B	0.42				0.07
	D*		1.60	2.06		1.06
		(1.25)				(1.26)
Ripogonum scandens	L*	0.42		1.20		0.53
	D*		0.40	0.86	1.81	0.92
				(2.06)		(1.45)
Rhopalostylis sapida	L			2.06		0.79
	D			3.60		1.39
				(5.66)		(2.18)
Rubus spp.	D		15.60			2.58
Schefflera digitata	L*			1.54		0.59
	D*				1.81	0.53
						(1.12)
Vitex lucens	N				0.68	0.20
	D*			0.51		0.20
						(0.40)
Total identified		71.67	55.20	78.03	72.33	71.60
Unidentified	L	0.83	1.20			0.33
	I			4.29		1.65
	epiphytes	5.00	4.00	6.52	15.42	8.45
	'diseased' tissue			1.03	0.23	0.46
	unknown	22.50	39.60	10.13	12.02	17.51
Total unidentified		(28.33)	(44.80)	(21.97)	(27.67)	(28.40)
Number of observations		240	250	583	441	1,514