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DIET OF THE STEWART ISLAND BROWN KIWI *(APTERYX AUSTRALIS LAWRYI)* AT SCOLLAY'S FLAT, SOUTHERN STEWART ISLAND

Summary: The diet of the Stewart Island brown kiwi at Scollay's Hat, southern Stewart Island was determined by analysis of 146 faeces collected during 11 field-trips from September 1982 to October 1984. A variety of invertebrates and a small quantity of plant matter were represented in the faeces. The four invertebrate groups excluding Annelida, that contributed most soft tissue dry matter to the sample were Lepidoptera (36%), Coleoptera (21%), Arachnida (19%) and Hemiptera (10%). Circumstantial evidence suggests that the habit of the Stewart Island brown kiwi of foraging by day is partly a response to low invertebrate biomass in the island's nutrient-poor soils.

Keywords: Stewart Island brown kiwi, Apteryx australis lawryi, southern Stewart Island, diet, faecal analysis, soft tissue, diurnal activity.

Introduction

The kiwi's nocturnal and secretive behaviour makes it difficult to watch feeding and virtually impossible to identify food taken. Knowledge of kiwi diet in the wild has depended largely on examination of gizzard contents from accidentally killed birds. This shows that kiwi feed on a wide range of invertebrates and varying amounts of vegetable matter (Gurr, 1952; Bull, 1959; Watt, 1971; Reid, Ordish and Harrison 1982).

Apart from a study of the diet of North Island brown kiwi *(A. a. mantelli)* in Waitangi State Forest, Northland (Colbourne & Kleinpaste, 1984), samples have been too small to detect seasonal changes in the diet. In the present study, food remains were identified from faeces and seasonal changes were recorded. This allows comparisons of the diet at the northern (Waitangi State Forest) and southern (Stewart Island) extremities of the brown kiwi's range. We hoped, too, that the study would suggest why the Stewart Island brown kiwi forages much more often by day than do the two mainland subspecies.

Study Area

Scollay's Flat is at the south-eastern end of the Tin Range (47°09 'S, 167°45 'E), 100 to 300 m a.s.l. The rolling country, dissected by streams, is covered in a mosiac of vegetation types. The forest structure and composition reflect the aspect, soil depth, water table and whether mining occurred there (Wilson, 1982). Low-lying, poorly-drained flats are dominated by wire rush *(Empodisma minus)* and tangle fern *(Gleichenia dicarpa)*. On sheltered sites podocarp-hardwood forest is dominated by rimu *(Dacrydium cupressinum),* yellow-silver pine *(Lepidothamnus intermedius),* southern rata *(Metrosideros umbellata)* and kamahi *(Weinmannia racemosa)*. Surrounding the forest is scrub dominated by manuka *(Leptospermum scoparium),* which is often testimony to the activities of tin and gold miners from 1880 to 1940. A detailed description and map of Scollay's Hat area are given in Best (1984). Scollay's Flat has a kiwi population of about 1 pair per 20-40 ha, as determined from calls and sightings.

Methods

The foods of the kiwi were determined by faecal analysis, though we are aware that some potential foods, such as fungi and slugs, without indigestable components, could go undetected.

Kiwi faeces were collected from tracks from September 1982 to October 1984 inclusive during 11 New Zealand Wildlife Service field-trips. No wekas *(Gallirallus australis)* inhabit southern Stewart Island, so there was no difficulty in recognising kiwi faeces. Faeces were stored individually in 75% alcohol. In the laboratory the samples were washed with detergent in hot water to dissolve mucus, they were then sieved twice, initially through a 250 μ gauze to collect the large invertebrates and vegetable remains, and then through a 180 μ gauze to collect annelid chaetae.

Fragments of food items were sorted and counted under a binocular microscope (x10). All invertebrates were identified to family level, but some were taken to specific level by comparing fragments with whole identfied specimens collected from Scollay's Flat. The number of specimens of each taxon in a dropping were determined by counting the most conspicuous

Table 1: *Mean monthly number of annelid chaetae and of 14 categories of invertebrates per dropping of Stewart Island brown kiwi; and the number of invertebrates (excluding annelids) per mean dropping. *Total Dry Weight (g) of 10 animals. **Dry weight (g) of soft tissue* in *10 animals.*

	1982		1983				1984							
	Sep	Dee	Jan	Feb	Mar	Jun	Dec	Mar	Apr	Jun	Oct	Total	DW*	DW"
Number of faeces	10	10	5	8	8	17	25	15	11	30	7	146		
Annelida: chaetae	10	40	38	135	242	98	104	193	98	183	175	120		
Arthropoda														
Crustacea: amphipod	-	-	0.2	-	0.1	0.1	-	-	-	-	-	0.03	0.1	0.1
Chilopoda: centipede	0.1	0.1	-	-	0.1	0.5	0.2	0.3	0.6	0.5	0.3	0.31	0.2	0.2
Arachnida: spider	0.5	0.8	1.2	0.5	1.9	2.2	1.9	0.7	0.9	1.0	0.7	1.21	0.4	0.4
Insecta														
Orthoptera : weta	0.1	0.3	0.2	-	1.1	0.5	0.8	0.3	0.2	0.3	0.1	0.40	0.6	0.5
Hemiptera: cicada	0.4	0.7	0.2	0.1	-	0.6	0.1	0.1	0.1	0.2	2.0	0.33	1.0	0.8
Lepidoptera: caterpillar	0.2	0.2	0.2	0.1	-	0.1	0.1	3.3	11.6	1.0	1.0	1.53	0.7	0.6
Diptera														
Tipulidae	0.1	-	0.4	-	-	0.1	0.1	1.0	-	0.1	-	0.18	0.3	0.3
Coleoptera														
Carabidae - adult	0.7	1.1	1.0	0.8	1.6	0.9	0.9	0.8	0.7	0.7	1.0	0.88	0.4	0.3
- larva	-	-	-	-	-	0.1	0.1	0.1	-	0.1	-	0.03	0.4	0.4
Elateridae	0.3	0.1	0.6	0.1	0.3	0.2	0.3	0.3	0.3	0.1	0.4	0.24	0.4	0.3
Scarabaeidae - adult	0.1	0.8	0.2	-	-	0.1	0.3	-	0.1	0.1	0.1	0.16	0.5	0.3
- larva	-	0.1	-	0.1	-	0.2	0.1	-	-	0.4	0.9	0.19	0.7	0.7
Staphylinidae	-	-	-	-	-	0.1	0.1	-	-	-	0.1	0.04	0.3	0.2
Indeterminate	0.1	0.1	0.2	-	-	-	0.1	-	-	-	-	0.3		
Number of invertebrates (excluding annelids) per mean dropping:	2.6	4.3	4.4	1.7	5.1	5.7	5.1	6.9	14.5	4.5	6.6	5.56		

Table 2: *Percentage occurrence of 15 categories of invertebrates and vegetable matter* in *each monthly sample of faeces of Stewart Island brown kiwi.*

	1982		1983				1984					
	Sep	Dec	Jan	Feb	Mar	Jun	Dec	Mar	Apr	Jun	Oct	Total
Number of faeces	10	10	5	8	8	17	25	15	11	30	7	146
Annelida : chaetae	60	80	60	75	100	65	84	80	100	90	57	80
Arthropoda												
Crustacea : amphipod	-	-	20	-	13	12	-	-	-	-	-	3
Chilopoda : centipede	10	10	-	-	13	53	24	33	46	47	29	28
Arachnida : spider	40	70	100	38	88	94	72	60	73	77	43	71
Insecta												
Orthoptera : weta	10	30	20	-	63	53	48	27	18	20	14	30
Hemiptera : cicada	30	30	20	13	-	41	12	6	9	16	57	20
Lepidoptera : caterpillar	20	20	20	13	-	-	4	80	73	37	43	28
Diptera												
Tipulidae	10	-	20	-	-	6	12	27	-	10	-	9
Coleoptera												
Carabidae - adult	70	80	60	63	88	65	80	73	73	63	86	72
- larva	-	-	-	-	-	12	8	6	-	10	-	4
Elateridae	30	10	80	13	25	24	20	27	27	10	29	22
Scarabaeidae - adult	10	50	20	-	-	6	20	-	-	10	14	12
- larva	-	10	-	13	-	24	8	-	9	13	29	10
Staphylinidae	-	-	-	-	-	12	12	-	-	-	14	3
Indeterminate	30	30	-	-	13	-	4	-	-	3	-	6
Vegetable matter	70	80	100	63	63	53	28	27	64	43	43	47

remains (e.g. foretibias of cicada nymphs, head parts of adult beetles and chelicerae of spiders). Left and right mandibles of beetle larvae were counted separately; if the counts differed, the larger was accepted as the number of specimens in the dropping. Earthworm chaetae were also counted.

In order to allow for variations in prey size and food value, mean dry-weight values of each prey category were determined. Samples of each prey species (1-10 individuals), representative of the prey sizes found in the faeces, were dried to a constant weight in an oven at 60ºC, then placed in concentrated hydrochloric acid for about 12 hours until only the chiton remained. The dry weight of the chiton was subtracted from the total dry weight to provide a measure of the dry weight of soft tissue likely to be available to a kiwi.

On each trip the date and time were recorded when a kiwi was seen or heard calling by day, to note the extent of daytime activity. A juvenile kiwi, fitted with a leg-mounted radio transmitter, was monitored for five days in June 1985 to record its nocturnal and diurnal movements. With the transmitter attached to the leg the signal intensity varied when the bird moved so that it was possible to determine whether the bird was resting or active. Checks were made randomly, three times a day (15 checks) and at half hourly intervals at night (96 checks).

Results

A total of 146 kiwi faeces were examined, and 15 invertebrate groups were recognised as prey (Tables 1 & 2, Figure 1).

Discussion

Diet

The number of annelid chaetae per dropping peaked in March of 1983 and 1984, indicating either an increase in earthworm consumption of a change in the species eaten. Lee (1947) described seven species of earthworms on Stewart Island. While the large clay worms *Octochaetus multiporus* and *O. huttonii,* with 1600 and 1864 chaetae per mature worm respectively, occur in the study area, the size of the chaetae in the faeces suggested that the medium-sized earthworm *Plutellus stewartensis,* with 1300 chaetae per mature worm, was the main species eaten throughout the year. Chaetae from the other four species of earthworms (small sized) were not present in the faeces. In comparison with the number of chaetae per mature earthworm, very few chaetae were found in each dropping; about one-tenth of those from one *P. stewartensis*. Similarly, Colbourne & Kleinpaste (1984) found that faeces in the recta of four North Island brown kiwi contained about one-eigth of the chaetae that were present in their gizzards. The chaetae give an unreliable indication of the number of earthworms eaten because the number of chaetae per earthworm differs between species and between different sized (aged) earthworms of the same species (Wroot, 1985). Too few earthworms were collected, so the species present at Scollay's Flat and the relationship of dry weight to mean chaetae length (Wroot, 1985) were not determined. For these reasons we could not determine the proportion of soft tissue in the kiwi's diet contributed by annelids. The percentage occurrence of annelids in the faeces of Stewart Island brown kiwi was greater than 70% for most of the monthly samples, and averaged 80% overall. Reid *et al*. (1982) found annelids in 94% of 50 gizzards of North Island brown kiwi and Colbourne, Baird and Jolly (unpublished data) recorded them in 75% of 61 faeces of little spotted kiwi *(Apteryx owenii)* from Kapiti Island.

Mamaea grandiosa was the most commonly identified spider in the faeces. It is a small vagrant species found in litter and under logs. Some *Centauria* spp., a trapdoor spider, were also eaten. Spiders were present in 71% of faeces. Although the dry weight of soft tissue avaiable from a spider was small, collectively they contributed about 19% of the non--annelid soft tissue in the sample and were the third most important invertebrate group (Figure 1). Spiders formed only 3% of the total dry matter intake of North Island brown kiwi at Waitangi State Forest (Colbourne & KIeinpaste, 1984). They were recorded in 66% of 61 little spotted kiwi faeces from Kapiti Island (Colbourne, Baird & Jolly, unpublished data), but in only 30% of 50 North Island brown kiwi gizzards (Reid *et al.,* 1982).

The small cicada *Kikahia rosea* was the only. hemipteran in the faeces and all were nymphal remains. Nymphs were eaten in most months but most frequently in December 1982 and October 1984. At this time of the year they move closer to the soil surface before emerging as adults and so become more accessible to kiwi. A cicada nymph contained the most soft tissue dry matter of the invertebrate categories. Although eaten in small numbers (0.3/per dropping), cicada nymphs contributed about 10% of the non-annelid soft tissue dry matter in the diet. By comparison, nymphs of *Amphisalta zelandica* contributed 41.7% of the total dry matter in the

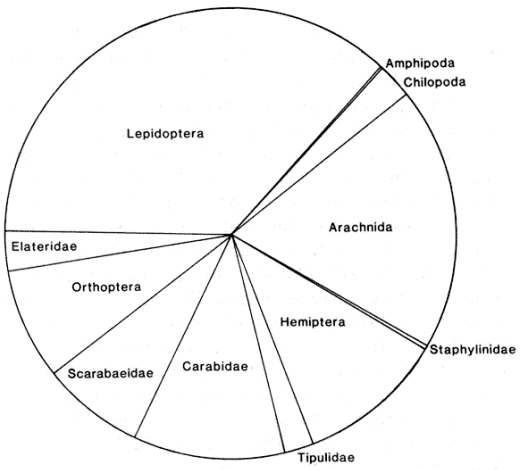

Figure 1: *Percentage dry weight of soft tissue of each invertebrate category, except annelids, represented by the prey remains in the* 146 *Stewart Island brown kiwi faeces.*

North Island brown kiwi's diet at Waitangi State Forest (Colbourne & Kleinpaste, 1984).

Lepidoptera were found in 28% of faeces, sometimes in large numbers. Up to 80 porina caterpillars were represented in single droppings in March and April 1984, although none were recovered from samples collected in March 1983. Porina moths caught in April 1984 were identified as a species of '*Protoxycanus*'. Porina caterpillars live in underground tunnels in the day and emerge at night to feed on surface vegetation. Only the largest instars were eaten. Overall, Lepidoptera formed about 36% of the non-annelid soft tissue dry matter in the sample (Figure 1), but because of the marked difference in consumption between years, this figure may not accurately reflect the average intake. For the North Island brown kiwi, caterpillars are a minor component of the diet, both in terms of the percentage occurrence (Reid *et al.,* 1982) and of the dry weight of food consumed (Colbourne & Kleinpaste, 1984).

Adult ground beetles (Carabidae) were eaten in moderate numbers (about one per dropping) in all months, but their larvae were seldom taken. On the basis of percentage occurrence carabids were the second most frequently eaten invertebrate group. The majority of adults were a small (length c. 12 mm) species of *Mecodema*. Each beetle provided little soft tissue dry matter, but collectively they contributed about 11% of the non-annelid intake. Species of Carabidae occur regularly in gizzards and faeces of North Island brown kiwi (Gurr, 1952; Watt, 1971; Reid *et al.,* 1982) but contribute a minor proportion of the dry matter eaten (Colbourne & Kleinpaste, 1984).

Stewart Island brown kiwi occasionally ate a few chafer beetles and their larvae (mainly *Odontria* spp.). Together they contributed about 7% of the non-annelid soft tissue in the sample. Scarabaeids seem to be more important in the diet of the North Island brown kiwi both numerically (Watt, 1971; Reid *et al.,* 1982) and by dry weight (Colbourne & Kleinpaste, 1984). Scarabaeid larvae represented 20% of the total dry matter eaten by brown kiwi in Waitangi State Forest, making these larvae the second largest component of their diet.

Some invertebrate groups contributed little to the diet. Amphipods were present in large numbers in the study area but were seldom eaten by kiwi. The quick and erratic movements of disturbed amphipods probably makes them difficult prey for kiwi to capture with their long, thin bills. Rove beetles (Staphylinidae) were also rarely eaten whereas a few were found in gizzards of North Island brown kiwi (Watt, 1971; Reid *et al.,* 1982). The ground weta, *Zealandosandrus* sp., was the only orthopteran found in the faeces and small numbers were eaten throughout the year. Other genera of wetas are frequently eaten by brown kiwi (Buller, 1888; Reid *et al.,* 1982; Colbourne & Kleinpaste, 1984). Crane fly (Tipulidae) larvae were found irregularly in low numbers in faeces. Centipedes (Chilopoda) and wireworms (Elaterid larvae) occurred regularly in the diet, but were eaten in low numbers. Wireworms contributed about 3% of the non-annelid soft tissue in the sample. Similarly, about 3% of the North Island brown kiwi's total dry matter intake was elaterid larvae (Colbourne & Kleinpaste, 1984).

Half of the faeces contained small quantities (1-5% by wet volume) of vegetable matter, which was mainly the leaves of *Gleichenia dicarpa, Leptospermum scoparium, Halocarpus biforme,* a *Coprosma sp.,* the liverwort *Bazzania* sp. and unidentified mosses. All of these plants are widespread at Scollay's Flat. Their small leaves were probably ingested accidentally. A few seeds of *Dacrydium cupressinum* and *Pentachondria pumila* were found in 10 faeces, suggesting that fruit were deliberately eaten. Buller (1888) and Reid *et al.* (1982) thought that some plant matter (minute bark and twig fragments, and solitary, small fibrous leaves) was incidentally eaten, but that

berries and fruits were selected for their nutritive content and/or their action as grinding aids in the gizzard. Vegetable matter has been frequently found in North Island brown kiwi and their faeces. Reid *et al*. (1982) found that 93% of 50 gizzards contained vegetable matter, and Colbourne & Kleinpaste (1984) calculated that it constituted about 5% of the dry matter in the diet of brown kiwi in Waitangi State Forest.

Dry weight of soft tissue ingested

The dry weight of digestible soft tissue represented by the 5.6 non-annelid invertebrates per mean dropping is 0.25 g. Assuming a defecation rate of once every 30 minutes at night (from captive North Island brown kiwi feeding trials; R. Colbourne, unpublished data), the resultant 24 faeces per 24-hour period represents an intake of 6 g dry weight (c. 60 g wet weight) of digestible soft tissue. This amount of food seems low to sustain a 2-3 kg kiwi. The proportion of earthworms in the diet needs investigating. Errors in these findings may result from the following. (I) Invertebrates in the faeces may be underestimated owing to the complete digestion of cuticle. This is unlikely as mandibles and chaetae were almost always completely undigested. (2) Invertebrates, such as slugs, that leave no evidence in the faeces, may be important in the diet. (3) The defecation rate of wild birds at night may be much greater than assumed.

Diurnal foraging

A distinctive feature was that Stewart Island brown kiwi foraged and called during the day, throughout the year, sometimes in open habitats on clear, sunny days. We have 20 observations of kiwi seen in daytime at Scollay's Flat during the study. Although kiwi called by day, daytime calling rates were much lower than night-time rates. A juvenile male kiwi fitted with a radio transmitter for a week in June 1985 ranged over 50 ha and was active during each of the diurnal checks. It rested for about two hours one night. Before removing the transmitter the bird was observed as it moved about actively foraging at midday under low scrub. Occasionally, it ventured out into open marshy areas to feed. The observations obtained to date indicate that diurnal foraging could be a common habit of the subspecies.

Reid *et al*. (1982) suggested that Stewart Island brown kiwi feed by day because they are larger than the North Island subspecies and live in mean ambient temperature 3-6°C colder than in the North Island. This would increase their maintenance energy requirements, and perhaps compel them to feed by day.

We suggest that there is a lower biomass of invertebrates in the litter and soil of Stewart Island than in the North Island. The soil of the study area is peaty (Leamy, 1974) with a pH of 3.6 to 4.9. The soil surface at Scollay's Flat rarely dries because of the high annual rainfall evely spread throughout the year. Peat soils are typically nutrient-poor and anaerobic (Hamilton & Hodder, 1979), and contain few invertebrates (A. Moeed pers. comm.).

If the number of invertebrates per dropping reflects the rate at which the kiwi eats them, then the mean number of items per dropping from Scollay's Flat might be lower than in kiwi faeces from habitats with more productive soils. The number of non-annelid invertebrates in a mean monthly kiwi dropping from Scollay's Flat was usually four to seven. This is much fewer than the 11-27 non-annelid invertebrates per mean monthly dropping from Waitangi State Forest (Colbourne & Kleinpaste, 1984). Similarly, preliminary results show that 5-30 invertebrates were represented per mean monthly dropping of little spotted kiwi on Kapiti Island (Colbourne, Baird & Jolly, unpublished data). Thus, there may be relatively few invertebrates in the soils of Stewart Island and this may compel Stewart Island brown kiwi to forage by day, as well as by night.

Acknowledgements

We thank Andrew Grant, Jim Jolly, Brian Lloyd, Kevin Moynihan and Kaye Stark for collecting faeces and noting kiwi behaviour; J. Dugdale, R.R. Forster, J. Johns and R. Kleinpaste for identifying invertebrates; B. Dayly of the Soil Bureau, DSIR for determining the pH of the soil samples; and Malcolm Crawley, Jim Jolly, John McLennan, Jim Mills and Brian Reid for comments on drafts of this paper.

References

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

Bull, P .C. 1959. Stomach contents of a North Island kiwi *(Apteryx australis mantelli)* from the Raetihi district. *Notornis* 8: 143-5.

Buller, W.L. 1888. *A history of birds of New Zealand*. 2nd Edn., Vol. 2, London: 359 pp.

Colbourne, R.; Kleinpaste, R. 1984. A study of kiwis in an exotic forest. Unpublished report in the New Zealand Forest Service library, Auckland.

Gurr, L. 1952. Some food of the North Island kiwi *(Apteryx australis)*. *Notornis 4*: 209-10.
Hamilton, L.S.; Hodder, A.P.W. 1979. Proceedings of a symposium on New Zealand Peatlands, Hamilton, 23-24 November, 1978. Hamilton, University of Waikato.
Leamy, M.L. 1974. Soils of Stewart Island (Rakiura), New Zealand. New Zealand Soil Survey Report 22. Wellington, DSIR.
Lee, K.E. 1947. The earthworm fauna of New Zealand. New Zealand Department of Scientific and Industrial Research Bulletin 130.
New Zealand Meteorological Service 1982. Summaries of climatological observations to 1980. New Zealand Meteorological Service Miscellaneous Publication 177.
Reid, B.; Ordish, R.G.; Harrison, M. 1982. An analysis of the gizzard contents of 50 North Island brown kiwis, *Apteryx australis mantelli,* and notes on feeding observations. *New Zealand Journal of Ecology 5:* 76-85.
Watt, J.C. 1971. The North Island kiwi: a predator of pasture insects. *New Zealand Entomologist 5*: 25-7.
Wilson, H.D. 1982. *Field guide to Stewart Island plants*. Christchurch, Field Guide Publications.
Wroot, A.J. 1985. A quantitative method for estimating the amount of earthworm *(Lumbricus terrestris)* in animal diets. *Oikos 44*: 239-42.