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SHORT COMMUNICATION

ENERGETICS OF SOUTH ISLAND KAKA *(NESTOR MERIDIONALIS MERIDIONALIS)* FEEDING ON THE LARVAE OF KANUKA LONGHORN BEETLES *(OCHROCYDUS HUTTONI)*

Summary: Kaka *(Nestor meridionalis meridionalis)* studied in Big Bush State Forest spent 35% of their feeding time digging out *Ochrocydus huttoni* larvae from live mountain beech trunks *(Nothofagus solandri* var. *cliffortioides)*.

Larvae of *O. huttoni* had a high energy value compared to that of other insects. The assimilation efficiency for energy of two captive kaka was 91 j: 3% when fed a diet of O. *hut/oni*.

Using the energy intake of the aviary birds during the feeding trials, the requirement for existence metabolism at 8.5°C for 593 g kaka was about 490 kJ per day. This was consistent with estimates made using Kendeigh's allometric equations for existence metabolism.

Unless the cost of digging for *O. huttoni* was less than half that of flying, there would be a net loss of energy for a kaka feeding on the larvae. Kaka would need to balance their energy budget by eating other foods, the abundance of which may be currently threatened.

Keywords: Kaka; Nestor meridionalis meridionalis; kanuka longhorn beetle; Ochrocydus huttoni; honeydew; energetics; assimilation efficiency; existence metabolism; conservation.

Introduction

Early in an autecological study of kaka *(Nestor meridionalis meridionalis)* in Big Bush State Forest, we found that kaka spent 35% of their feeding time digging in trunks of mountain beech *(Nothofagus solandri* var. *cliffortioides)* for the larvae of kanuka longhorn beetles *(Ochrocydus huttoni),* and an unknown amount of time searching for the larvae. The large huhu-like larva is described by Hosking (1978). The majority (72%) of *O. huttoni* excavated by kaka were at their most vulnerable stage, packed into the pupal chambers and unable to escape into lower portions of their tunnels. They were also more easily located at this stage by the plugged exit hole on the surface of the tree. *O. huttoni* was one of the few invertebrate prey for which we could quantify the time a kaka spent gaining a known amount of energy. Kaka excavated live wood to obtain *O. huttoni* larvae, an activity for which we had to use hammer and chisel, and make a distinctive scar on the trunk. They spent up to two hours of vigorous activity while clinging to the vertical trunk of a tree to extract one larva, so we hypothesised that more energy was expended obtaining one larva than was gained from it, and that kaka would have to balance their energy budget by gaining energy from other foods. This has significant implications for their conservation.

In this study, therefore, we calculate the energy yield of an *O. huttoni* larva, record the time taken to dig one out, and estimate the possible cost of obtaining it. The theoretical energy requirements of kaka are calculated from allometric equations in the literature, and compared to our estimates of existence metabolism.

Methods

The study area is the catchment of Duckpond Stream (41 °47'S, 172°51 'E) in Big Bush State Forest. This is an area of mixed red *(Nothofagus fusca)*/*silver (N. menziesii)*/mountain beech forest with large areas of pole-stand mountain beech on the upper slopes and tops of a dome of predominantly glacial debris. This southern end of Big Bush rises from 610 m a.s.l. at lake level to a little over 1000 m a.s.l.

Twenty-seven kaka captured by mist-netting in Nelson Lakes National Park and Big Bush State Forest were weighed and the upper mandible measured. Kaka with upper mandibles 50.0 mm or longer were regarded as male, and those with upper mandibles less than 50.0 mm as female.

When a kaka was observed beginning to excavate an *O. huttoni* larva the time spent digging was recorded, and all excavated wood was collected. We searched for other recent excavations and similarly collected all excavated wood, which we dried to constant weight. We could thus calculate the mean time taken for a kaka to dig out one gram of wood, and the mean time taken to dig out an *O. huttoni* larva.

Only two South Island kaka (1 male, 1 female) were available for feeding trials. These aviary-reared kaka were weighed and put into individual holding cages of 1 m cube in a shed with natural lighting. Temperature was measured using a maximum/minimum therometer. Excreta were collected daily from beneath the cages. The birds were re-weighed at the end of the experiments. The kaka were fed according to the following schedule:

1. 24 hours of dilute honeywater to ensure that all solid food was voided.
2. 25 hours of an aviary diet of apple, celery, carrot, orange, corn, sunflower seed and lettuce.
3. 22 hours of dilute honeywater.
4. 34 hours of *O. huttoni* larvae.
5. 8 hours of dilute honeywater.

A sample of the aviary diet was left under the same aviary conditions as a control for the rate of dessication, so that wet weight of food eaten by the kaka could be calculated by subtracting weight of uneaten food from original weight of food.

All material to be analysed was dried at 70°C to constant weight, and its energy content determined using a Gallenkamp ballistic bomb calorimeter with benzoic acid as a standard. The total energy intake and energy excreted for each diet were measured for the male and female separately, and assimilation efficiencies calculated.

The aviary kaka were not undergoing reproduction, moult, migratory unrest, growth or fat deposition, so an estimate of their existence metabolism could be made (Kendeigh, Dol'nik and Gavrilov, 1977). The total assimilated energy intake was calculated for the duration of the feeding trials.

Results

The mean weight ± s.e. of male kaka (n = 16) was 589± 7 g, and the mean weight of female kaka (n = 11) was 514± 10 g. These weights were significantly different (t = 6.29, P <0.05).

When excavating for O. *huttoni,* kaka took 2.82:t 0.23 minutes to remove one gram of dry wood. The mean dry weight of wood removed to obtain one larva was 23.30:i: 2.65 g. Assuming that a kaka's excavation rate is constant, they took an average of 81:t 8 minutes to dig out a chambered larva, i.e. a larva packed into its pupal chamber with the future emergence hole cut.

In the feeding trials, the kaka ate only the apple, corn and sunflower seeds from the aviary food offered. Table I details the weights and energy values of the foods eaten. The male's intake (622 kJ) and output (131 kJ) were about three times greater than the female's, compensated for by the female's greater weight loss. The assimilation efficiencies were, however, similar; 78.91070 and 78.47% respectively for the male and female (Table I).

During the 34 hours of the O. *huttoni* feeding trial the male ate 19 beetle larvae, and the female 12. The female extracted the larvae from the skin, so skin remains were allowed for in calculations of wet weight and energy value. The O. *huttoni* larvae had a mean energy value of 33.93:t 0.34 kJ/g dry weight and a mean moisture content of 53.07:t 1.03%. There was no significant differences between the energy value per gram of chambered and unchambered beetle larvae (t=0.94, p>0.05).

The assimilation efficiency of kaka when fed a diet of O. *huttoni* was 91 % (Table 2). The mean weight of an O. *huttoni* larva at the stage when most are taken by kaka was 1.77:t 0.32 g. The energy assimilated from one beetle larva was therefore on average 54.40 kJ.

The intake and excretion of energy was measured over 59 hours (25 hours aviary diet + 34 hours O. *huttoni* diet) with an average air temperature of 8.5°C (min. 4.0°C, max. 13.0°C). Both kaka lost weight

Table 1: *Calculation of energy obtained from different food items in aviary diet, and of energy excreted on aviary diet ±.standard error. Sample size in brackets.*

	Item	Wet weight (g)	Dry weight (g)	Energy value (kJ/g)	Total energy (kJ)	Assimilation efficiency (%)
MALE						
Input	Apple	28.21	4.80	16.91± 0.12 (5)	81.19±. 0.58	
	Sunflower seed	18.18	15.81	33.54± 0.72 (3)	530.40± 11.38	
	Corn	0.75	0.55	19.47±1.48 (7)	10.80±. 0.81	
Output	Excreta	-	7.55	17.39± 0.26 (8)	131.26± 1.96	78.91 ± 3.10
FEMALE						
Input	Apple	42.54	7.24	16.91 ± 0.12 (5)	122.41± 0.87	
	Sunflower seed	2.27	1.97	33.54±. 0.72 (3)	66.2±. 1.42	
	Corn	2.20	1.63	19.47±1.48 (7)	31. 75± 2.41	
Output	Excreta	-	3.27	14.52± 0.62 (7)	47.4± 2.03	78.47± 2.06

Table 2: *Calculation of energy intake, energy excreted, and assimilation efficiency (A.E.) of kaka when fed a diet of* O. huttoni *larvae (±standard error). A.E. =100x(Energy uptake - energy excreted)/energy uptake.*

	Male	Female
Wet weight larvae consumed (g)	48.04	22.99
Mean moisture content per larva(OJo)	53.07 ± 1.03	53.07:t 1.03
Energy value of larva (kJ/g dry wt)	33.93 ± 0.34	34.93:t 0.34
Total energy intake (kJ)	764.96 ± 16.79	376.88 ± 7.97
Dry weight excreta (g)	4.30	2.45
Energy value of excreta (kJ/g)	15.73 ± 0.27	15.10 ±0.20
Energy excreted (kJ)	67.63 ± 0.58	37.04 ± 0.49
Assimilation efficiency (%)	91.16 ± 3.22	90.17 ±3.02

while in the holding cages. Using the value 19.5 kJ per gram of fat (Kendeigh *et al.,* 1977), the male obtained 204 kJ and the female 509 kJ from weight loss over 59 hours, assuming the rate of weight loss was constant and that only fat was metabolised for energy. Assuming an assimilation efficiency of 100% for honeywater, then an estimate of the energy required for existence metabolism can be made (Table 3). For a 593 g kaka (the average weight of the two birds) this is estimated here at 490 kJ/day.

Table 3: *Calculation of daily energy intake using the assimilated energy intake from the feeding trials, and the energy gained from weight loss (±standard error).*

	Male	Female
Assimilated energy from aviary diet (kJ)	491.12 ± 11.59	172.93 ± 3.56
Assimilated energy from beetle larvae (kJ)	697.33 ± 16.83	339.83 ± 7.98
Energy from weight loss (kJ)	204	509
Total energy intake in 59 hours (kJ)	1392.45 ± 20.43	1021.76 ± 8.74
Energy intake per 24 h day (kJ)	566.42 ± 8.31	415.63 ± 3.55

Discussion

The usual requirements for measuring existence metabolism were met, except that the kaka did not maintain constant weight (± 1-2%) during the experiment. The male lost 4% of body weight, and the female 8%. Nevertheless our estimate of existence metabolism (490 kJ/day) at 8.5°C is consistent with the energy requirements predicted by allometric equations for 0°C, 10± hour photo-period (528± 5 kJ/day) and 30°C, 15 + hour photo-period (310± 6 kJ/day) (Kendeigh *et al.,* 1977).

The mean energy value of *O. huttoni* larvae was almost certainly underestimated, since the larvae to be analysed were air dried at 70°C and some volatile oils may have been driven off. Nevertheless, *O. huttoni* larvae have a high energy value (34 kJ/g), compared to the 22.45± 0.20 kJ/g that Golley (1961) gives for Insecta. Richman and Slobodkin (1960) suggested that the energy value of an animal at a storage stage may increase to 25 or 30 kJ/g dry weight - slightly less than we measured for *O. huttoni* larvae.

The mean assimilation efficiency found here for a kaka feeding on *O. huttoni* larvae (91%) was higher than the 70-75% usually quoted for insect diets (Ford and Paton, 1976; Catterall, 1985), and higher than when kaka were fed the aviary diet.

In terms of the costs of feeding, we have no direct measure of the energy required to excavate live wood. In the absence of this measure we have estimated energy requirements in various situations (Fig. 1). The energetic costs for sustained horizontal flight of more than one or two minutes is independent of ambient temperature (Kendeigh *et al.,* 1977), so a male kaka (589 g) would require 113 kJ/h, and a female kaka (514 g) 103 kJ/h. This is about 9 times the energy required for existence metabolism at 30°C compared to a higher estimate of 12 times, suggested by King (1974). We assume the energetic cost of digging for *O. huttoni* larvae is also independent of ambient temperature, as the muscles generate excess heat while working.

Figure 1 illustrates the relative energy gain or loss of a male or female kaka depending on the length of time taken to excavate larvae judged against the energetic cost of the feeding activity. It shows that if the energetic cost of digging out a larva was half or more that of flying, then there would be a net loss of energy. This conclusion is conservative since neither searching time nor unsuccessful excavations, which we observed, are taken into account. If there is such an energy loss, or only a small gain, then presumably it is compensated for by a gain in other nutrients (proteins or lipids) and/or minerals. The same may apply to other insect larvae which require excavation. This means that kaka would need to balance their energy budget with more energetically economic food (e.g. nectar, seed, fruit or honeydew). This need, and the requirements for the larvae, have important implications for conservation.

O'Donnell and Dilks (1986) found that in South Westland forests the flowers and sap of southern rata

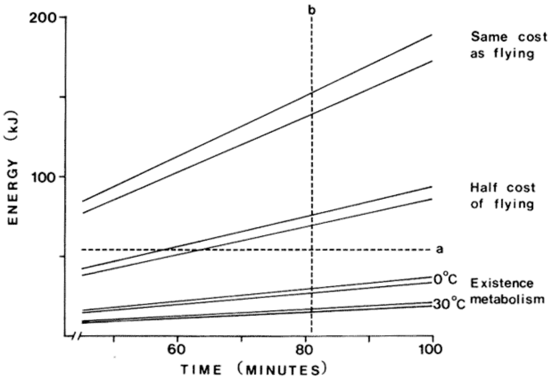

Figure 1: *The energetic cost to a kaka of excavating one* O. huttoni *larva, assuming different costs for the activity. In all cases the top line of each pair of lines* is *for a 589 g male, and the bottom line for a 514 g female. The mean energy value per chambered larva (a), and the mean time to excavate a chambered larva (b) are shown. Slopes for cost of flying, existence metabolism at O∞C, and existence metabolism at 30∞C were calculated using rates of 113kJ/h, 103 kJ/h;* 22 *kJ/h, 20 kJ/h; 13 kJ/h and 12 kJ/h respectively, each pair of figures referring to males and females.*

(Metrosideros umbellata) were important food sources for kaka, and that 60% of observations of kaka feeding in December and January were on flowering mistletoe *(Peraxilla* sp.).

Rata is absent in our study area, and mistletoes are rare in all forests where possums *(Trichosurus vulpecula)* are well established (Wilson, 1984; Ogle and Wilson, 1985). Honeydew excreted by the scale insect *Ultracoelostoma assimile* is clearly an important source of energy to kaka in the study area and its role in the energy budget of kaka is being investigated (Beggs and Wilson, unpubl.). In Nelson beech forests, kaka are now denied the use of mistletoes in summer when the quantity and quality of the honeydew resource is also severely reduced by large numbers of introduced wasps *(Vespula vulgaris* and *V. germanica)* (pers. obs,; H. Moller, pers. comm.).

The number of O. *huttoni* infesting mountain beech may be increased by the close proximity of stands of manuka *(Leptospermum scoparium)* and kanuka *(Kunzea ericoides)* (Hosking, 1978; Wardle, 1984). The catchment of Duckpond Stream was adjacent to extensive areas of mature kanuka, and this may account for the large number of mountain beech infested with *O. huttoni*. The recent conversion to exotic plantations of the majority of the kanuka stands from the southwestern end of Big Bush, may in future reduce the number of *O. huttoni* in the mountain beech, and thus affect the efficiency with which kaka locate the exit holes of larvae.

It appears, therefore, that both the insect and high-energy foods of kaka may be threatened, by management and biotic factors respectively.

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