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HUNTING AND THE ENERGY BUDGET OF THE BLACK-SHOULDERED KITE

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The Black-shouldered Kite (*Elanus caeruleus*) is a small, diurnal raptor occurring widely in Africa and the Orient (Brown and Amadon 1968). The species is common in parts of its range; McLachlan and Liversidge (1970) considered it to be one of the two most common hawks in southern Africa. It resembles closely its congeners the White-tailed Kite (*E. leucurus*) in North and South America, and Australian Black-shouldered Kite (*E. notatus*) and Letter-winged Kite (*E. scriptus*) in Australia. All four species share the habit of hovering when searching for prey.

This paper deals with the hunting behavior and the time and energy budget of the Black-shouldered Kite. Field observations were made from May 1975 through September 1976 near Nylsvley Nature Reserve (24°29′S, 28°42′E), South Africa, where the species is a common breeding resident.

METHODS

Observations were made from a vehicle along roads traversing a study area of 70 km². In the area, 31 kites were color-marked, and most observations were made on recognizable individuals using a 40× telescope and 7 × 35 binoculars.

Daytime activities of kites were recorded using "focal animal sampling" and a modified form of "instantaneous sampling" (Altmann 1974). In the first of these, activities of "focal" birds were monitored continuously for up to 12 h (total of 133.6 h), and the time that they engaged in different activities was recorded. These activities were categorized as: (1) perched birds were either inactive, preening, eating, "casually searching," "intently searching" or other; and (2) flying birds were either soaring, hovering, directionally flying or other. Birds hunted for prey by searching the ground from perches or by hovering. A bird that was searching intently watched the ground keenly and made frequent perch changes and dives at prey. A hovering bird maintained a constant aerial position from which it scanned the ground for prey, then paused and glided to a new position from which it repeated the rapid flapping. "Casual searching" was a catch-all category in which a perched bird alternated frequently between inactivity, preening and searching intently. Nest-associated activity has been excluded from the sample, and no breeding females were used as focal birds.

Instantaneous sampling supplemented the activity measure. The activity of every kite at first sighting was recorded (N = 849), using four classes—perched, directional flying, hovering and soaring. This method underestimated the contribution of hovering and soaring to total activity, and overestimated that of directional flying.

The species' food was determined by analyzing 261 pellets collected in the study area and from 81 sightings of birds carrying prey. Fragments of animal skulls in pellets were identified with the aid of a reference collection of known specimens and a key by Coetzee (1972).

RESULTS AND DISCUSSION

DAILY ACTIVITY

All non-breeding kites in the study area roosted communally at night. During daytime the birds dispersed in individual hunting territories. Some of these territories were occupied continuously throughout the study period by the same individuals, while others were occupied by a succession of birds. Data on the activities of birds in both groups were pooled in a sample that included both sexes, and marked and unmarked birds.

The usual activity of a bird, after leaving the roost in the morning, commenced with a period lasting up to 2 h of inactive perching or preening. Thereafter, the bird hunted until successfully capturing prey. The size of the prey item apparently determined whether the bird hunted again on the same day. The overall time spent hunting per day was determined largely by the rate of prey capture. A marked female was watched for four days in a two-week period and she hunted for 0.70, 4.40, 4.35 and 9.15 h (respectively 5.6, 35.2, 34.8 and 73.2% of her day).

Based on focal birds, Table 1 shows that hunting (intent searching and hovering) occupied, on average, 54% of the kite's daytime activity and was highest (63%) during midday. More time was spent on preening during the morning (20%) than during the rest of the day. On average, a kite spent 20% of the daytime flying and 80% in stationary activity.

This pattern is supported by data from the instantaneous sampling method. Of all birds sighted (849), 18% were flying and 82% were perched. I made no attempt to distinguish different activities in these perched birds, but classed flying birds as being engaged in hovering, soaring or directional flying. About 8% of the birds were flying directionally and 8% were hovering and soaring.

HUNTING BEHAVIOR

Black-shouldered Kites searched for prey from perches (71% of hunting time) or by hovering

TABLE 1. Activity of the Black-shouldered Kite, based on focal animal sampling. The recorded number of hours of each activity in the morning (05:00–10:00), midday (10:00–15:00) and afternoon (15:00–19:00) are given.

	Number of hours				
	Morning	Midday	Afternoon	Total	Percent
Perched					
Intent search	31.27	13.58	6.43	51.28	38.4
Casual search	5.63	1.12	3.42	10.17	7.6
Preening	14.87	2.87	2.17	19.91	14.9
Inactive	8.82	6.55	2.20	17.57	13.1
Eating	2.58	0.95	1.65	5.18	3.9
Other	1.37	0.85	0.20	2.42	1.8
Subtotal	64.54	25.92	16.07	106.53	79.7
Flying					
Hovering	7.63	10.33	2.87	20.83	15.6
Soaring	2.07	1.20	0.30	3.57	2.7
Directional	0.62	0.43	0.27	1.32	1.0
Other	1.05	0.03	0.27	1.35	1.0
Subtotal	11.37	11.99	3.71	27.07	20.3
Total	75.91	37.91	19.78	133.60	100.0

in the air (29%). During periods of intent searching, the birds changed perches frequently and often performed tail-cocking behavior (Steyn 1963) when intensely excited, just prior to and after a strike. Tail-cocking occurred during 14% of the intent-searching time. After a perched bird sighted prey, it dove to the ground, grasped and killed the prey with its talons. The prey was then taken to a perch and eaten.

While hovering, a bird maintained position for short periods (10–20 s) over different places at heights of 20 to 60 m. The total time (20.8 h) recorded for hovering includes the time hovering and the time spent changing position between hovers. Periods of aerial hunting averaged 7.8 min (SD = 6.3, range = 1–27 min, N = 100), which is similar to a mean of 6.1 min for the White-tailed Kite (Warner and Rudd 1975). When prey was sighted, a hovering bird usually descended part of the way to the ground, hovered again, and then made a final rapid dive to the ground.

The term "half-strike" was used to describe a dive interrupted just before the bird would have struck the ground. "Full strikes" occurred when the bird actually struck the ground. About 14% (35) of all strikes (252) were successful, which is considerably lower than the 39% recorded for the White-tailed Kite (Warner and Rudd 1975). Table 2

TABLE 2. A comparison between the effectiveness of two forms of hunting in the Black-shouldered Kite.

	Hovering	Perching
Total time (h)	20.83	51.28
Percent of time	28.9	71.1
No. strikes		
Full[a]	90	66
Half[b]	37	59
Total[a]	127	125
Strikes/h	6.10	2.44
No. successful strikes[a]	24	11
Strike success (%)		
Full	26.7	16.7
All	18.9	8.8

[a] Difference between hovering and perching very highly significant (chi-square, $P < 0.001$).
[b] No significant difference ($P > 0.05$) between hovering and perching.

shows that hovering was associated with 2.5 times as many strike opportunities as perch-hunting, and that hovering birds were 2.2 times more successful in obtaining prey as those perch-hunting. Both differences are highly significant ($P < 0.001$).

PREY

Small, diurnal rodents constitute the main prey of the Black-shouldered Kite, as in the White-tailed Kite. Siegfried (1965) recorded 82 of 97 prey objects taken by Black-shouldered Kites to be striped field mice (*Rhabdomys pumilio*). I recorded 341 prey objects, and all but two were small mammals belonging to 13 species. However, only two species, the striped field mouse (43%) and the vlei rat (*Otomys angoniensis*, 30%) were of importance. Both species are essentially diurnal and their average (N = 100) masses are 41 g and 91 g, respectively (Rautenbach, unpubl. data). The third commonest prey species (13.8%) was the multimammate mouse (*Praomys natalensis*, 42 g), which is normally nocturnal.

A free-living Black-shouldered Kite with a mass of 243 g needs 61 g of rodent prey daily to maintain constant mass, or about 25% of its body mass (Tarboton 1977). Allowing for some waste, this is equivalent to two *Rhabdomys* or *Praomys*, or one *Otomys* per day.

ENERGY BUDGET

Activity data from Table 1 were regrouped into six activity classes (Table 3), and the energy cost of each was computed using published metabolic rates for non-passerine birds (Ashoff and Pohl 1970, Tucker 1974, King 1974). The daily energy expenditure of a Black-shouldered Kite was estimated to be 98.3 kcal (Table 3). Perched activity, ac-

TABLE 3. Energy budget of the Black-shouldered Kite.

	Hours/24 h	Energy cost (kcal/24 h)
Perched[a]		
Inactive[b]	12.62	16.08
Low activity[c]	3.05	5.05
High activity[d]	5.64	17.97
Subtotal	21.30	39.10
Flying[e]		
Soaring	0.35	7.67
Directional	0.26	5.70
Hovering	2.09	45.82
Subtotal	2.70	58.19
Total	24.00	98.29

[a] BMR (basal metabolic rate) $= 3.60W^{0.734} = 1.2745$ kcal/h (Ashoff and Pohl 1970; for non-passerines using $W = 0.243$ kg). Inactive perching considered to be at BMR, low activity at 1.3 × BMR, and high activity at 2.5 × BMR (King 1974).
[b] "Inactive" includes roosting (11.0 h), inactive perching (1.48 h), and other (0.14 h).
[c] "Low activity" includes casual searching (0.96 h), preening (1.99 h), and other (0.10 h).
[d] "High activity" includes eating (0.52 h) and intent-searching (5.12 h).
[e] All flying activity has been reckoned at 17.2 × BMR. This multiple is derived from Tucker's (1974) equation 8.

counting for 89% of all activity, cost the bird only 40% of its total energy requirement. The total energy required for flight (58 kcal) greatly influenced the bird's total energy requirement, and the estimated figure is greatly affected by choice of metabolic conversion factor. For example, Tucker's (1974) equation gives a conversion of 17.2 times basic metabolic and a total daily energy requirement of 98.3 kcal. If, however, a conversion of 12 times basic metabolic rate (King 1974: 32) is used for flight, the total daily energy requirement is only 80.2 kcal. Although different types of flying have been reckoned in Table 3 at the same rate, it is clear that their respective energy costs will differ.

The observed daily energy intake by Black-shouldered Kites of 99.7 kcal was close to the higher of the above two values. It was computed using the following data and conversions: body mass of Black-shouldered Kite, 243 g (N = 232, Mendelsohn, unpubl. data); daily rodent food intake, 61 g (Tarboton 1977); dry matter in rodent, 35% (Bird and Ho 1976); energy value of rodent, 5.84 kcal/g dry matter (Cummins and Wuycheck 1971, Bird and Ho 1976); assimilation efficiency, 0.8 (White, pers. comm.).

The difference between the time and energy budgets of the different activities is shown in Table 3. Low activity and inactivity accounted for 65% of the bird's 24-h day, but only 22% of its energy expenditure. Hunting (perched and hovering) accounted for 30% of its day, but 61% of its daily energy expenditure. The cost-effectiveness of perch-hunting versus hovering can be similarly compared. Hovering (per unit time) required 6.9 times as much energy as perch-hunting (17.2 versus 2.5 kcal), and the energy expenditure per day from hovering was 2.8 times that of perch-hunting (45.82 versus 16.31 kcal). If the energy cost of hovering is assumed to be a constant 17.2 times basal metabolic rate, then perch-hunting was energetically more efficient than hunting by hovering (1.2 versus 1.5 prey objects caught per energy/time unit). Hunting by hovering was, however, much more effective, since it provided kites with more strike opportunities and a higher strike success rate than perch-hunting (Table 2).

The cost/benefit ratio of the two forms of hunting, and the proportion of time devoted to each, are likely to be affected by several other variables. Wind speed is likely to affect the energy cost of hovering and, hence, the relative efficiency of this form of hunting versus perch-hunting. I observed that kites rarely hovered during calm periods or high winds. Prey density, the amount of ground cover available to prey and the availability of perches are other such variables, and I predict that hunting methods and success rates will vary in time and place dependent on these.

SUMMARY

From the average daily activity budget, based on field observations and published metabolic rates, the average daily energy expenditure of the Black-shouldered Kite was computed to be 98.3 kcal. This agrees well with the observed daily energy intake of the species (99.7 kcal), based on measured daily food intake.

Black-shouldered Kites hunted from perches (71% of hunting time) and by hovering (29%). The latter method had a 6.9 times higher energy cost per unit time, but was more effective than perch-hunting, as it resulted in 2.5 times more strike opportunities and had a 2.2 times higher strike success rate.

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LITERATURE CITED

ALTMANN, J. 1974. Observational study of behaviour: sampling methods. Behaviour 49:227–267.

ASHOFF, J., AND H. POHL. 1970. Rhythmic variations in energy metabolism. Fed. Proc. 29: 1541–1552.

BIRD, D. M., AND S. K. HO. 1976. Nutritive values of whole-animal diets for captive birds of prey. Raptor Res. 10:45–49.

BROWN, L. H., AND D. AMADON. 1968. Eagles, hawks and falcons of the world. Vol. 1. Feltham, Great Britain.

COETZEE, C. G. 1972. The identification of the southern African small mammal remains in owl pellets. Cimbebasia (A)2:53–64.

CUMMINS, K. C., AND J. C. WUYCHECK. 1971. Caloric equivalents for investigations in ecological energetics. Int. Ver. Theor. Angew. Limnol. Verh. 18:1–158.

KING, J. R. 1974. Seasonal allocation of time and energy resources in birds, pp. 4–70. *In* R. A. Paynter [ed], Avian energetics. Publ. Nuttall Ornithol. Club, No. 15.

MCLACHLAN, G. R., AND R. L. LIVERSIDGE. 1970. Roberts' birds of South Africa. Third ed. Johannesburg, South Africa.

SIEGFRIED, W. R. 1965. On the food of the Black-shouldered Kite. Ostrich 36:224.

STEYN, P. 1963. The "wagtail" kite. Bokmakierie 15:9–10.

TARBOTON, W. R. 1977. Food consumption and pellet production in the Black-shouldered Kite, *Elanus caeruleus*. Zool. Afr. 12:252–255.

TUCKER, V. A. 1974. Energetics of natural avian flight, pp. 298–328. *In* R. A. Paynter [ed], Avian energetics. Publ. Nuttall Ornithol. Club, No. 15.

WARNER, J. S., AND R. L. RUDD. 1975. Hunting by the White-tailed Kite *Elanus leucurus*. Condor 77:226–230.

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