

On being disturbed, one of the nestlings climbed from the nest and up into the spruce tree, while the other flew to the ground and was captured. Its measurements include: length, 18.5 cm; wing spread, 22.0 cm; bill, 1.5 cm; and longest retriex, 7.5 cm; weight was estimated at 50–75 g. By the afternoon of 9 June, both nestlings were gone from the vicinity of the nest tree, and on 10 June the adult pair chased a Common Raven (*Corvus corax*) from the area. On 23 June, at my nearby base camp, a pair of adults

and the two young were present; the latter were fed table scraps by their parents. The family group was still there as late as 22 October, the date of my last visit.

I am grateful to various people for information on the status of the Gray Jay in New Mexico and to John P. Hubbard for comments on an earlier draft of this note. Color slides of the nest and nestlings were taken and are in my personal collection.

Accepted for publication 14 May 1973.

## THE BIOENERGETICS OF THE BLUE JAY IN CENTRAL ILLINOIS

ROBERT J. CLEMANS

Cook County Forest Preserve  
RR #1, Box 541  
Dundee, Illinois 60118

Experiments on the House Sparrow (*Passer domesticus*) show a seasonal adjustment in bioenergetics as a condition for permanent residency (Kendeigh 1949). Migratory species appear not to have evolved as great a capacity for a photoperiodic-induced change and this may be why they move to areas with more suitable climates in winter (Seibert 1949). The breeding range of the northern subspecies of the Blue Jay (*Cyanocitta cristata bromia*) extends northward to Edmonton, Alberta, Canada, and southward to the northern parts of the Gulf states in the United States. Birds from the more northern part of the range are known to migrate south during the winter, while those in the more southern part are presumed to be stationary. The jays in central Illinois during the winter represent a combination of the sedentary and migratory populations. This investigation attempts to determine and quantify the bioenergetics of the permanently resident birds.

No studies of existence metabolism have been conducted on a passerine bird as large as the Blue Jay. Thus, a further objective of this study is to extend and verify the equations of Kendeigh (1970) depicting the relation of weight to existence energy requirements.

### METHODS

Blue Jays were captured in 36-mm mist nets in the vicinity of Champaign County, Illinois, using cracked corn as bait or a mounted specimen of the Great Horned Owl (*Bubo virginianus*) as a decoy. During the summer (May, June, July) the birds were used immediately in summer-phase experiments. The survivors were housed out-of-doors and used the following winter, along with additional captures in early October, for the winter-phase experiments. Because winter migrants were not present in Champaign at the time of trapping, I assumed that the birds were residents. Fifty-two birds were trapped of which 31% lived long enough to complete one successful experiment. Jays that died from unknown causes or shortly after capture averaged  $85.7 \pm 2.4$  g and were quite fat. Wild birds weigh  $84.5 \pm 17.5$  g.

Those that survived the initial caged conditions were maintained in good health on dog food and cracked corn. The dog food was Ken-L Ration, which has a guaranteed content of 10% crude fibre, 0.4%

ash, 0.5% calcium, 0.3% phosphorus, and 600 U.S.P. units of vitamin D<sub>2</sub> per pound of feed. The ingredients include meat by-products, soy grit, horse meat by-products, oatmeal, cracked barley, cracked milo, iodized salt, onion powder, choline chloride, garlic powder, vitamin A supplement, irradiated yeast, sodium nitrite, and thiamine mononitrate. The moisture content was 69%, and the average caloric value was 5.61 kcal/g. The cracked corn contained 12.5% moisture and had a caloric content of 4.45 kcal/g.

Weighed portions of cracked corn were given to the birds at the beginning of each experimental run. The dog food was given to the birds in weighed, daily portions to maintain its palatability and to reduce spoilage. The dry weight of the fresh food was calculated.

The energy balance experiments were similar to those of Kendeigh (1949). The runs varied from 2 days at low temperatures to 3 days at elevated temperatures. At the end of each run the excreta, corn, and dog food were separated from each other by hand, dried at 65°C until the sample weight stabilized, weighed, and the caloric value of the excreta determined in a Parr macro-bomb calorimeter. The caloric value of the feces and of the urinary waste is the *excretory energy* (EE). The measured dry weight of the excess food was subtracted from the calculated value of the initial weighed portion to determine the *gross energy intake* (GEI). The GEI minus the excretory energy is the metabolized energy of the food consumed. No correction was made for fermentation of the undigested food or for energy used by bacteria in the intestine. *Existence metabolism* (EM) is the amount of energy utilized during periods when the birds did not vary more than 2% in weight. During an experiment, the birds were kept in  $46 \times 32.5 \times 45$  cm cages with 2.5-cm wire mesh false floors. A 1.25-cm diameter dowel perch was placed across the cage. A pan underneath the cage caught the falling feces and scattered food. Water was supplied at temperatures above 0°C and snow at temperatures below freezing.

The experiments were performed after the birds had acclimated to the experimental conditions for a week, or until they maintained constant weight. Each group of three to seven birds was run at several consecutive descending or ascending temperatures. Birds were changed from one experimental temperature to the next in 5°C steps. Experimental temperatures were maintained at  $\pm 1^\circ\text{C}$  in walk-in temperature cabinets. The humidity in the cabinets ranged from 35 to 98%.

The photoperiods in the "winter" and "summer" experiments were 9L:15D and 15L:9D, respectively. The light intensity ranged from 20 foot-candles at  $-30$  and  $-20^\circ\text{C}$  to 80 foot-candles at 28 and  $38^\circ\text{C}$ .

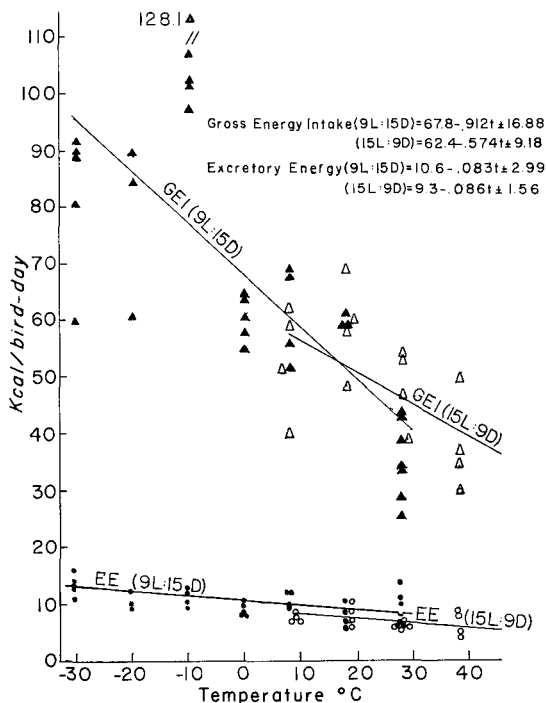


FIGURE 1. Relationship of gross energy intake (GEI) and excretory energy (EE) to temperature at a "summer" and "winter" photoperiod (15L:9D) and (9L:15D), respectively ( $\circ$   $\Delta$  15L;  $\bullet$   $\blacktriangle$  9L).

## RESULTS

The increase in the gross energy intake under both photoperiods is inversely related to temperature (fig. 1).

The amount of energy lost through excrement also is inversely related to ambient temperature. Summer birds ( $3.9 \pm 0.07$  kcal) have significantly higher caloric content per gram of feces than winter birds ( $3.6 \pm 0.05$  kcal), probably due to the consumption of higher percentages of dog food during the "summer" experiments.

Existence metabolism parallels but is reduced below GEI in both "summer" and "winter" birds (compare figs. 1 and 2). Neither the  $0^\circ\text{C}$  intercepts (53.2, 57.4) nor the regression coefficients (0.485*t*, 0.829*t*) were significantly different between summer and winter because of wide variability. The average of the regression equations for summer and winter is  $M = 55.3 - 0.657t$ , where  $M$  is calories/gram/bird/day and  $t$  is temperature in degrees C.

The utilization coefficient for the birds, expressed as (metabolized energy/gross energy intake)  $\times$  100, remains relatively constant under all conditions at  $83.1 \pm 1.25\%$ . There was no significant change in weight at different ambient temperatures, the average being  $84.5 \pm 1.10$  g.

The lowest mean temperature that the one-half of the jays could tolerate (LD50) changed from  $-30^\circ\text{C}$  during the winter to  $+8^\circ\text{C}$  during the summer. The upper lethal temperature changed in the Blue Jay from  $30$ – $35^\circ$  to  $40$ – $44^\circ\text{C}$  under winter and summer photoperiods, respectively.

The jays in cages had minimum activity although they spent some time calling to each other and hopping back and forth between the perch and the

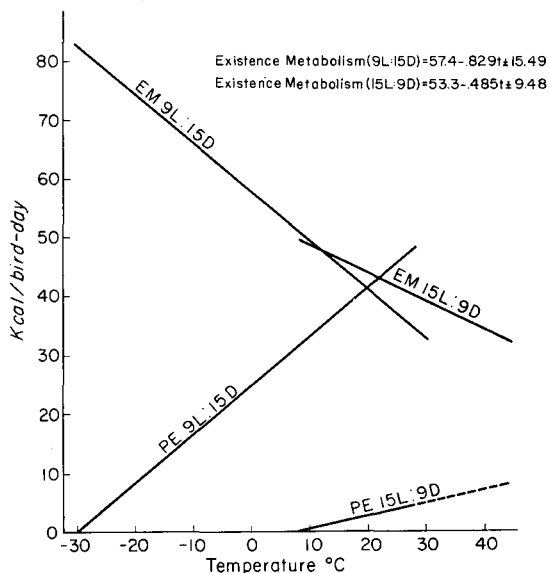


FIGURE 2. Interrelations of existence metabolism (EM) and productive energy (PE) to longer (summer) and short (winter) photoperiods.

floor. There was no observed movement at night. At temperatures of and below  $0^\circ\text{C}$ , the winter birds remained perched, with their feathers fluffed and heads withdrawn. They moved only to eat or when they were disturbed. The summer birds restricted their activities similarly at  $8^\circ\text{C}$ .

At the lowest winter temperatures that the birds tolerated, they were evidently utilizing the maximum amount of energy that they could mobilize (82.3 kcal/bird-day). During the summer their maximum output dropped to 49.4 kcal/day. Assuming that under other conditions of stress (migration, molt, reproduction) the birds could metabolize similar energy, *productive energy* (PE) may be calculated at any given temperature as the difference between the maximum and the existence metabolism. Thus as ambient temperatures increase, the potential PE increases (fig. 2) at least until heat stress begins to affect the birds (Kendeigh 1969b).

## DISCUSSION

Fundamental differences occur in the energy balance of the Blue Jay out-of-doors during mid-winter and mid-summer (table 1). Existence metabolism may be calculated by using the regression equations from the experimental work and normal monthly temperatures from Champaign, Illinois. Productive energy each month is the difference between their maximum metabolic capacity attained at the winter and summer lower lethal temperatures and these calculated rates of EM. The jays in the 3 winter months use an average of 71.5% of their potential energy for existence, while during the summer they use 85.3%, even though this is a smaller absolute amount of energy than needed during the winter. The jays have an average of 23.5 kcal/bird-day during the winter and 7.3 kcal/bird-day during the summer in PE. Food is less plentiful during the winter and the wild diet is mainly vegetable material. Much of their PE in the winter is needed just searching for

TABLE 1. Monthly energy budget (kcal/bird-day).

Month	Normal temperature °C	Existence metabolism	Productive energy
December	-1.0	58.2	24.1
January	-2.8	59.7	22.6
February	-1.5	58.6	23.7
June	21.8	42.7	6.7
July	24.1	41.6	7.8
August	23.0	42.1	7.3

food. The birds have completed their nesting by early summer, and less energy is required to find food although molting of the plumage is occurring. The data available do not justify attempting an energy budget for the peak reproductive period of April and May.

Blem (1969) and Owen (1970) showed that under stimulus of long days, birds remain active longer and consequently use more energy at any given temperature. In the jays, however, this was true only at higher temperatures (fig. 2). At lower temperatures the birds sat quietly and seemed to be asleep even during the day.

The lowest mean temperature of the House Sparrow, a permanent resident of central Illinois, shows that a seasonal change in low temperature tolerance may be characteristic of permanent residents outside of the tropics. These seasonal changes result from difference in efficiency of the plumage insulation and from hormone and enzyme changes (Barnett 1970; Kendeigh and Wallin 1966). According to Kendeigh's (1970) log-log relationship between weight and metabolism for passerines at 30°C ( $\log M = 0.1965 - 0.6210 \log W + 0.0633$ , where  $W =$  weight in grams and  $M =$  EM in kcal/bird/day), the Blue Jay (84.5 g) should use 24.7 kcal/day. The determined values are 32.5 kcal/day for the 9L and 38.8 kcal/day for the 15L photoperiod. The differences between expected and actual values border on significance. Kendeigh's equation for all taxa of birds at 0°C ( $M = 0.6372 + 0.5300 \log W \pm 0.0613$ ) predicts that the jay should metabolize 45.5 kcal/day, while the experimental values were 57.4 and 53.3 kcal/day for winter and summer photoperiods, respectively. These differences, however, are not significant. A plot of Kendeigh's values for existence energy of the Blue Jay against temperature yields a line with the equation  $M = 45.5 - 0.693t$ , while those determined experimentally are  $M = 57.4 - 0.830t$  and  $M = 53.3 - 0.483t$  for 9L and 15L photoperiods. The high values for my birds may be caused partly by some disarray of their plumage resulting from confinement in cages, in some cases for as long as 12 months. The reduced body insulation should not be important at high ambient temperatures, however. In contrast, standard metabolism, as measured by Misch on Michigan birds (Kendeigh 1969a), falls somewhat below the re-

gression line for passerine species. Apparently, the cost of cage existence (existence metabolism minus standard metabolism) is exceptionally high in this species.

#### SUMMARY

1. Existence metabolism measured from -30° to +28°C and from -8° to +38°C for winter and summer photoperiods, respectively, increases linearly with decreasing temperature.
2. At high temperatures (15°C), the birds under summer photoperiods (15L:9D) have a higher rate of metabolism than do winter (9L:15D) birds.
3. Productive energy is greater during the winter than during the summer.
4. The limits of tolerance to low temperature change from 30°-35° to 40°-44°C. Seasonal changes of this magnitude may be characteristic of permanent resident species outside the tropics.

The present study is from a thesis submitted for a Master of Science degree at the University of Illinois and was supported by a grant from the National Science Foundation. I would like to thank Edward Pentecost for his assistance in the field and Cady Soukup and Priscella Brown for their assistance in the laboratory. Special thanks are due to S. C. Kendeigh for his advice and editing of this manuscript. Several of my colleagues provided helpful suggestions.

#### LITERATURE CITED

- BARNETT, L. B. 1970. Seasonal changes in temperature acclimatization of the House Sparrow, *Passer domesticus*. *Comp. Biochem. Physiol.* 33: 559-578.
- BLEM, C. R. 1969. Geographic variation in the bioenergetics of the House Sparrow, *Passer domesticus*. Ph.D. thesis, Univ. Illinois.
- KENDEIGH, S. C. 1949. Effects of temperature and season on energy resources of the English Sparrow. *Auk* 66:113-127.
- KENDEIGH, S. C. 1969a. Tolerance to cold and Bergmann's Rule. *Auk* 86:13-25.
- KENDEIGH, S. C. 1969b. Energy responses of birds to their thermal environment. *Wilson Bull.* 81: 441-449.
- KENDEIGH, S. C. 1970. Energy requirements for existence in relation to size of bird. *Condor* 72: 60-65.
- KENDEIGH, S. C., AND H. E. WALLIN. 1966. Seasonal and taxonomic differences in the size and activity of the thyroid gland in birds. *Ohio J. Sci.* 66:369-379.
- OWEN, R. B., JR. 1970. The bioenergetics of captive Blue-winged Teal under controlled and outdoor conditions. *Condor* 72:153-163.
- SEIBERT, H. C. 1949. Difference between migrant and non-migrant birds. *Auk* 66:128-153.

Accepted for publication 9 August 1973.