ENERGY METABOLISM OF THE CATTLE EGRET

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INTRODUCTION

This paper reports part of a fairly comprehensive study designed to investigate the food and feeding ecology of the Cattle Egret *Ardeola ibis* in the south-western Cape. Some of the findings are preliminary, insofar as most of the data have been derived from a series of relatively crude tests because it was first necessary to investigate the suitability of the bird as an experimental animal and to develop and adapt techniques accordingly.

King and Farner (1961), in reviewing the field of avian metabolism and energy requirements, and Engelmann (1966) discussing terrestrial energetics in general, state that there is a relative paucity of information available on the subject. The present study considers the energy demands of Cattle Egrets in captivity and relates the experimental findings to what might apply under natural conditions.

METHODS

The ten captive birds used in these experiments were reared in captivity. All were older than two years (fully grown and sexually mature) when first subjected to experimentation. The birds were caged in outdoor flight-aviaries and, consequently, were exposed to natural daylight and fluctuating ambient temperatures. Each rodent-proof aviary, measuring 6 x 2 x 2 metres, accommodated two birds at a time. Perches and shelters were provided. The birds were able to exercise by making short flights between the perches. Excrement, in the form of urine and faeces, was collected on removable plates on the floor of the aviary.

The captive birds were fed raw, lean beef, freshly minced and rolled into pellets; a multivitamin supplement was added to the meat at weekly intervals. The food was placed in metal pans and screened from insects such as ants and flies. Water was always available. Egrets kept under these conditions have remained in apparent perfect health for a number of years. During the course of experiments, handling of the birds was kept to a minimum. Food was given once a day; the amounts provided were always in excess of what the birds could consume during the course of a 24-hour period. Before replenishment, food remaining from the previous feeding was removed. Fresh food was given in the morning before first light and, at the same time, a control experiment was started each day to measure loss in weight of the food sample due to desiccation. Weighings were made at set intervals during the course of a 24-hour period. The control sample, to ascertain water-loss, was placed in an aviary adjoining the one in which the birds were kept; the conditions of placing were identical in both aviaries. In this way, by comparing the discrepancy it was possible to calculate the true weight of meat consumed by the birds. Although the food was offered and weighed

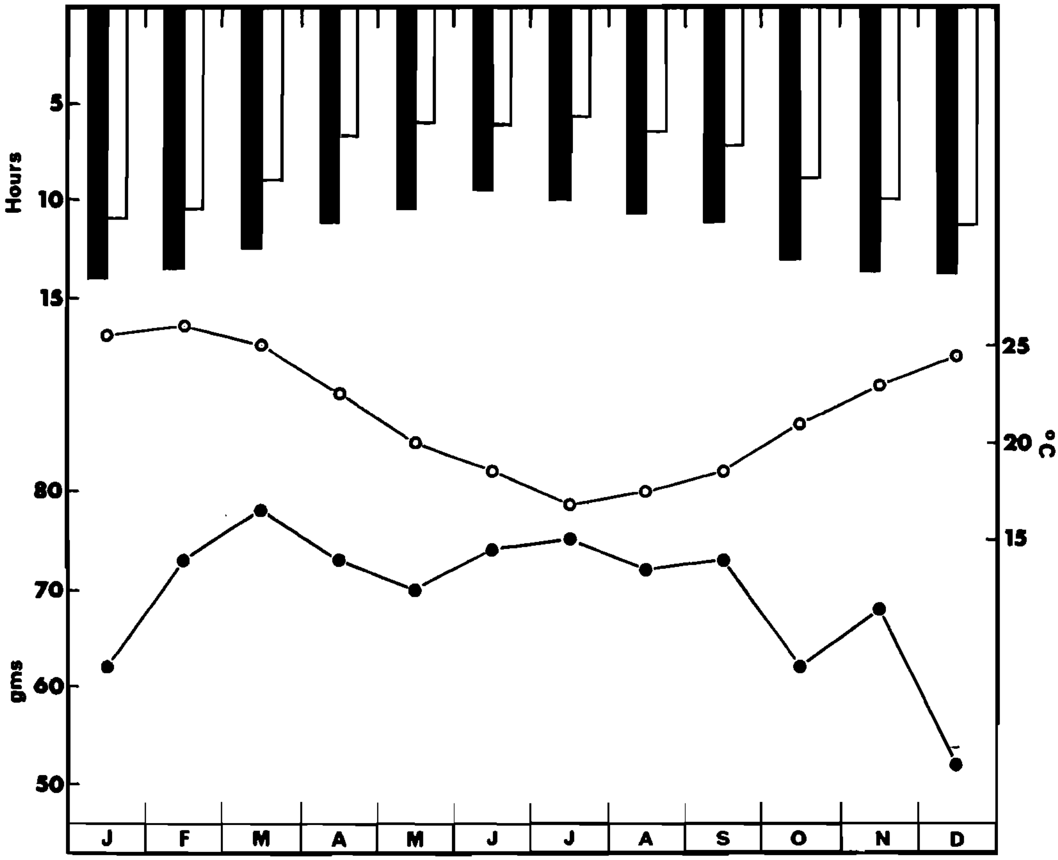

FIGURE 1
Average food consumption of ten captive Cattle Egrets in relation to mean air temperature, day-length and sunshine according to months. Shaded bars represent day-length, unshaded indicate hours of sunshine; solid circle graph traces food intake per day.

in a fresh condition, the dry weight was also determined. Caloric determinations were made using an oxygen-bomb calorimeter and water content, dry substance and ash were determined.

The birds' excretory rates were determined by direct visual observation. Birds were kept under continuous observation for up to 36 hours at a time and the frequency of excretions recorded. Excrement was collected, as voided, through a number of 24-hour cycles; the excrement was weighed fresh and its moisture content determined. These samples were oven-dried, as was also other excrement saved at the end of each day from other aviaries, and calorimetrically analysed after having been stored in a freezer. The casting up of pellets occurred so seldom—no doubt as a result of the "soft" food—that this factor could safely be ignored.

GROSS ENERGY REQUIREMENTS

From Figure 1, which shows the food consumption of the captive birds over one year, it will be seen that food intake was proportionately greater during the cooler winter months than the warmer summer ones. However, as has been demonstrated by Kendeigh (1934 and 1949) and Seibert (1949) and also other workers, the amount of gross energy intake is influenced by factors other than temperature as well. The relatively large food demands shown by the experimental Egrets during late summer (February-March) is tentatively attributed to the increased energy requirements for the birds' annual moult which regularly occurs at this time of the year (Kendeigh, *in litt.*, 1967, confirms that the annual moult in birds is extra-energy demanding).

In order to examine further the apparent relationship between food and temperature, the mean daily food intake is plotted against air temperature in Fig. 2, where it can be seen that the two appear inversely related. However, no valid relationship could be demonstrate when the two sets of data were subjected to statistical testing. Analyses designed to test whether perhaps a time delay existed between change in temperature and volume of feeding (Davis (1955) has demonstrated for the House Sparrow *Passer domesticus* that reduced food-intake in response to rising temperatures is not immediate, but delayed for some days) also indicated that the relationship was spurious. The actual daily intake may be obscured, however, by a tendency on the part of some experimental birds to overeat on one day and then to compensate by eating less on the following one or more days when given unlimited supplies of food.

Using the data depicted in Fig. 1, for the whole year a mean daily meat intake of 70 gm. (wet weight) per day was obtained per bird. However, in a more strictly controlled experiment lasting 114 days, eight birds consumed an average of 68 gm. of meat per day; daily mean air temperatures varied between 26°C and 15°C with an average of 19°C and with a 13-hour average daylight period. The average weight of the birds used in the experiment was 383 gm.; the birds were weighed in the early morning before feeding commenced and again in the evening after the last feeding had taken place. The average weights of the birds fluctuated to no significant extent and displayed no consistent differences at different air temperatures. In terms of food consumed in relation to bodyweight, the captive Egrets ate, on average, about 18 per cent (wet weight) per day. In contrast, Junor (1965) working with captive hand-reared herons established that the daily food intake of fish, expressed as per cent of bodyweight, of the Grey Heron *Ardea cinerea* and the Black-headed Night Heron *Nycticorax nycticorax* averaged 32 per cent and 60 per cent respectively. These values appear rather high when compared with the Cattle Egret or with the figures reported by Kahl (1964) for the piscivorous Wood Stork *Mycteria americana*—about 16 per cent—or for meat-eaters like the Marabou Stork *Leptoptilos crumeniferus* and owls which consumed, on average, between 10 and 20 per cent (fresh tissue) per day (*vide* Kahl 1966 and Graber 1962).

The energy value (caloric content) of the meat given to the captive Egrets is shown in Table 1. From these data, on calculation, it emerges that the actual gross energy intake of each bird was, on average, 105 kcal. per day (17·36 gm. x 6·04 = 105 kcal./bird/24 hr.) or 274 kcal./kg/24 hr.

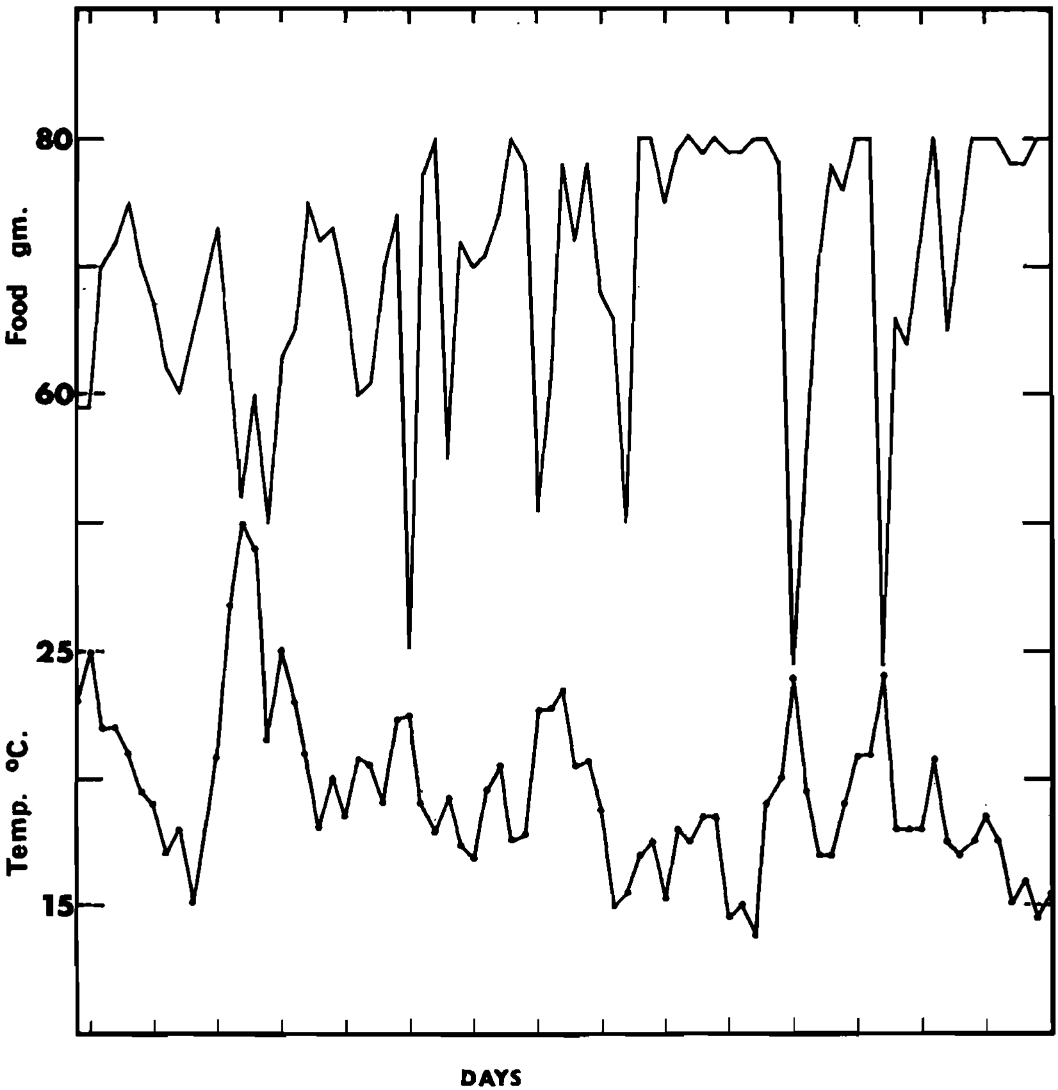

FIGURE 2
Mean daily food consumption of six captive Cattle Egrets and mean daily air temperatures.

EXCRETION

The excretory products of birds, voided through the cloaca, consist of nitrogenous waste matter from the kidneys, together with both undigested and digested (but unabsorbed) food from the large intestine. In this paper the term excrement refers to all wastes, i.e., faecal and urinary matter.

Figure 3 shows rates of excretion in some of the experimental birds in relation to time of day—the excretory rates being highest in the afternoon and early morning; in terms of weight, most excrement was voided between 1400 and 1800 hours.

Calorimetric determination of samples of dried excrement collected at different times gave values which varied slightly (between 2·64 and 3·52 kcal.). However, the data were too meagre to determine whether any significant correlation existed between the energy value of the excrement and environmental factors. For instance, Kendeigh (1945 and 1949) found that caloric values declined, and Seibert (1949) that the total number of calories lost through the faeces increased, with decreasing air temperatures. The increase in total number of calories lost is probably due to the greater amount of food eaten on cold days. Kendeigh (1949) has, moreover, pointed out that changes in the caloric value of birds' excrement may be caused by differences in the ratio of waste energy discharged by the two sources, i.e., kidneys and alimentary canal. Surgical methods for the separation of urine and faeces and their quantitative collection have been reviewed for domestic fowls by Rothchild (1947) and more recently by Newberne *et al.* (1957), but it would be difficult and in many instances impossible to apply these techniques to wild birds. However, in the experiments reported here it was not important to separate kidney wastes from undigested matter from the alimentary canal, as the material voided all represented energy that was taken in but not utilized.

Adopting mean figures here, a caloric output value of 3·03 kcal. was obtained for the captive Egrets' excrement, while the mean 24-hour excrement accumulation was 5·15 kcal. per bird.

TABLE 1

PERCENTAGE ANALYSES AND ENERGY VALUES OF VARIOUS FOOD TYPES

Food	*Water*	*Ash*	*Ash-free dry matter*	*Energy (caloric value)*
	%	%	%	*kcal./gm.*
Caterpillars (Maize-Stalk Borer *Calamistis fusca*)	70·00	1·71	28·29	5·83
Grasshoppers (Orthoptera - Acridiidae)	65·00	1·70	33·30	5·61
Meat (minced lean beef)	73·33	1·13	25·54	6·04*

* Although lean, there must have been an appreciable amount of fat included to register a caloric value of 6·04

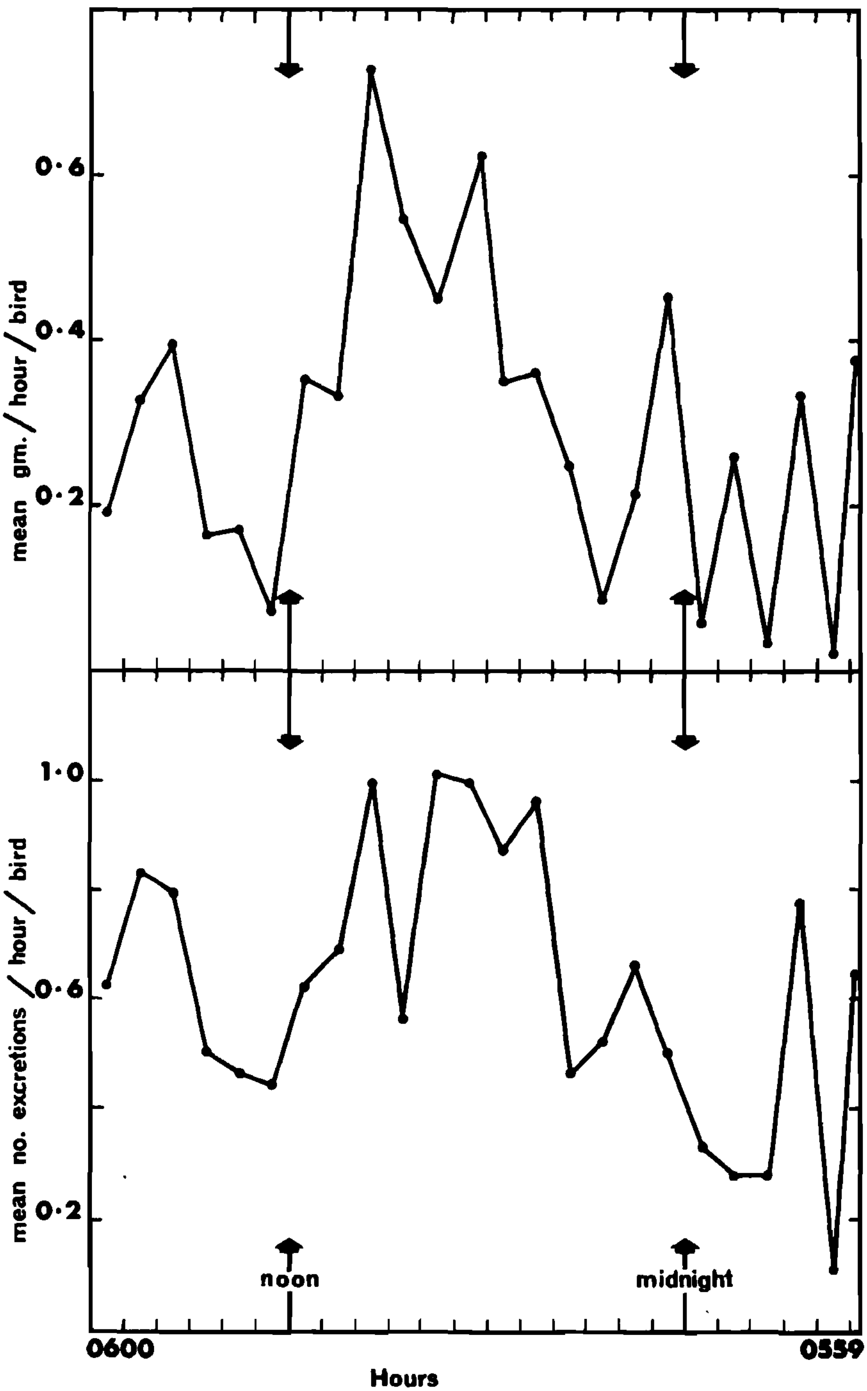

FIGURE 3
Rates of excretion according to time of day in captive Cattle Egrets (data derived from eight birds which were observed for a total of 510 hours).

ENERGY METABOLISM

Metabolisable energy is the composite energy required by a bird to perform existence and productive activities; it is, in actual fact, the food digested and absorbed by the bird, and is determined by subtracting the amount lost through excretion from the total energy intake.

The procedure adopted was to maintain the birds at a constant weight and to collect all the excrement produced during the experimental period; this was then compared with the total amount of food consumed. The food taken in during a period of time must balance against the energy eliminated in the excrement and utilised by the bird. Mean values for food intake and excrement measured over a period lasting six days were employed to calculate daily average metabolised energy. As mentioned above, the average total caloric output for one bird was 5·15 kcal. per day; during the same period 105 kcal. were ingested each day without any change in the bird's weight. These figures yield a daily metabolised energy value of 100 kcal./bird, or 261 kcal./kg. of bird for aviary existence (16°C to 19°C daily mean air temperatures and 13 hours of daylight). This would be about 95 per cent of the Cattle Egret's gross energy intake, which seems rather a high value in view of the statement by King and Farner (1961) that: "Depending upon the species of bird, the composition of the ration, and the environmental conditions, this fraction (*metabolisable energy*) amounts to about 70-90% of the gross energy". However, Graber (1962) obtained comparable energy rates in excess of 90 per cent when working with owls.

Standard metabolism was calculated using the formula* provided by King and Farner (1961) for birds which weigh more than 0·1 kgm. (see also Lasiewski and Dawson 1967). By this method, standard metabolism of a Cattle Egret weighing 383 gm. was calculated to be 36 kcal./24 hr. The Cattle Egret's aviary-existence energy level is apparently three times higher than its standard rate. Graber (1962) working with Long and Short-eared Owls *Asio otus* and *Asio flammeus*, ranging in weight between about 250 and 400 gm., demonstrated, on the basis of pellet-analyses and indirect calorimetry, that average metabolic rates of aviary-held birds were approximately four times greater than standard rates.

DISCUSSION

Table 1 shows the energy values of grasshoppers and caterpillars—typical Egret food in nature. Extrapolating the data obtained for the energy requirements of the meat-fed experimental birds, it is possible to arrive at an estimate of a captive Egret's natural food demands (but see below). It would require about 56 gm. (live tissue) of grasshoppers per day.

Wild, free-flying Egrets undoubtedly have higher metabolic rates than captive individuals. Graber's (1962) data show that the natural existence levels of *A. otus* and *A. flammeus* in North America in winter (0°C $\pm$ 10°C) exceeded standard rates some five to six times. For a much larger bird, the American Wood Stork *Mycteria americana*, Kahl (1964) considered—on the basis of Wood Storks being probably not very much more active in the wild during the breeding season than in captivity—roughly 1·5 times the aviary metabolic intensity to be

*$\log M = \log 74\cdot3 + 0\cdot744 \log W \pm 0\cdot074$.

a reasonable estimate of the metabolic rate in nature. However, the Cattle Egret is a much more active bird than the relatively sluggish Wood Stork and presumably operates under a heavier workload. In horses and cattle, energy demands for varying loads of work vary from three to eight times standard levels (Brody 1945). Raveling and Le Febvre (1967) propose, on the basis of weight loss and fat depletion, that the energy expenditure of birds (mainly small passerines) in migratory flight (sustained hard work) can be estimated as twelve times the standard metabolism rate. Figures given by Uramoto (1961) indicate that the energy cost of free existence compared with aviary (cage) existence generally varies between 30 and 50 per cent higher.

Taking all these facts together, it appears reasonable to assume that in the case of the Egrets studied here—which were able to exercise by making short flights in their cages—metabolic level in nature would be about one and a half times aviary rate or roughly 4 times standard rate. This would mean that a free-flying bird requires about 150 kcal. per day or, assuming that assimilation efficiency is the same as that determined for the meat-eating captives, on extrapolation, some 720, 2 cm.-long grasshoppers each weighing about 0·125 gm. (according to Gibb (1957), however, the digestive coefficient of adult insects might be relatively low — about 70%).

With regard to the number of grasshoppers required per bird per day, it is of interest to compare the figure calculated above with an estimate obtained through direct observation in the field. During a six-month period January-July, 1964, individual Egrets were observed feeding in kikuyu grass *Pennisetum clandestinum* fields, on 42 different occasions, involving some 104 hours of observation, spread over all hours of daylight. The procedure followed was to record the amount of time that individual birds spent on feeding, preening or resting and the number of times prey items were captured. Single periods of continuous observation were seldom less than one hour in duration and in a number of instances lasted up to three hours. At the end of any single period of observation the birds concerned were shot and their stomach contents examined. Relating the observations made on those Egrets found to have been feeding primarily on grasshoppers (*c*2 cm. in length) to an average period of 12 daylight hours, it was calculated that a bird spends eight hours feeding and the other four resting, preening, etc. A mean value of 100 successful "prey captures" was obtained for every feeding hour, which gives a tentative estimate of 800 (100 x 8) food-items (primarily grasshoppers) per Egret per day.

SUMMARY

Estimates of the gross energy requirements and metabolised (existence) energy, expressed as kcal. per bird per day, for aviary held Cattle Egrets *Ardeola ibis* are presented. Metabolic rates were determined through measuring consumption and excretion; energy values were calculated by means of calorimetry. Average gross food intake was 105 kcal./bird/24 hr. (274 kcal./kg./24 hr.), and average aviary existence metabolism was 100 kcal./bird/24 hr. (261 kcal./kg./24 hr.) or about three times the calculated standard rate of 36 kcal./bird/24 hr. These findings are discussed in terms of the Cattle Egret's natural existence requirements.

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REFERENCES

BRODY, S. 1945. *Bioenergetics and Growth.* Reinhold, New York.

DAVIS, E. A. 1955. Seasonal changes in the energy balance of the English Sparrow. *Auk.* 72: 385.

ENGELMANN, M. D. 1966. Energetics, terrestrial field studies, and animal productivity. *In, Advances in Ecological Research.* Vol. 3. Ed. J. B. Cragg.

GRABER, R. R. 1962. Food and oxygen consumption in three species of owls (Strigidae). *Condor,* 64 (6) 473.

GIBB, J. 1957. Food requirements and other observations on captive tits. *Bird Study,* 4 (4): 207.

JUNOR, F. J. R. 1965. Lake productivity studies. *In* report of the Director of National Parks and Wildlife Management (1964). Salisbury, Rhodesia.

KAHL, M. P. 1964. Food ecology of the Wood Stork (*Mycteria americana*) in Florida. *Ecol. Monog.* 34: 97.

KAHL, M. P. 1966. A contribution to the ecology and reproductive biology of the Marabou Stork (*Leptoptilos crumeniferus*) in East Africa. *J. Zool.* 148:289.

KENDEIGH, S. C. 1934. The role of environment in the life of birds. *Ecol. Monog.* 4: 299.

KENDEIGH, S. C. 1945. Resistance to hunger in birds. *J. Wildl. Manag.* 9: 217.

KENDEIGH, S. C. 1949. Effects of temperature and season on energy resources of the English Sparrow. *Auk,* 66 (2): 113.

KING, J. F., and FARNER, D. S. 1961. Energy metabolism, thermoregulation and body temperature. *In, Biology and Comparative Physiology of Birds.* Vol. 2. Ed. A. J. Marshall.

LASIEWSKI, R. C. and DAWSON, R. 1967. A re-examination of the relation between standard metabolic rate and body weight in birds. *Condor,* 69: 13.

NEWBERNE, P. M., LAERDAL, O. A., and O'DELL, B. L. 1957. A method for urine-faeces separation in young chickens. *Poultry Sci.* 36: 821.

RAVELING, D. G. and LE FEBVRE. 1967. Energy metabolism and theoretical flight range of birds. *Bird Banding,* 38 (2): 97.

ROTHCHILD, I. 1947. The artificial anus in the bird. *Poultry Sci.* 26: 157.

SEIBERT, H. C. 1949. Differences between migrant and non-migrant birds in food and water intake at various temperatures and photoperiods. *Auk,* 66 (2): 128.

URAMOTO, M. 1961. Ecological study of the bird community of the broad-leaved deciduous forest of central Japan. *Yamashina Inst. Ornith. and Zool., Misc. Repts.* 3 (1):1.