DAILY AND ANNUAL TIME BUDGET OF THE YELLOW-BILLED MAGPIE

NICOLAAS A. M. VERBEEK

THE daily and seasonal allotment of time for the various activities needed for self-maintenance and reproduction by birds is of vital importance to their survival. Time is as important a commodity as, for instance, food and the presence of a suitable nest site. The amount of time birds devote to a particular activity depends among other things, on the life style (Pearson, 1954; Orians, 1961), body size (Gibb, 1954), food availability (Gibb, 1956), and temperature (Verbeek, 1964). Reproduction requires extra time above that needed for self-maintenance (Verner, 1965a). Verner postulates that each species has its own optimum time budget that is adapted to local environmental conditions. Those individuals with the best adapted time budget are favored in natural selection.

This paper deals with the annual and daily time budget of the Yellow-billed Magpie (*Pica nuttalli*), at the Hastings Reservation, Monterey County, California. As magpies are conspicuous and inhabit open country, they are ideal subjects for a time-budget study.

The major food of the magpie, invertebrates found in grassland and savanna, shows a peak in abundance in May, followed by a rapid decline in June, and reaches its lowest level in September–October, prior to the fall rains. Food is almost exclusively found on the ground and includes soil invertebrates, cryptozoa, and invertebrates clinging to vegetation. Nestling diet consists of invertebrates obtained from within a home range of 40 ha. When the nestlings have fledged, magpies of all age classes of several neighboring colonies gather in flocks that wander throughout the summer dry season over an area of about 600 ha.

METHODS

I selected several activities that are easily recognized in the field, and I timed their duration with a wrist watch on a ½-minute basis. Because other kinds of data had to be collected concurrently, it was impossible to follow the birds continuously from dawn to dusk. I therefore collected data over several days. For instance, on one day I watched the birds from dawn till 09:00 and again from 12:00 to 14:00. The next day I filled the gap between 09:00 and 12:00 and from 16:30 to 19:00. The remaining gap (14:00 to 16:30) was filled on the 3rd day. These data were then treated as if they had been obtained in 1 day, and collectively they illustrate one daily activity record. Most 24-hour activity records were thus recorded over 2 ($N = 15$) or 3 days ($N = 12$) and a few over 4 days ($N = 6$). Of the 4-day instances, five fell in summer and early fall when magpies are least sedentary and most unpredictable. As time spent on feeding, for instance, is subject to temperature, and as data were collected over several days and

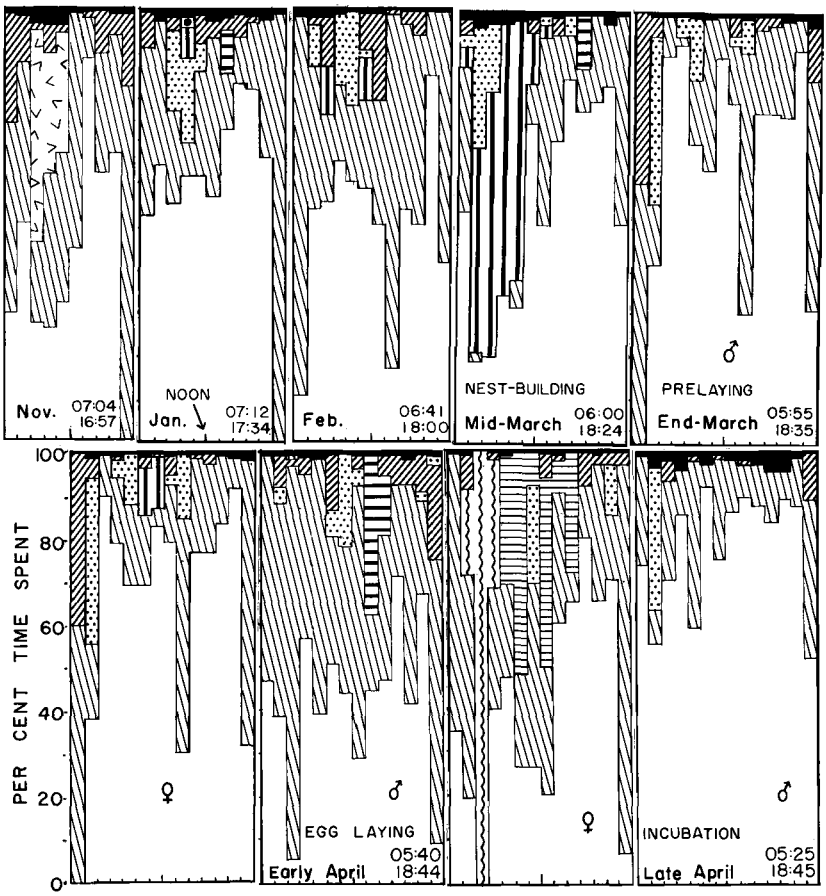

Figure 1. Daily patterns of time expenditure. Percent of time spent on various activities is analyzed per hour (or less at the beginning and end of each day). Length of each day is shown in lower right-hand corner. Activity records for both sexes are given during the breeding season.

then treated as if collected in 1 day, I started on an activity record only when the weather was sunny and promised to remain so for several days. Such standardization was necessary to be able to compare activity patterns throughout the year. Under such conditions the birds showed a remarkable daily consistency in activity and movement, so that I could almost always locate them in the same place, and find them engaged in the same activity as when I left them the previous day.

Feeding includes all the time needed to search for food, plus the time to prepare it for consumption, once it was found. Flying time was obtained by actual timing or by estimating the flight distance and translating this into time. Preening includes all the time the birds were engaged arranging feathers with the bill. Preening associated with bathing was included with bathing. Nest-building includes the search for material, its

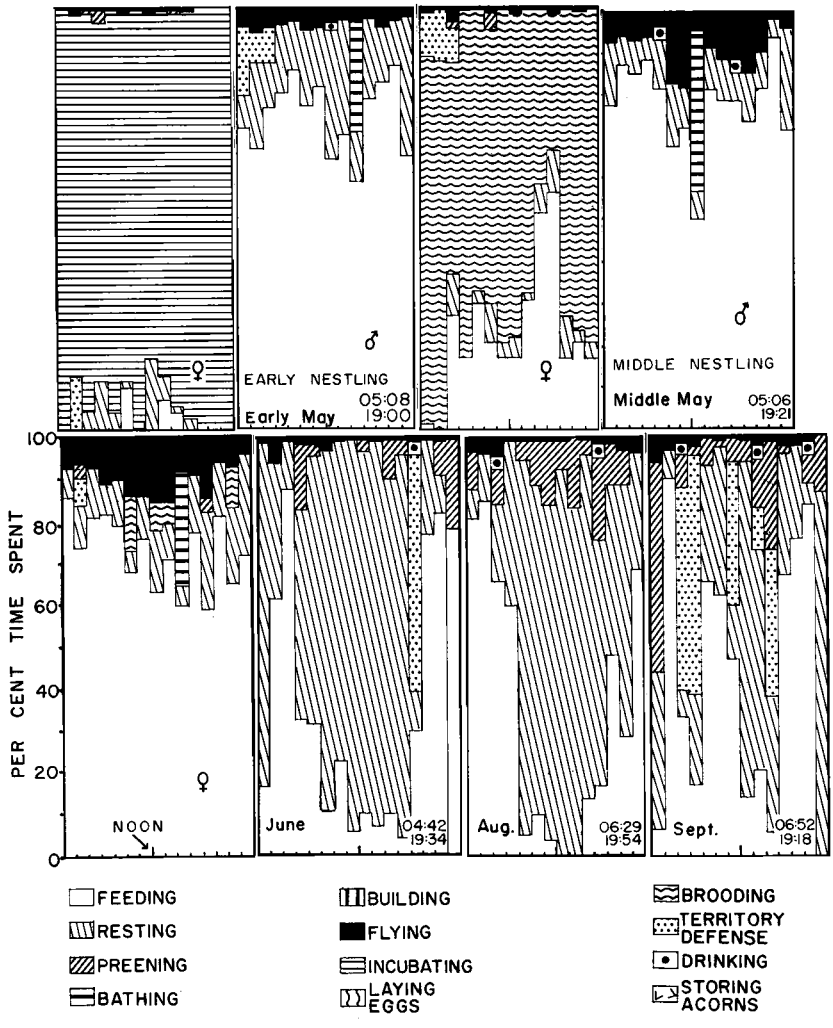

Figure 1, continued

transport to the nest, and time spent in building itself. Territorial defense includes flight during chases and time spent standing, when the interaction was limited to display. Resting includes perching and all other time that the birds were not engaged in any of the other activities listed.

Activity records were obtained in all months except July, from August 1968 to June 1970. In March, April, and May I concentrated on one marked pair and recorded the activities of each sex. I made 15 day-long activity records covering a total of 195 hours for each sex. For the other months I recorded what the average member of a flock did (Verbeek, 1964). This produced 18 activity records covering 206 hours.

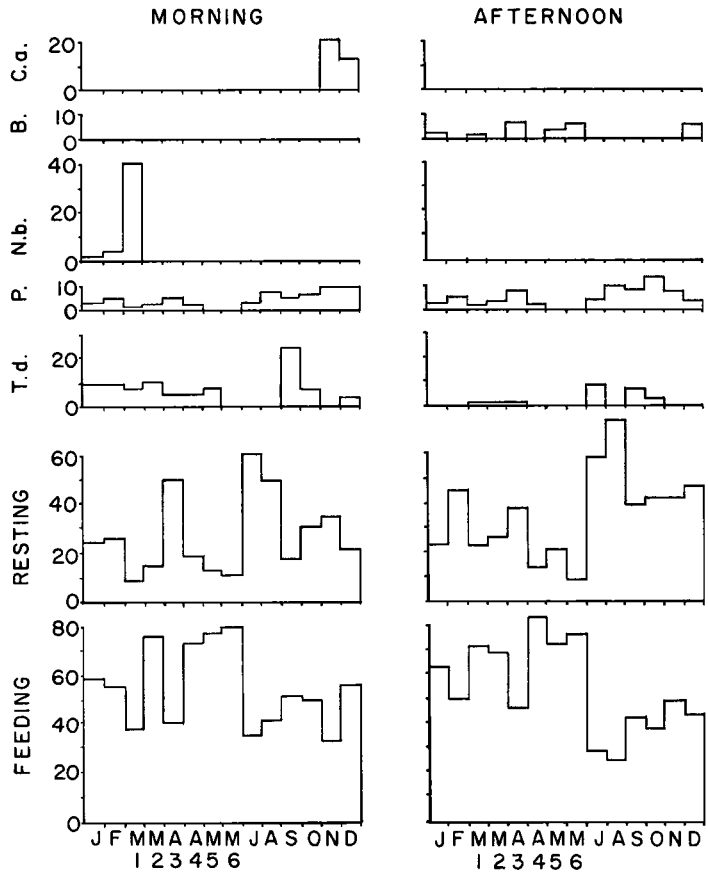

Figure 2. Diurnal time expenditure of a ♂ magpie comparing the morning with the afternoon. The numbers indicate stages in the nesting cycle: 1 = nest-building, 2 = prelaying, 3 = laying, 4 = incubation, 5 and 6 = early and late nestling stage. T.d. = territorial defense, P. = preening, N.b. = nest-building, B = bathing, and C.a. = carrying acorns.

RESULTS AND DISCUSSION

DAILY TIME EXPENDITURE

Records of daily time expenditure show great fluctuations, particularly noticeable in time spent feeding, and in the emphasis placed on certain activities at certain times of the day (Figures 1 and 2). In Figure 1 the data are presented in periods of 60 minutes, except for the first and last part of each day. As the difference between the shortest and the longest day is almost 5 hours, little is gained by dividing the days into equal intervals (see Verner, 1965a).

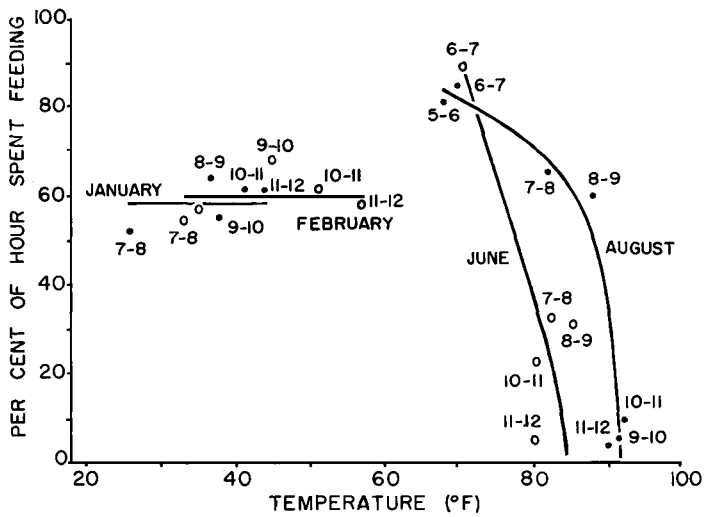

Figure 3. Percent of morning hours spent feeding in relation to maximum ambient temperature. Numbers indicate time of day.

Feeding.—Feeding occupies a large part of the day but the distribution of time spent on this activity throughout the day varies from month to month, depending on such factors as temperature and priority given to other types of activity. In the coldest months, December and January, the birds spend more time on feeding in the afternoon than in the morning, while the reverse is true during the summer. The same occurs in the Rock Pipit (*Anthus spinoletta*, Gibb, 1956). Lees (1948) finds that from October to March the Robin (*Erithacus rubecula*) feeds as much in the morning as in the afternoon, but the Blackbird (*Turdus merula*) feeds more intensely in the afternoon.

In winter food is available at all times of the day. Increased feeding in the afternoon apparently anticipates the long cold night. In summer, because of the midday heat, food is most available in the early morning before invertebrates go into hiding. Also, this same heat severely limits the birds in their feeding. This relationship between ambient (standard shelter) temperature and time spent feeding is shown in Figure 3. In August the birds feed at higher temperatures, probably the result of physiological acclimatization and enhanced by reduced solar radiation in the latter part of summer.

At some point near the middle of the day feeding activity often declines. On cold days, e.g. in January (see also Morton, 1967) and during the breeding season this rest period is eliminated and on hot days, e.g. in August, it is much prolonged, for reasons stated above. As feeding activity is deter-

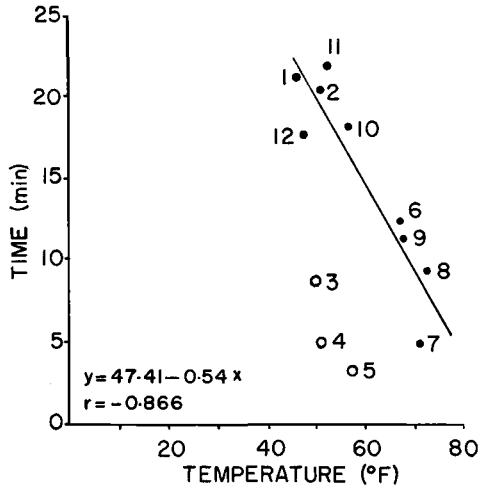

Figure 4. Time between awakening and first feeding in relation to mean ambient temperature. Figures indicate months. March, April, and May are not included in the regression equation, because the reproductive effort necessitates searching for food whenever possible.

mined, among other factors, by size of species, temperature, food habits, and feeding habitat (Kuusisto, 1941; Verner, 1965a) and reproductive state, it follows that the occurrence of a rest period and its relative position in the diurnal cycle will vary among species and in time as conditions change.

Resting.—The second most important time expenditure is resting. During the summer months the birds often sit while taking a siesta. As it was not always possible to see whether a bird was sitting or perching raised on its feet, I combined these two activities in the analysis. I may add that sitting rarely occurred at other times of the year.

While feeding in grassland, magpies frequently flee to nearby trees in response to predators or to alarm calls from other birds. This results in an intermittent pattern of feeding, flying, and resting, as occurs in other species that feed in grassland, such as Starlings (*Sturnus vulgaris*) and Brewer's Blackbirds (*Euphagus cyanocephalus*, Verbeek, 1964). It contributes to much of the resting time, particularly in the fall and winter, when the avian predator load increases. Up to a point, increased feeding time, because of lower temperatures, thus generates increased resting time. Theoretically, still lower temperatures would result in yet more time spent feeding and a decrease in watchfulness.

The times of going to sleep and of wakening adhere closely to sunset and sunrise. In November 1968 I noticed that magpies stopped feeding in the late afternoon long before one would expect them to do so, considering the

relative low temperatures and the long night ahead. During summer and the breeding season the reverse was true. Similarly, departure from the roost in the morning is much delayed in the winter in contrast to the summer. In July the birds fed till roosting time and flew straight from the feeding ground into the roost. This behavior appears at least in part related to temperature (Figure 4). With much of the midday made unsuitable by heat (Figure 3), the birds have to begin earlier and stop later. The lower arc of the sun at this time, coupled with the hilly terrain of the study area, produces longer shadows and prolonged diffuse light. In winter magpies are much more cautious before entering and leaving the roost. The selective advantage of a prolonged resting time at dawn and dusk may be that it reduces exposure to predation.

Nest-building.—At a given temperature and food availability, a certain amount of time has to be spent feeding. In winter when nights are long, enough energy reserves have to be stored to maintain the birds till next morning. When temperatures are favorable, and with the day ahead of them, the birds can limit time spent on feeding to meet current physiological requirements, leaving time for other activities such as nest-building or storing acorns. Both these activities occur in the morning. On cold days time spent on nest-building is reduced. On 20 March, with temperatures ranging from 43° to 52°F, a pair brought 41 sticks to the nest from 07:30 to 09:00. In the same period next day, when temperatures ranged from 40° to 44°F, they took only 13 sticks to the nest. Building occurs intermittently over a period of 2.5 months, as magpies build a very large, domed nest. One nest that I took apart stick by stick contained 1,573 branches, and weighed 11,270 g, including the nest lining.

Territorial defense.—The Yellow-billed Magpie maintains its territory year-round. It has no territorial song and defense is effected mainly through postures or by simply standing conspicuously in a tree top on the territory. Although territorial defense can occur at any time of the day it occurs more often in the morning than in the afternoon (Figure 2) for several reasons.

Early in the morning, while engaged in nest-building, birds at times stray onto neighboring territories in search of nesting material. As mentioned, nest-building occurs in the morning, while in the afternoon the birds feed in a flock at some distance from the colony. In the breeding season more time is spent on the territory, and the birds are present there, off and on, all day. Territorial encounters are thus spread out more throughout the day. The high percentage of time spent on defense in the early morning in this period results from frequent visits of yearlings. As in adults, a favorable energy balance in the morning gives yearlings extra time to visit old and new nests in the colony. In the afternoon yearlings feed together with adults. In summer, territorial defense occurs at the end of the morning

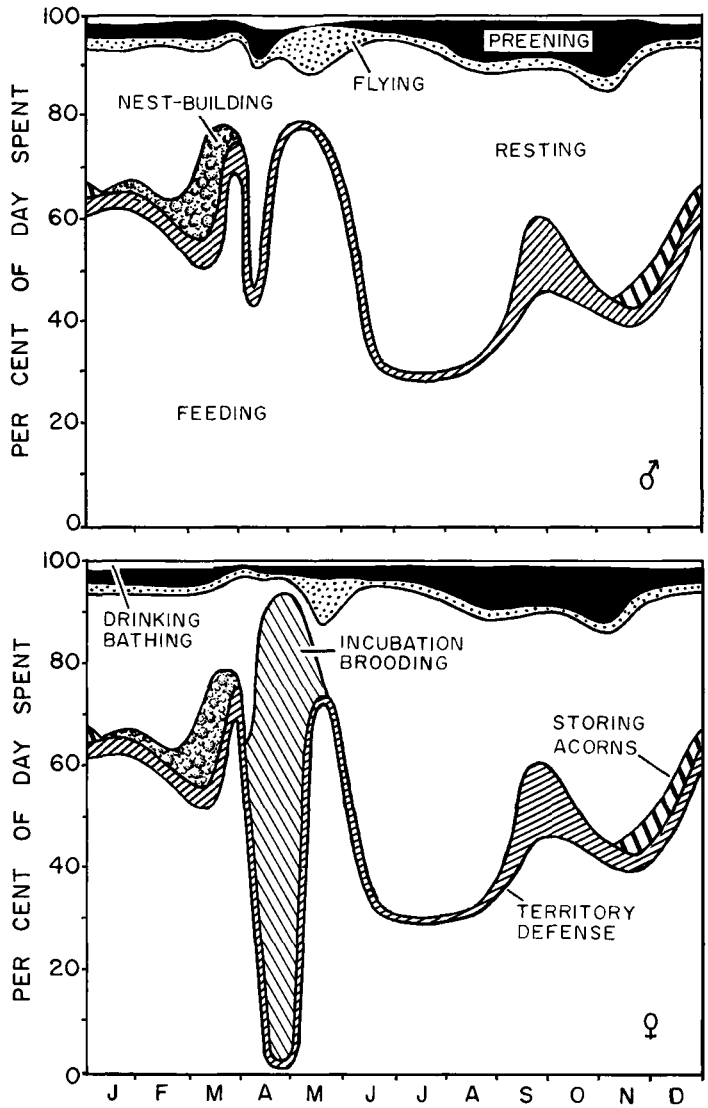

Figure 5. Annual time expenditure of a male and female Yellow-billed Magpie.

feeding period or at the end of the siesta (see Figure 1, June). It is usually associated with a visit of the summer flock to the Hastings Reservation magpie colony in search of water. Territory owners in the flock then try to evict trespassing birds.

Preening and bathing.—Preening is not dependent on a particular time

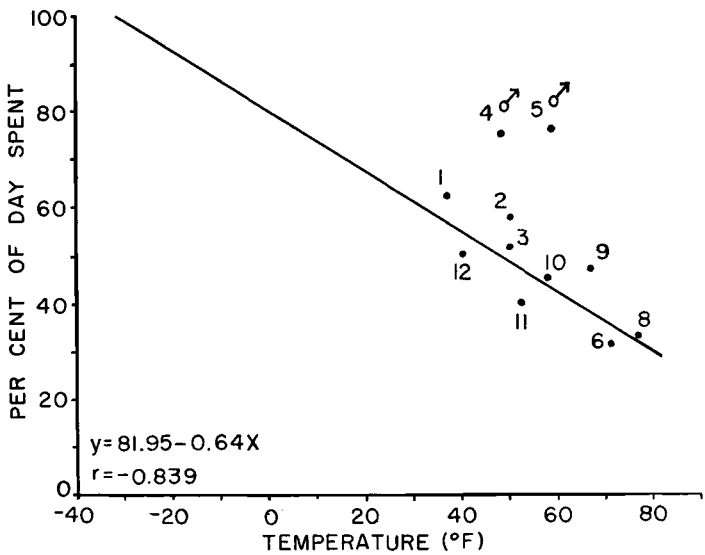

Figure 6. Relationship between percent of day spent feeding and mean ambient temperature. Numbers indicate months. April and May are not included in the calculation of r, because the males increase their feeding time during the time the females incubate. Theoretically, at −28.20 F the birds feed 100 percent of the time.

of the day and occurs almost as much in the morning as in the afternoon. In contrast, bathing and the preening that follows it are essentially restricted to the afternoon. Of 26 records of bathing, only 4 occurred in the morning and 1 at dusk. The remaining 21 occurred in the early afternoon. The temperature at which bathing occurred and the maximum temperatures on those same days were not significantly different (Wilcoxon Rank Correlation test, $P > 0.52$). As bathing occurs primarily in winter and spring when standing water is available, magpies apparently select that time of day when the temperature is highest, which enhances the drying of their feathers. In all cases of bathing the sun was shining.

Annual Time Expenditure

Figure 5 shows the annual time expenditure of a male and a female magpie. As mentioned, only in the breeding season (March, April, and May) was I able to record activities of each sex simultaneously. Time expenditures during the remaining 9 months are based on the "average" bird. For these months the curves in Figure 5 are thus the same, assuming that males and females expend the same amount of time on each activity.

Feeding.—The amount of time spent feeding is related to the ambient temperature (Figure 6) and to the abundance and availability of food.

Food is most plentiful in April and May and scarcest in August and September (Verbeek, 1970). As the female is responsible for incubation (92.3 percent of the day attentive) the male has to feed her. The amount of time he spends feeding is doubled during this period, reaching almost 80 percent of the day. Breeding could not occur earlier in the year simply because of lack of time, as more than 60 percent of the day is devoted to feeding for self-maintenance. Although little time is spent feeding during the summer, breeding could not occur then, even if food were more plentiful, because high temperatures eliminate foraging during most of the day (Figure 3). Considering time alone, breeding could occur in the fall, were it not that food abundance is lower and less stable at this time than in April and May. Timing of the breeding season in the magpie is thus not only related to food abundance but also to the ambient temperature and its effect on time spent on feeding strictly for self-maintenance.

In both sexes time spent feeding is highest during the nestling period. The next highest time expenditure occurs between the completion of the nest and the beginning of egg laying. During this 10-day period increased energy intake in the female is required for egg production. Increase in feeding by the male is less clear, but probably occurs because of his greater energy expenditure for flying and feeding in order to bring food to the incubating female.

Territorial defense.—In the summer, when food is scarce, magpies wander in flocks, and adults spend little time on their territories. This changes in September when adults become more sedentary and yearlings (young of the previous year, now molting into full adult plumage) try to establish themselves in the colony. These various events lead to more time being expended on territorial matters in September and early October than in any other month. Time expenditure on territorial defense continues to decrease as the days become cooler and as more time has to be spent on feeding, and increases again during nest-building and egg laying. From then on it diminishes into the summer.

In the magpie exploitation system, then, territorial matters are decided early in the fall, when demands on time for other activities are low. With a rough outline of the spatial mosaic of territories established early, and increasing familiarity with other members of the colony, little time is devoted to territory in spring. As feeding and nest-building occupy 80 percent of the day at that time, this leaves little room for territorial defense on a scale as displayed in the fall. On this basic aspect of social organization, there appear to be no satisfactory data for *Pica pica*; a point of special interest because of the more severe environment that species occupies.

Preening.—During the nestling period about 80 percent of the day is devoted to feeding. With so much of the day spent on one activity, time

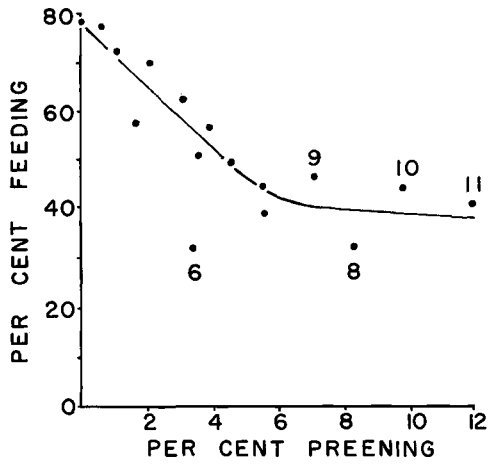

Figure 7. Relationship between percent of day spent feeding and percent of day spent preening.

spent on other activities has to decrease even to the point of total elimination. Whatever is the least important has to give. During the incubation and nestling periods, for instance, the male preens little or not at all (Figure 5). Gibb (1954) reports no decrease in time spent preening during the nestling period in chickadees. Yet with so much of the day devoted to feeding and flying, some form of feather maintenance is necessary. If water is available male magpies usually bathe during the incubation and nestling periods. The bath at this time lasts longer than at other times of the year, but occupies less time than preening would. One long bath a day apparently substitutes for many short periods of preening scattered throughout the day.

Time spent feeding and time spent preening are inversely related for most of the year except during the summer and fall (Figure 7). Also, time spent preening and time spent resting are directly related, except in the summer and fall when proportionately more time is spent preening than resting. Increased preening at this time is associated with molt. Timing of molt is adaptive in that it occurs at a time when high ambient temperatures require less time for procurement of food, which in turn allows more time for resting and preening.

Flying.—Excepting the time spent on flight during nest-building, incubation, and the nestling period, Yellow-bills are on the wing about 1.5 percent of the day. As summer days are longer, actual time spent flying then is greater than in winter. While incubating, the female flies about 0.2 percent of the day. Next to incubation, flying occupies least time during the

TABLE 1
PERCENT ANNUAL DAYTIME EXPENDITURE OF A MALE AND FEMALE MAGPIE

Activity	Male			Female		
	Self-maintenance	Reproduction	Total	Self-maintenance	Reproduction	Total
Feeding[1]	45.5	10.9	56.4	41.8	4.3	46.1
Resting	29.4		29.4	28.3		28.3
Incubating[2]					13.4	13.4
Preening	4.6		4.6	4.2		4.2
Territorial defense		3.6	3.6		3.2	3.2
Flying	1.4	1.3	2.7	1.2	1.3	2.5
Nest-building		1.7	1.7		1.7	1.7
Bathing	1.2		1.2	0.4		0.4
Drinking	0.3		0.3	0.2		0.2
TOTAL	82.4	17.5	99.9	76.1	23.9	100.0

[1] Including carrying acorns.
[2] Including brooding and egg laying.

10 days between the completion of the nest and egg laying. During this time the pair stays close to the nest and spends most of the day feeding. Reduction of flight at this time conserves energy needed for egg production.

SELF-MAINTENANCE AND REPRODUCTION

The foregoing clearly shows that an optimum time exists, both daily and seasonally, for the various activities pursued to maximize survival. The optimum time is that time of the day or year when an activity can be performed most economically in relation to total cost of all activities. By spacing their major activities, birds make most efficient use of their productive energy (Kendeigh, 1969, and earlier). Reproduction in the magpie occurs at a time of the year when higher daytime temperatures lower energy requirements for existence, and when food abundance reaches its highest level. In spite of this, more time is needed during reproduction to satisfy basic energy demands for the adults, for the young, and to supply the extra energy needed to find the food for the young. If food were not plentiful, or energy requirements for existence were higher, reproduction could not occur because of lack of time in a day.

The annual percent of daytime devoted to reproduction is dependent on many factors, such as life style, number of broods per year, and food supply. An adult magpie spends about 20 percent of the annual daytime on reproduction (Table 1). As nonbreeding yearlings do not defend territories, I have included all time spent in territorial defense, even if outside the breeding season proper, in the reproduction budget. As the female alone

TABLE 2
PERCENT TIME EXPENDITURE OF A MALE AND FEMALE MAGPIE DURING INCUBATION AND THE NESTLING PERIOD

Activity	Male			Female		
	Self-maintenance	Reproduction	Total	Self-maintenance	Reproduction	Total
Feeding	38.1	33.4	71.5	29.0	13.1	42.1
Resting	18.2		18.2	9.3		9.3
Incubating[1]					40.6	40.6
Preening	0.8		0.8	0.6		0.6
Territorial defense		1.4	1.4		0.8	0.8
Flying	1.4	4.4	5.8	0.9	4.1	5.0
Bathing	2.2		2.2	0.4		0.4
Drinking	0.2		0.2	0.1		0.1
TOTAL	60.9	39.2	100.1	41.3	58.6	99.9

[1] Including brooding and egg laying.

incubates, the annual percent of time spent on all her other activities, except nest-building, is slightly lower than in the male. The reproductive period (egg laying till fledging) is about 55 days. Table 2 indicates that about 50 percent of this time is devoted to reproduction. The female lays six or seven eggs (ca. 54 g total, and one-third her body weight) for which she herself obtains most of the energy. Part-time incubation begins with the laying of the first egg, which also marks the beginning of the male feeding the female. When full incubation is in progress the female depends almost totally on the male to feed her (Figure 1).

In Tables 1 and 2, the percentage of the feeding time devoted to reproduction is obtained from Figure 5. Assuming that the male did not have to feed the female and the young, his time spent feeding would decline progressively from the level in March to that in June. Time spent feeding above this line is time devoted to reproduction. A similar line drawn for the female shows her feeding time deficit during incubation and the brooding period. During incubation the male doubles his feeding time to 78 percent of the day and quadruples his flying time, because food is found at progressively greater distances from the nest. The male must find more than twice the amount of food each bird found prior to incubation to offset the extra energy needed for incubation and his increased foraging and flying time. Time expenditure in feeding during the nestling period still remains at about 78 percent of the day, while flying time is raised sixfold (9 percent of the day). Eliminating all other activities during the nestling season except feeding and flying, a magpie could devote 90 percent of the day to feeding and 10 percent to flying at temperatures and food levels as occur in May. The observed time expenditure of 87 percent for these two activities is

probably close to the maximum that can be devoted to them, leaving some necessary time for resting and feather maintenance. As feeding time apparently cannot be increased and the total amount of food required increases as the nestlings grow, more food must be found per unit time. In the exploitation system of the magpie this demand is met by timing of the nestling period to peak food abundance, individual exploration for and location of pockets of abundant food, and subsequent mutual exploitation of these by all birds in the colony.

The diurnal time budget of the male Long-billed Marsh Wren (*Telmatodytes palustris*), between 13 March and 30 July (the breeding season) is divided as follows: 61.2 percent feeding, 31.6 singing (including standing and preening), 0.8 territorial defense (all singing excluded), 5.2 nest-building, and 1.2 courtship (data calculated from Verner, 1965a). With two broods per season, the combined nestling and fledgling period is about 60 days, although Verner (1965b) found that not all males participated fully. Considering feeding, for about 75 days of the study period the male only feeds himself and during 60 days he has to feed himself and the nestlings. Thus, about two-thirds of the 61.2 percent (40.8) feeding time is for self-maintenance, the rest (20.4) for the young. Also, only about one-third of the singing time was actually devoted to singing, leaving 21.1 percent for standing and preening. Total time devoted to reproduction is 38.1 percent (20.4 plus 10.5, 0.8, 5.2, and 1.2). The annual time expenditure for reproduction is then 14.5 percent, admittedly a crude value, compared to 17.5 percent in the male magpie. With this amount spent on reproduction the male wren helps to produce two broods, so that the effort per brood is 7.25 percent, although the first brood probably requires more time than the second.

Considering the great variation in the breeding biology of birds, with differing degrees of participation of the sexes in the various phases of the breeding effort, and varying degrees of emphasis placed on them, the amount of annual time devoted to reproduction will vary from species to species and place to place. It is thus of little value to say that the wren is more efficient than the magpie in its use of time. The real test of efficiency is between pairs of the same species in the same area. Natural selection will favor the pair that makes most efficient use of its time, both daily and seasonally.

ACKNOWLEDGMENTS

The manuscript was read critically by F. A. Pitelka, J. Davis, and O. P. Pearson. I wish to thank the researchers at the Hastings Reservation for their cooperation, which made it possible for me to follow the magpies without the birds being disturbed. Gene M. Christman gave advice concerning the figures. A part of this study was supported by a Chapman Grant from the American Museum of Natural History. My wife, Linda, typed and edited the manuscript.

SUMMARY

The time budget of the Yellow-billed Magpie was studied in all months, except July, from August 1968 till June 1970, at the Hastings Reservation, Monterey County, California. A new procedure was developed in which a record of time expenditure per typical day was obtained over several days. The data are presented on a daily and annual basis. Time spent feeding is related to temperature and food abundance and occupies 56.4 percent of the year. High midday temperatures in summer limit feeding to the early morning and late afternoon, and little time is wasted between entering and leaving the roost and feeding. In winter, low daytime temperatures allow feeding all day, although more time is spent feeding in the afternoon than in the morning, as energy has to be stored for the long night. As sufficient energy can be obtained in the afternoon during this season, part of the morning can be devoted to other activities such as nest-building. Annually only 3.6 percent of the time is devoted to maintenance of the territory. Most territorial activity falls in September and October; little time is devoted to it during the spring breeding cycle when other activities require much time. Time spent preening (4.6 percent annually) is proportionately greater in summer and early fall when the birds molt and growth of new feathers requires extra care. Flying time (2.7 percent annually) is greatest in the nestling period. Annually about 20 percent of the time is devoted to reproduction. The time expenditure of the Long-billed Marsh Wren and the Yellow-billed Magpie are compared.

LITERATURE CITED

GIBB, J. 1954. Feeding ecology of tits, with notes on Tree Creeper and Goldcrest. Ibis, 96: 513–543.

GIBB, J. 1956. Food, feeding habits and territory of the Rock Pipit *Anthus spinoletta*. Ibis, 98: 506–530.

KENDEIGH, S. C. 1969. Energy responses of birds to their thermal environments. Wilson Bull., 81: 441–449.

KUUSISTO, P. 1941. Studien über die Ökologie und Tagesrhythmik von *Phylloscopus trochilus acredula* (L.) mit besonderer Berücksichtigung der Brutbiologie. Acta Zool. Fennica, 31: 1–120.

LEES, J. 1948. Winter feeding hours of Robins, Blackbirds, and Blue Tits. Brit. Birds, 41: 71–76.

MORTON, M. L. 1967. Diurnal feeding patterns in White-crowned Sparrows, *Zonotrichia leucophrys gambelii*. Condor, 69: 491–512.

ORIANS, G. H. 1961. The ecology of Blackbird (*Agelaius*) social systems. Ecol. Monogr., 31: 285–312.

PEARSON, O. P. 1954. The daily energy requirements of a wild Anna Hummingbird. Condor, 56: 317–322.

VERBEEK, N. A. M. 1964. A time and energy budget study of the Brewer Blackbird. Condor, 66: 70–74.

VERBEEK, N. A. M. 1970. The exploitation system of the Yellow-billed Magpie. Unpublished Ph.D. dissertation, Berkeley, Univ. California.

VERNER, J. 1965a. Time budget of the male Long-billed Marsh Wren during the breeding season. Condor, 67: 125–139.

VERNER, J. 1965b. Breeding biology of the Long-billed Marsh Wren. Condor, 67: 6–30.

Museum of Vertebrate Zoology, University of California, Berkeley, California 94720. Present address: Redpath Museum, McGill University, Montreal 110, Quebec, Canada. Accepted 8 June 1971.