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## Daily and Seasonal Activity of Moorhens Studied by Motion-Sensitive Transmitters

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**Abstract.**—We studied the diurnal and seasonal activity budget of Moorhens (*Gallinula chloropus*) along a river in NW Italy. Since visual observations are sometimes difficult, we utilized radio-tracking with motion-sensitive transmitters, a technique that distinguishes between resting and walking/foraging activities. Radio-tracking estimates of the home ranges provided values (mean 3-5 ha) about one order of magnitude higher than those reported in the literature and based on visual estimates. Analysis of habitat preferences showed a positive selection for reeds, marsh woods and stretches of water, while cultivated fields were avoided. The percentage of time spent in activity during the day was distributed differently between the colder (December to February) and warmer months (March and April). In winter, the birds were active mainly in the early morning, and resting increased progressively as the day proceeded. In spring, activity was distributed uniformly throughout the day. However, there was no overall difference between the colder and warmer periods in the total time spent in activity each day (about 44%). The time spent in activity was not related to daily temperature. In the same group of birds, the fat reserves were progressively depleted during winter, as demonstrated by a gradual decrease of total body mass and fat; moreover, the loss of mass was greater on colder days. The findings for both activity budget and mass variation suggest that the birds do not try to counteract fat loss; they do not increase the time spent feeding in the colder months nor do they increase their activity during days with lower temperatures. *Received 1 June 1999, accepted 22 October 2000.*

**Key words.**—Moorhen, *Gallinula chloropus*, activity budget, winter, radio-tracking, motion-sensitive transmitters.

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In winter, adverse climatic conditions affect the physiology and behavior of birds (Biebach 1996). Among the adaptations of non-migratory birds in the temperate area, a "true fattening strategy" has been described in passerines (Lehikoinen 1987). This strategy implies that resident birds, when faced with the worst climatic conditions, increase their mass as an insurance against starvation. On a daily basis, mass should be highest in the late afternoon, before the overnight fast. However, fattening involves a trade-off since it can increase the risk of predation (Lima 1986; Gosler *et al.* 1995), bone injury during landing, or pathological costs related to obesity (Witter and Cuthill 1993). A true fattening strategy has been experimentally verified in several small passerines (Biebach 1996). Other birds, including some waterfowl and the Moorhen (*Gallinula chloropus*) do not seem to adopt a "true fattening strategy"

since a gradual decline in body mass is generally observed from autumn to spring (Reincke *et al.* 1982; Whyte and Bolen 1984; Miller 1986; Pawlina *et al.* 1993; Acquarone *et al.* 1998). In these species, the depletion of body reserves during winter leads to an appreciable decrease of mass by spring.

Since an appropriate allocation of lipid reserves is so important in winter, behaviors that increase as a result of foraging or saving of energy should be optimized. Time-budget studies quantify the time animals allocate to different activities, and the resulting information can increase our understanding of wintering strategies in birds.

Several studies have analyzed the wintering strategies of waterbirds from a time-budget perspective by visual inspection of their activities (Goudie and Ankney 1986; Allouche and Tamisier 1989; Rave and Baldassarre 1989; Thompson and Baldassarre 1991).

However, assessment of the activity budget in elusive species or in individuals ranging over large territories requires different techniques. The use of radio-tracking to locate the position of an individual is one such technique. For example, in the Lesser Scaup (*Aythya affinis*), feeding bouts were easily recorded since the radio signals are weaker during diving but stronger while the bird was on the surface (Custer *et al.* 1996). Recently, a motion-sensitive transmitter was used in the European Oystercatcher (*Haematopus ostralegus*) to record activity and foraging patterns (Exo *et al.* 1996).

The aim of the present study was to determine by means of radio-tracking the home range, habitat selection and activity budget in a group of Moorhens resident in north-west Italy. Two-stage transmitters allowed us to distinguish activity and rest periods. Another aim of the research was to integrate into this our previous findings of a progressive body mass decrease during winter (Acquarone *et al.* 1998) with behavioral data on movements and time budget in this season. We also tested whether air temperature, which in our study birds was related to daily variations in body mass, also influenced the daily activity pattern.

#### METHODS

The study was carried out at Novi Ligure along the Scrivia River (NW Italy, 44°46'N, 8°51'E), during the winters and early springs of 1996-1997 and 1997-1998 (from December to April). The area is 100 m a.s.l. and has a temperate continental climate. The birds were captured in funnel traps and were marked with numbered, metal bands (Acquarone *et al.* 1998). Individuals were equipped with motion-sensitive radio transmitters (148 MHz) contained within plastic collars positioned on the bird's neck. We used commercially available two-stage transmitters (Ziboni techniques, Bergamo, Italy) with outer dimensions of 30 × 15 × 18 mm and a weight of 11 g, equivalent to 3-4% of Moorhen body mass. A 3.5 v lithium battery provided about 5 months of life. Each transmitter was tuned to an individual frequency. With a six-element Yagi antenna, the signals could be detected over a distance of 2 km. To record activity patterns, we used 10 mm long mercury tilt-switches as a motion sensor (Exo *et al.* 1996). The transmitters emitted brief pulses (10-20 msec) and the pulse interval varied from 90 pulses min<sup>-1</sup> (fast pulse rate) to 55 pulses min<sup>-1</sup> (slow pulse rate). To interpret the meaning of results, we scaled the pulse intervals by visual observations. When Moorhens engaged in dynamic activities, such as foraging or walking, the transmitter always produced a slow pulse rate, while quietly swimming or resting it produced a fast pulse rate.

We did not notice any short-term effects of the presence of the transmitters on the behavior of the individual. Marked birds returned to forage in small groups with other Moorhens, and foraged, swam and walked in the same manner as untagged birds. We followed five Moorhens in the winter of 1996-1997 and four in 1997-1998, but only six individuals (three each winter) provided a five-month series of data (due to battery problems and the disappearance of three birds). The telemetry sessions, usually lasting six hours, were diurnal (between 06.00 and 20.00 h) and alternated between morning and afternoon, every three days or weekly. During each session, fixes and pulse rate assessments were performed every 15 min. We did not carry out regular nocturnal telemetry sessions, since on several nights, exploratory studies showed the Moorhens were always resting and inactive.

We quantified the activity patterns as percentage values by calculating the ratio: (N radio fixes with activity) / (N fixes with activity + N fixes without activity) \* 100. The index varied from 0 (when all fixes indicate a quiet individual) to 100 (when all fixes indicate foraging activity).

The relationship between activity and air temperature was explored. We performed ANCOVAs with temperature and activity as x and y variables, and individuals as group, in order to account for the different individuals. Since rain and snow occur only occasionally in our study area, we could not utilize these variables. The temperature values were supplied by the Pioppicoltura Institute at Casale, 20 km from the Scrivia River area.

Range IV software (Institute of Terrestrial Ecology, Wareham, UK) was used for the analysis of the radio-tracking data. Range sizes and shapes were first obtained through kernel (95% areas) and minimum convex polygon (MPC) analyses. In the MPC method, the home range is described by connecting the outermost fixes by straight lines, while the kernel method is a contouring technique that uses a mathematical model to estimate fix density across the range (White and Garrott 1990). In order to investigate habitat selection, we compared the proportions of different habitat types (available habitat) in the study area with the proportions of habitat types within the individual home ranges (kernel and MPC habitat use). A second check on habitat selection was carried out by comparison of the proportions of available habitat types with those of a 10 m buffer area located around the fixes (buffer habitat use). By excluding all unused areas, this method allows a more precise assessment of short-distance habitat selection. Seven broad categories of habitats were designated: (1) open water, (2) reeds, (3) shrubs, (4) maize and wheat fields, (5) fields of grass, (6) marsh woods, (7) willow woods. The areas of available, utilized and buffer areas were calculated by MapInfo GIS, after digitization of the Range IV outputs and of the field data.

#### RESULTS

##### Habitat Selection

Home-range size was significantly greater from December to February (mean 5.07 ha ± 0.43 SD, N = 6, Kernel method) than from March to April (3.22 ha ± 0.32 SD, N = 6;  $t_{10} = 7.72$ ,  $P < 0.01$ ).

According to the MPC and kernel methods, Moorhens used reeds, marsh woods, and open water habitat categories more frequently than expected for the areas available, while maize and wheat field habitats were under-utilized (Table 1). Grass fields and shrubs were utilized in the same proportion as was available. The 10 m buffer areas showed a stronger selection for the open water habitat than evidenced with MPC and kernel method (Table 1).

Activity Budget

The activity of Moorhens in the colder months, from December to February, was highest in the morning and decreased progressively in the afternoon. Figure 1a shows the activity pattern of one individual in 1997. All individuals reduced their activity with similar regression slopes (ANCOVA  $F_{5,165} = 1.88$ , n.s.). On the whole, there was a signifi-

cant decrease of activity with time of day (ANCOVA  $F_{5,165} = 4.48$ ,  $P < 0.04$ ). In general, the activity decreased from more than 60% of the time in the morning to less than 30% in the afternoon. On each day, the individuals foraged an average of  $40\% \pm 6.5$  SD (N = 6) of the time.

Moorhen activity in March and April did not decrease progressively from morning to afternoon. Figure 1b shows the pattern of one individual in 1997. No individual exhibited a significant variation in the percent of time spent actively in relation to the time of day. On each day, the individuals foraged  $47\% \pm 6.0$  SD (N = 6) of the time.

There was no trend toward a variation in the percentage of time spent in activity each day as the season progressed (ANCOVA  $F_{5,287} = 0.18$ , n.s.; Fig. 2). On average, Moorhens spent  $44\% (\pm 5.2$  SD, N = 6) of their time foraging. No difference was found between individuals ( $F_{5,287} = 0.88$ , n.s.).

**Table 1. Relative habitat availability and habitat use by Moorhens at the Scrivia River. Observed frequencies of habitat use calculated with three methods: 1) kernel, 2) minimum convex polygon (MPC), and 3) 10-m buffer areas around fixes. The percentage of available habitats is reported in italics.**

Method	Habitat (%)						
	Marsh woods (19.4%)	Shrubs (3.25%)	Reeds (1.05%)	Maize & wheat (22.3%)	Grass fields (41.6%)	Willow woods (2.45%)	Stretches of water (9.89%)
December, January and February							
Kernel %							
Mean	23.5	8.1	2.1	6.7	39.7	2.5	17.4
(SE)	$\pm 5.8$	$\pm 1.9$	$\pm 0.5$	$\pm 7.8$	$\pm 8.9$	$\pm 1.2$	$\pm 0.7$
MPC %							
Mean	24.1	6.7	2.3	5.7	39.8	1.5	15.8
(SE)	$\pm 8.6$	$\pm 2.4$	$\pm 0.4$	$\pm 3.7$	$\pm 9.6$	$\pm 1.1$	$\pm 1.8$
Buffer area %							
Mean	26.7	7.1	2.9	4.7	33.6	2.5	22.3
(SE)	$\pm 6.2$	$\pm 2.4$	$\pm 0.6$	$\pm 2.9$	$\pm 9.9$	$\pm 1.2$	$\pm 1.3$
March and April							
Kernel %							
Mean	32.1	5.4	2.7	0.0	33.2	5.1	21.5
(SE)	$\pm 7.0$	$\pm 2.6$	$\pm 0.7$		$\pm 7.3$	$\pm 1.6$	$\pm 2.8$
MPC %							
Mean	50.7	1.4	3.9	0.0	13.8	7.8	22.3
(SE)	$\pm 2.7$	$\pm 1.4$	$\pm 0.6$		$\pm 2.5$	$\pm 3.8$	$\pm 1.7$
Buffer area %							
Mean	29.9	5.1	3.5	0.0	31.1	3.7	26.7
(SE)	$\pm 7.3$	$\pm 2.6$	$\pm 0.8$		$\pm 8.5$	$\pm 1.5$	$\pm 2.4$

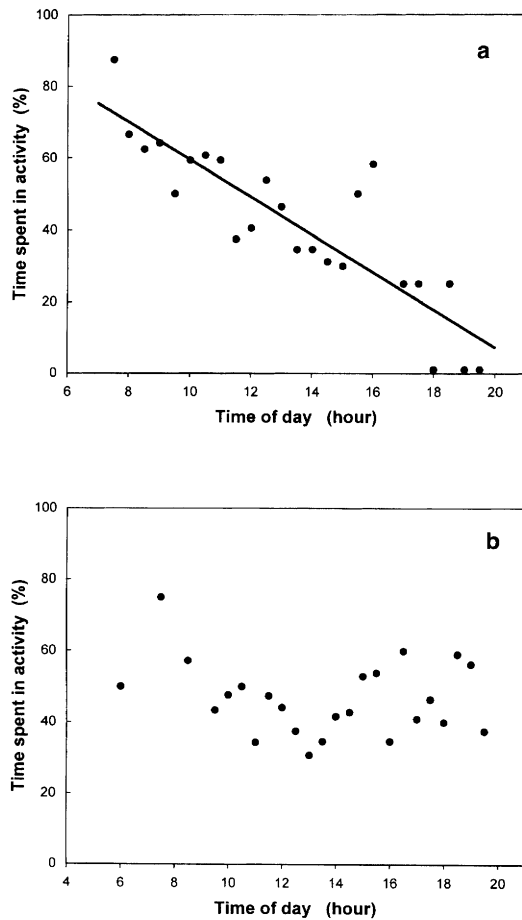


Figure 1. Daily activity budget of Moorhens in relation to time. Example of one individual in the winter 1996-1997. (a) colder period (December, January, February), line equation:  $y = -5.23x (\pm 0.63 \text{ SE}) + 111.9 (\pm 8.7 \text{ SE})$ . (b) warmer period (March and April).

The daily maximum temperature and time spent in activity were not correlated with each other (Fig. 3), either from December to February (ANCOVA  $F_{5,165} = 0.30$ , n.s.) or in March and April (ANCOVA  $F_{4,102} = 2.15$ , n.s.). A similar lack of a correlation was found between activity and minimum temperature (December to February: ANCOVA  $F_{5,165} = 0.48$ , n.s.; March and April: ANCOVA  $F_{4,102} = 0.04$ , n.s.).

#### DISCUSSION

##### Home Range and Habitat Selection

Moorhens can occupy either all-purpose or separate territories for pair-forming, brood-rearing or feeding (Cramp and Sim-

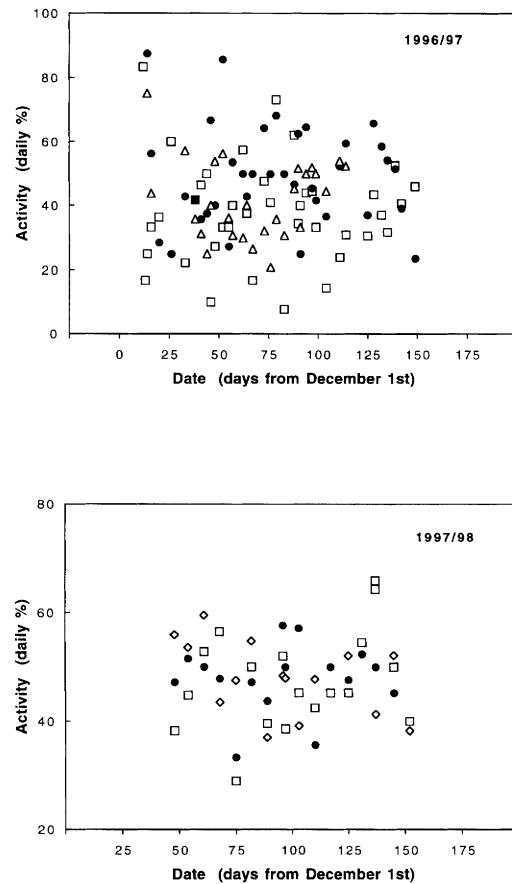


Figure 2. Seasonal variation of activity budget of Moorhens. Values from each individual indicated with different symbols. (Top: 1996-1997. Bottom: 1997-1998).

mons 1980). In our study area, all-purpose territories were not adopted. Moorhens did not defend territories throughout the year (aggressive behavior between individuals is absent in winter) and we found an appreciable reduction in the home range from winter to spring. This suggests that home-range size closely matches individual resource requirements (Petrie 1984) and that size was adjusted month after month.

The winter home range was very large (5 ha); indeed, even later in the season the value (3 ha) was still one order of magnitude higher than the values reported in England (0.06 ha, McRae 1997) and Italy (0.15 ha, Prigioni pers. comm.). The difference in size could be related to differences in habitat quality in the three areas, or to the different methods employed to estimate the home

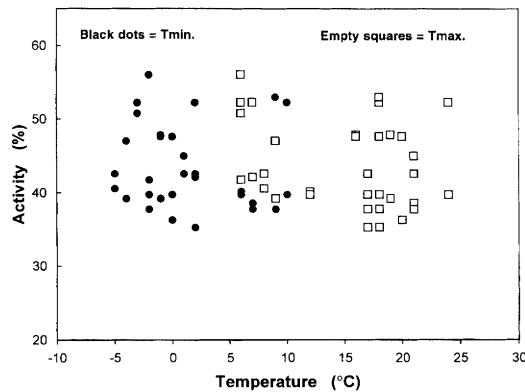


Figure 3. Daily maximum and minimum temperature and time spent in activity by Moorhens. Example of one individual in the winter 1996-1997 (activity percentage values on y-axis were normalized by arcsine transformation).

range. We tracked all movements by radio-transmitter signals, including excursions outside the core area. In the other two studies, it was likely that an underestimation of home-range size occurred because the assessment method (by visual observation of fights at the territorial boundary) did not include the undefended portion of the territory.

Several studies have examined the habitat preference of Moorhens during the breeding season (Wood 1974; Caruso *et al.* 1989; Heimsath *et al.* 1993); however, little is known about habitat selection during the rest of the year. In our study, Moorhens used reeds, open water and marsh woods more frequently than expected for the areas available; however, the dominant habitat (grass fields) still was the most frequented one. A selection of water environments appears to be typical of the species (Cramp and Simmons 1980), even though opportunistic occupation of slightly different water habitats is regularly observed.

### Activity

Moorhens showed a different pattern of diurnal activity between winter and spring. In winter, activity was mainly concentrated in the morning and decreased significantly as the day proceeded, whereas in spring activity was uniformly distributed throughout the day.

The Red-knobbed Coot (*Fulica cristata*) in a tropical climate, shows a reversed activity pattern, with an increase in the time spent foraging from morning to afternoon (Fasola and Canova 1993). The Moorhen's circadian pattern of winter activity (actively feeding in the early morning and then reducing the activity) could be explained as a strategy to minimize the risks of being heavy and active in the presence of diurnal predators (Metcalf and Ure 1995), such as raptors that prey mainly in the warmer hours of the day (pers. obs.).

Although Moorhens differed between winter and spring in their diurnal activity, the total amount of time each day devoted to feeding did not differ significantly. In our study, birds were active for about 44% of the day, a value similar to the 46% found in the Red-knobbed Coot in winter (Fasola and Canova 1993) and in line with the value predicted by the equation of Bryant and Westertep (1980) for birds of the Moorhen's size. However, a seasonal constancy in the total time spent feeding is not the rule in birds and adjustments of the activity budget have been found in other waterbird species. Gadwall (*Anas strepera*) reduce their activity in winter (Allouche and Tamisier 1989), while in the Green-winged Teal (*Anas crecca*) (Rave and Baldassarre 1989) the time spent feeding is higher in October-November (38%), a period of lipid deposition, and lower (28-33%) from December to March.

It is interesting to compare movements and activity budget with body lipid reserves. Fat reserves of Moorhens were progressively depleted during winter, and loss of mass was higher on cold days (Acquarone *et al.* 1998). However the birds did not try to counteract mass reduction, since they did not increase feeding time in the cold months nor did they increase their activity during days when temperatures were low. These findings suggest that Moorhens did not respond to higher metabolic demands in winter with a true fattening strategy. Instead, they adopted a reserve depletion strategy, in which they stored energy reserves before the cold season and minimized their energy requirements during winter through constant activity and reliance on stored reserves.

In our study, there was no obvious relationship between daily activity and climatic factors. This agrees with findings on five species of ducks (Hepp 1985; Thompson and Baldassarre 1991) but contrasted with increased feeding with decreasing temperature found in other species (Jorde *et al.* 1984). It is likely that the activity of waterbirds is more independent of weather in mild temperate and tropical climates because of the low number of days below the minimum critical temperature (Wooley and Owen 1978; Thompson and Baldassarre 1991).

In conclusion, we suggest that the Moorhen, like the Coot (*Fulica atra*) (Visser 1978) and many duck species, adopts a pattern of autumnal fattening, a preadaptation which may be important for survival in subsequent months. Since the seasonal decrease in body mass is very pronounced, even in mild winters (Visser 1978), this loss of mass could be adaptive. However, if extremely severe weather conditions make food unavailable or if prolonged low temperatures cause exceptional consumption of a bird's reserves, body mass could be depleted to very low values, with the risk of starvation (Suter and Van Eerden 1992). In these cases, a restoration of body mass through increased activity would be predicted.

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