and shell mass (Fig. 2). I will briefly note some of the patterns found in the data presented in these figures. First, there is a wide variation in the range of egg sizes found in the clutches (contrast the half- and fully-shaded circles). Second, egg size to component mass relationships can vary from log-linear to apparently random (in Fig. 1, contrast half-shaded squares with fully-shaded triangles). Third, a linear egg size to component mass relationship for one component does not necessitate a similar relationship for other components (contrast the half-shaded squares in Figs. 1 and 2). In short, there was no consistency in the way egg composition varied with egg size within a clutch.

These data suggest that it may be incorrect to infer the pattern of variation in egg composition within clutches from data describing variation among clutches. Although allometric relationships between egg size and component masses may exist when populations are considered as a whole, this was not consistently found in all separate clutches. Only water content was consistently predicted by egg size within clutches and bore a similar relationship with egg size both within and among clutches (Table 1). Thus it appears that egg size is generally a poor predictor of egg composition within a clutch. Unfortunately, clutch sizes of many species are too small for adequate regression analysis, as was the case here, and it would be difficult to test the generality of my findings. The data suggest that if egg composition has an effect on whether a chick is likely to die, this effect is not correlated with egg size. Laying sequence was not known for the eggs in this study. Egg composition may still function in brood reduction. Potentially, egg composition could vary in some systematic way through the laying sequence, which would indicate that laying sequence within a clutch is more important than egg size in determining which chicks are likely to die.

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SLEEPING BEHAVIOR OF BLACK-BILLED MAGPIES UNDER A WIDE RANGE OF TEMPERATURES[1]

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Key words: Sleep; thermoregulation; Black-billed Magpies; Pica pica.

Many bird species are reported to sleep with their bills tucked under their scapular feathers (Goodwin 1976; Amlaner and Ball 1983). This sleep posture probably offers thermoregulatory advantages because covering the bill in feathers is a likely means of preventing heat loss. In this context, it would be interesting to know whether nonmigratory birds adopt this posture more readily during the coldest nights of winter than during milder nights, and conversely whether they still sleep in that posture under summer temperatures that are within their thermoneutral zone. In an attempt to provide such information, I report here on my observations of Black-billed Magpies (*Pica pica*) sleeping under temperatures varying between −30°C and 23°C. I also give a brief description of their sleep posture and night behavior since these, to my knowledge, have never been reported for any single species under such a wide range of temperatures.

MATERIAL AND METHODS

The Black-billed Magpie is a medium-sized corvid whose distribution range extends from Alaska to central California and western Texas (Linsdale 1937). It is typically nonmigratory and is therefore present during the winter in central Alberta, where this study was undertaken. Here (Reebs 1985) as in other places (Mugaas and King 1981), magpies roost communally from July to April, in dense thickets of deciduous trees in the fall, and dense thickets of conifers in winter. In central Alberta, they must face average minimum night temperatures of −19°C in January and 12°C in July.

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Twice during the winter of 1984–85, three juvenile magpies were captured with a baited funnel trap (Alsager et al. 1972), individually-marked with black hair dye on their white belly feathers, and moved into an outdoor aviary located in a rural area 7 km south of Edmonton (115°30′W, 53°30′N). This aviary consisted of a 10.0 × 3.6 × 1.9 m wire mesh enclosure adjacent to a 1.8 × 3.6 × 2.3 m observation booth. A one-way glass window in the booth allowed unobtrusive observation of the birds in the flight cage. A linear arrangement of five perches on which the birds spent the night was present 2.4 m away from the one-way glass. Each perch consisted of a 3.8 × 3.8 × 190.0 cm post mounted with a dowel 1.76 m high, 20 cm long, and 1 cm in diameter. A row of four other posts 6 cm apart was present on both sides of each perch to provide some wind protection as well as physical separation from the other perches. The wire mesh directly above the line of perches was covered with planks to provide protection from rain, snow, and exposure to the open skies. Three infra-red lamps, each one made of a 60 W light bulb set up in a lightproof cardboard box that had a Wratten gel infra-red filter (Kodak #87C) mounted on one side, were hung from the ceiling of the flight cage 2.4 m away from the perches. Transmittance values for the filters were 0.55% at 790 nm and 78.5% at 890 nm. Air temperature near the perches was not significantly affected by the presence of the lamps, nor was there any sign that magpies were disturbed when the lights were on. Altogether, conditions in this aviary approximated those found in natural roosts, in that the birds slept in the company of conspecifics, were exposed to natural light-dark cycles and ambient temperatures, and were provided with overhead cover, partial wind protection, and dowels of appropriate diameter.

Three females made up the first group of magpies, which occupied the aviary from 1 December to 11 January. The second group, two females and one male, occupied the aviary from 27 January to 5 March. Nightlength (sunset–sunrise) varied between 16.1 hr and 16.5 hr during the first of these two periods, and between 12.9 hr and 15.3 hr during the second. In each one of the two trials, I haphazardly selected 10 nights for observation on the basis of their widely different temperatures (as measured 2 hr after sunset by the University of Alberta Meteorological Station, located 2 km south of the aviary). Observations were made *ad libitum* (Lehner 1979) during the first 4 hr following sunset, using an infra-red visionscope (FJW Industries) equipped with a 200 mm Nikon telephoto lens. Magpies never huddled, which allowed clear view of all three birds. Notes were made of the posture of each bird throughout the observation period. From these notes, the time at which each bird first adopted the sleep posture could be estimated to the nearest 6 min.

I also made qualitative observations of the magpie's nocturnal behavior during preliminary work at the aviary in the summer of 1984 (three magpies observed throughout six nights), and indoors in the summer of 1985 (two caged birds observed during three nights). These observations have been included in this report.

RESULTS

In what I call the sleep posture, magpies had their bills tucked under their scapular feathers and back feathers. In winter, the fluffed up belly feathers covered the tarsus and toes as well as the dowel upon which the bird sat. The scapular and back feathers were also fluffed up, covering the bill, most of the head, including the eyes, and part of the wings. The shape of the magpies in this position approximated that of a ball. On warm (12 to 20°C) summer nights, or inside at room temperature, the tarsus and toes were uncovered, and the back and scapular feathers were only slightly elevated, thereby covering less of the head and wings. One of the eyes could then be seen when observed at an angle from the front. I never observed it to be open, even after 10 min of continuous observation.

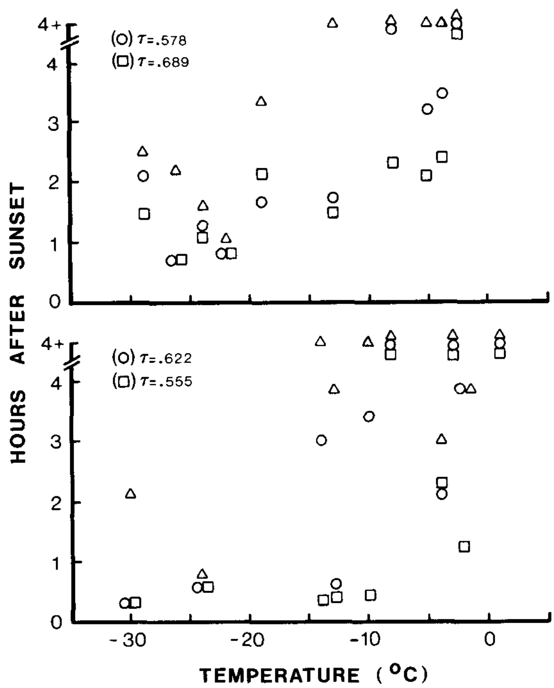

FIGURE 1. Latency to adopt the sleep posture at night as a function of ambient temperature in six black-billed magpies, divided into two groups. First group (top diagram) was observed in December and January, whereas second group (bottom diagram) was observed in February and March. Individual birds within groups are represented by different symbols. A latency value of 4+ indicates that the bird did not adopt the sleep posture during the first 4 hr after sunset. Kendall's tau correlation coefficients are shown for four of the birds. All four coefficients are significant ($P < 0.02$). In the correlation test, 4+ latency values were ranked as ties between themselves, as were latency values separated by less than 6 min.

Unless disturbed, magpies remained in the sleep posture once thay had adopted it. Shining a light beam for up to 15 min directly at the magpies when in the sleep posture never elicited any response from them, in either summer or winter, although the same stimulus greatly alarmed them when they were not in the sleep posture. On the other hand, unusual noises such as that made by planes passing overhead often prompted the magpies to expose their heads instantaneously, and to keep their eyes open and their bill pointing forward for various times (a few seconds to slightly more than 18 min) before resuming the sleep posture. Occurrence of, and response to, unusual noises were not measured in a systematic way, but it was my impression that both sensitivity to noise and latency to resume the sleep posture decreased as night progressed and also decreased under colder temperatures.

Prior to adopting the sleep posture, magpies remained immobile on their dowels with their feathers fluffed up, head drooped between the shoulders, bill pointing forward, and eyes open. I never saw their eyes closed in this posture, except on several occasions in winter, always 2 to 3 min before the observed bird took the sleep posture. Therefore I assume that magpies did not sleep until a few minutes before taking the sleep posture.

In winter, latency to adopt the sleep posture after sunset depended on temperature (Fig. 1). The data shown in Figure 1 are amenable to Kendall's rank correlation test (Conover 1980), if the following caveats are kept in mind. First, independence among members of the triads is assumed because magpies remained silent, immobile, and could not see each other easily in the dark. Second, independence between nights is assumed because the 10 nights of observation were spread out over more than a month. Finally, latencies of more than 4 hr theoretically could not be ranked between themselves but were nevertheless considered as ties. A large number of such ties would render correlation coefficients difficult to interpret. For this reason, the two birds that displayed a large number of latencies of more than 4 hr (half or more of the total number of observation nights, see triangles in Fig. 1) were not subjected to the correlational analysis. Only data yielded by the other four birds were subjected to the analysis. All four birds showed significant positive correlation between temperature and latency to adopt the sleep posture (Fig. 1), indicating that they assumed the sleep posture earlier on colder nights.

DISCUSSION

During winter nights magpies slept in a posture that reduced heat loss by minimizing surface/volume ratio as well as exposure of uncovered body parts (feet, bill, eyes). I observed that magpies adopted this posture more readily during the coldest nights of winter than during milder nights. This supports the notion that the sleep posture offers thermoregulatory advantages. However, it also raises the question of whether the sleep posture is always associated with sleep. To sleep during the early hours of long winter nights seems superfluous since magpies did not do it at near-zero temperatures. Is it possible that during the early hours of the coldest nights magpies adopted the sleep posture to reduce heat loss but remained awake, possibly to better detect unusual noises that might signal the approach of danger? In the absence of EEG recordings, this question remains unanswered. Until more research is conducted on this topic, caution should be used when relying only upon postural criteria to define sleep under cold temperatures.

On warmer (12 to 20°C) summer nights, magpies ceased to cover their feet and eyes, an indication that thermoregulatory needs can modify the characteristics of a sleep posture. However, even indoors at room temperature, magpies still tucked their bill under their scapulars. This seems surprising because the thermoneutral zone of the Black-billed Magpie extends from 21.0 to 32.5°C (Hayworth and Weathers 1984), and thus there is no need for heat conservation at 23°C. It is possible that, in the magpie at least, the "bill under scapulars" posture is the only one compatible with the neck muscle relaxation that commonly occurs in sleeping birds (Goodman 1974). Without scapular feathers and folded wing to hold it in place, the bill might slide over the shoulder, causing the head to drop forward when the bird falls asleep. This could hinder its balance on the perch. This mishap sometimes happens to young (about 3 weeks old) magpie chicks when they put their bill on rather than under their partially developed back feathers (pers. observ.).

Magpies appeared to keep their eyes closed while in the sleep posture. In this they differ from other species such as the Mallard (*Anas platyrhynchos*) (Lendrem 1983), Herring Gull (*Larus argentatus*) (Amlaner and McFarland 1981), and Barbary Dove (*Streptopelia risoria*) (Lendrem 1984), all of which have been reported to open their eyes at regular intervals of a few seconds during their sleep, presumably to visually scan the environment for predators (Amlaner and Ball 1983). Magpies, in contrast, seemed to rely more on their sense of hearing than on vision to first detect disturbances. This could be related to the need to cover the eyes with feathers to reduce heat loss on very cold nights, and/or to the nature of the Magpie's usual roosting sites. In the wild, magpies roost in dense thickets where visibility is reduced and darkness deep. It may not be possible to see a predator, but it would be possible to hear the noise this predator would make when moving through the network of branches and twigs that characterizes such habitat. Ducks, gulls, and doves, on the other hand, roost in open places, or sleep during the day when levels of illumination allow for good visibility (e.g., Lendrem 1983). Further observations of different bird species sleeping in various environmental conditions would be needed to establish any possible relationship between sleeping/vigilance behavior and roosting site.

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