Zoology in the Middle East

ISSN: 0939-7140 (Print) 2326-2680 (Online) Journal homepage: https://www.tandfonline.com/loi/tzme20

Magpies, *Pica pica*, at the southern limit of their range actively select their thermal environment at high ambient temperatures

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Abstract. The effect of high ambient temperatures on the behaviour of Magpies (*Pica pica*) was assessed in northern Cyprus, which marks the southern limit of their European range. Magpies actively selected their thermal environment when temperatures rose above 31°C, by retreating to shaded areas. On days when the temperature was higher, Magpies appeared to spend more time perched in the shade and less time foraging. Flying and foraging activities were generally restricted to cooler parts of the day. Magpies were rarely seen panting or drinking and gular fluttering was not observed. We suggest that utilisation of shade is important for Magpies to regulate their body temperature, allowing them to remain common at the southern limit of their range despite experiencing high temperatures.

Kurzfassung. Bei der Elster (*Pica pica*) wurde im nördlichen Zypern, dem südlichsten europäischen Vorkommen der Art, der Effekt hoher Umgebungstemperaturen auf das Verhalten untersucht. Wenn die Umgebungstemperaturen über 31°C ansteigen, wählen Elstern aktiv ihre thermische Umwelt aus, indem sie sich an schattige Plätze zurückziehen. An Tagen mit hohen Umgebungstemperaturen verbringen Elstern mehr Zeit im Schatten mit Ruheverhalten, und dafür weniger für Nahrungssuche. Fliegen und Nahrungssuche sind dann normalerweise auf die kühleren Tagesstunden beschränkt. Erhöhte Atemfrequenz und Trinken wurde nur selten bemerkt, Hecheln gar nicht. Wir vermuten, dass die Ausnutzung von Schatten für die Thermoregulation der Elster von großer Bedeutung ist, und das Vorhandensein schattiger Plätze die Voraussetzung für das häufige Vorkommen an der Südgrenze ihres Brutareals trotz der hohen Umgebungstemperaturen ist.

Key words. Behavioural thermoregulation, Magpie, geographical distribution, northern Cyprus, Mediterranean, heat stress.

Introduction

Abiotic factors, such as climate, have long been thought to be the primary driving force that determines the distribution and abundance of species (ANDREWARTHA & BIRCH 1954). However, remarkably little is known of the factors that limit the broad geographical ranges occupied by avian species. While the winter range limits of birds in relation to cold stress has been investigated (ROOT 1988), the effect of heat stress in shaping avian distributions has received little attention. The extent to which temperature restricts the distribution of avian species may be investigated by the study of widely distributed resident species such as the Magpie (*Pica pica*), a non-migratory bird which is found throughout most of the northern hemisphere (BIRKHEAD 1991). In the Palaearctic its distribution ranges from Britain and Ireland in the west, to the Kamchatka Peninsula in eastern Russia. In Europe it extends from

Zoology in the Middle East 32, 2004: 13–25.
ISSN 0939-7140 © Kasparek Verlag, Heidelberg

Published online 28 Feb 2013

71°N in Norway and Sweden to 35°N in the Mediterranean (CRAMP & PERRINS 1994). In Cyprus, the Magpie is at its southernmost limit in Europe yet is described as a common resident occurring at altitudes of up to 1500 m and is present in all habitat types (FLINT & STEWART 1992).

Cyprus lies in the eastern Mediterranean and has an extreme Mediterranean type climate, characterised by long, hot, dry summers. During the period of July to September rainfall is negligible and the average daily temperature during July and August is 29°C but midday temperatures frequently exceed 39°C (FLINT & STEWART 1992). As most bird species are diurnal, they face potential thermoregulatory problems in hot climates such as that prevailing in Cyprus (DAWSON & HUDSON 1970). Many studies have been carried out to investigate the physiological and behavioural means by which birds can reduce heat stress (e.g. DAWSON & HUDSON 1970, CALDER & KING 1974, THOMAS & ROBIN 1977, WARD & PINSHOW 1995). Some studies have investigated these factors in Magpies (STEVENSON 1971, HAYWORTH & WEATHERS 1984). These studies involved laboratory based investigations of body temperature regulation, oxygen consumption and evaporative heat loss in relation to the operative temperature experienced by the birds. Although birds lack sweat glands and are covered by an insulating layer of feathers, cutaneous water loss and thus heat loss through evaporation over the body surface can be considerable (MCNABB & MCNABB 1977, WILLIAMS 1996). Respiratory evaporative cooling is also an important method of thermoregulation when birds are faced with high operative temperatures and the thermoregulatory demands exceed that possible by convection. This is augmented in many birds by panting and gular fluttering (CALDER & KING 1974). However, physiological means may not be sufficient and so birds have a variety of behavioural means by which they can reduce heat stress, including retreating to shaded areas during periods of intense heat (DAWSON & HUDSON 1970).

Since Magpies in Cyprus are faced with consistently high temperatures during the summer, they may employ physiological and/or behavioural means to reduce heat stress. While the general ecology of Magpies has been extensively investigated (BIRKHEAD 1991), very little work has been published on thermoregulation in this species. HAYWORTH & WEATHERS (1984) and STEVENSON (1971) used physiological measurements of captive Magpies at a range of temperatures to demonstrate that the limits to the southern and eastern range of the Magpie in North America were determined by an upper critical temperature of about 40°C. However, they presented no data on Magpie ecology in the field to support this conclusion. No comparative studies of Magpie distribution in relation to climate have been undertaken on Eurasian Magpies (BIRKHEAD 1991).

The selection of an agreeable thermal environment is an important part of thermoregulation in birds (CALDER & KING 1974) and although this is well known in all vertebrate groups (HAMMEL 1968) it has been little studied in birds. Here, we investigated whether Magpies in northern Cyprus actively selected their thermal environment and if this behaviour was related to the temperature experienced by the birds in the field.

Material and methods

Fieldwork was carried out in northern Cyprus between June and September 1996. In order to investigate whether Magpies in this area, which marks the southern limit of their European distribution, showed any behavioural or physiological adaptations likely to be aimed at reducing heat stress, two types of transect were carried out.

12 km driving transect

A distance of 12 km was travelled by car along the same 12 km stretch of road from Alagadi (35°33'N, 37°47'E) to the outskirts of the main town of Girne (Kyrenia), with the number of Magpies observed being recorded. In order to standardise the data, a speed of 48.3 km/h (30 m/h) was adhered to. In addition, only one, non-driving observer recorded activity in order to compensate for possible observer bias (BIBBY et al. 1992). This transect was carried out at varying times of the day between 07:00 and 19:00 with a total of 120 transects being completed between June and September, inclusively. Magpie activity was classified as follows: (1) Active i.e. flying or foraging; (2) Inactive i.e. perching above ground. All Magpies on the ground were deemed to be foraging. The information gathered from these transects was expected to illustrate a general trend of activity with fewer Magpies seen at times of day when they were resting or hiding. In order to more closely investigate any heat avoidance behaviour, a second, walking transect was undertaken.

3 km walking transect

A 3 km route was chosen in the vicinity of Alagadi in a valley surrounded by maquis covered hills and consisted of a mixture of cultivated and uncultivated land scattered with Olive (*Olea europaea*) and Carob (*Ceratonia siliqua*). This transect was carried out at all times of the day from 06:00 to 19:00 hrs during the period 13 August to 24 September, with 1–6 replicates for each hour. Preliminary observations of Magpie behaviour were undertaken along the same transect route during July. Data recorded during these trial runs were discarded. A total of 54 transects were completed within the study period with Magpie activity being recorded as follows (1) Flying; (2) Foraging (All Magpies on the ground were deemed to be foraging); (3) Perching in direct sunlight above ground level; (4) Perching in the shade above ground level. In order to standardise the data collected from these transects, a steady pace of approximately 3 km/h was adhered to and spot observations of the birds' behaviour were recorded when the birds were first observed. This was to control for the possibility of disturbance by the observer affecting the birds behaviour. On one part of the walking transect, a pastoral water trough was available for Magpies to drink from.

Temperature

In thermoregulation studies, measurements of operative and standard operative temperatures using mounts of the species being studied are the measurements of choice (BAKKEN 1992). However, we were unable to use heated or unheated mounts to measure the operative temperature as recommended by BAKKEN (1992). Heated mounts were impractical as the environmental temperature was likely to exceed Magpies body temperature and would therefore require cooling (BAKKEN et al. 1983). Unheated mounts could not be used due to habitat heterogeneity (BAKKEN et al. 1983) and multiple sampling of the habitat was not possible. Therefore, in order to compare Magpie activity to temperature during the study period, temperature was measured using Tinytalk Data Loggers (TK-0040: Gemini Data Loggers U.K. Ltd). These cylindrical probes, consisting of an internally mounted, encapsulated sensor, were 54 mm in length, 34 mm in diameter, weighed 30 g and were encased in a splashproof, semi-transparent 35 mm film canister. The probes operated within a temperature range of -30°C to +50°C with a 40 minute response time in air. Sensor accuracy was ±0.2°C at temperatures below 50°C with 0.25°C resolution at 0°C. One was placed in direct sunlight and one in the shade. Although this method of temperature measurement is relatively crude it is sufficient to illustrate the difference between the two regimes. The data loggers recorded temperature every 48 minutes from 8th August to 30th September, inclusively. Only temperatures during daylight hours i.e. between 06:00 and 19:00hrs were used in comparisons with behaviour and for calculating average daily and variations in diurnal temperatures.

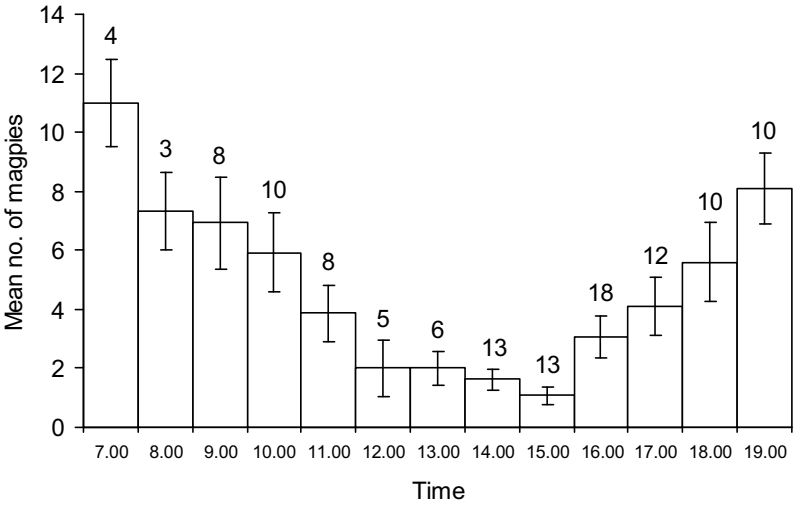

Fig. 1. Mean number of Magpies (±SE) observed for each hour of the day between 12 June and 24 September, 1996. The number of replicates for each hour of the day are shown.

Statistical Analyses

The frequency of distribution of the four behavioural categories observed during the walking transect was compared using a Chi-square test. The mean temperatures recorded in the shade and in direct sunlight were compared using a t-test. The proportion of Magpies perching in the shade was found to be normally distributed after arcsine transformation and so the parametric Product Moment Correlation Coefficient (r) was used to show the relationship between Magpies perching in the shade and the operative temperature (of the probe) in direct sunlight. The non-parametric Spearman's rank correlation was used to compare the proportion of active Magpies and temperature in direct sunlight and in the shade. Means values reported in the results are ± SE.

Results

12 km driving transect

A total of 120 transects were completed between June and September with three to 18 replicates for each hour of the day from 07:00 to 19:00. The mean number of Magpies observed for each hour of the day over the study period is shown in Fig. 1. The bimodal distribution shows a general temporal distribution of Magpie activity in northern Cyprus, with a peak in numbers detectable at dawn followed by much reduced activity levels between the hours of 12:00 to 16:00 hrs. A second, smaller, peak was observed in late afternoon and early evening (17:00–19:00 hrs). Figs. 2A–C show the mean number of Magpies that were observed flying, foraging or perching, respectively.

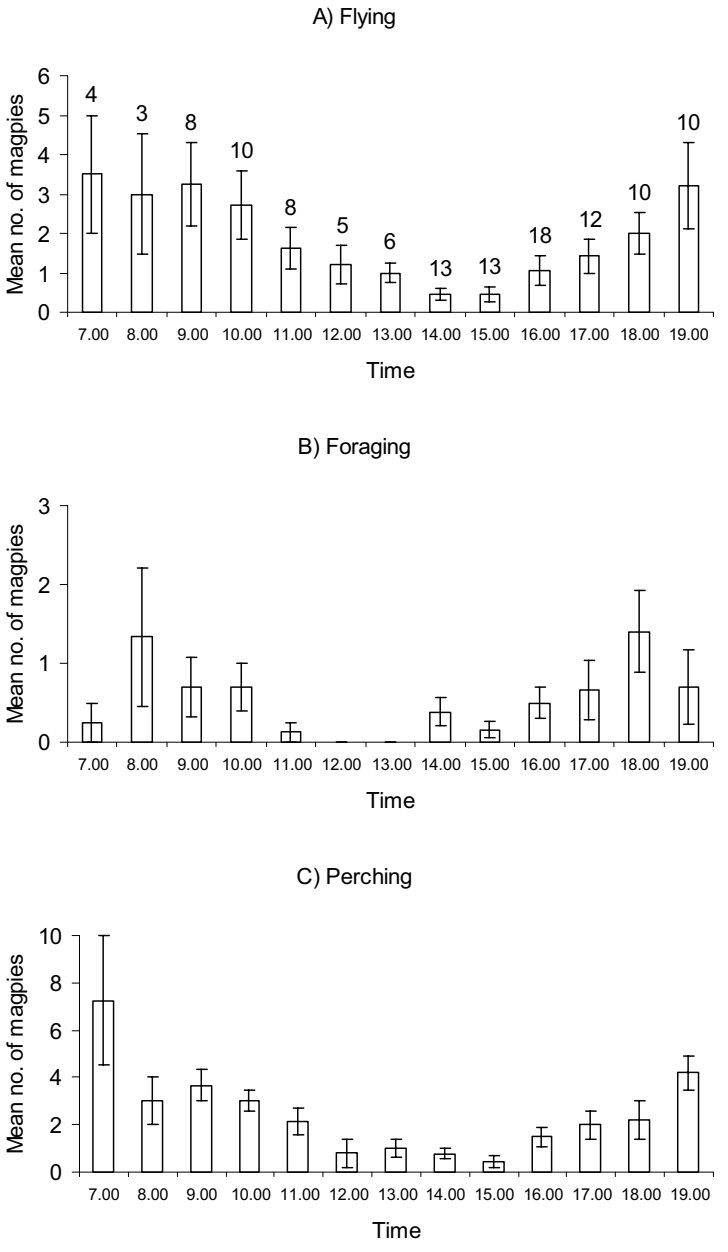

Fig. 2. Mean number of Magpies (±SE) observed A) flying B) foraging or C) perching for each hour of the day between 12 June and 24 September, 1996. The number of replicates for each hour of the day are shown in A.

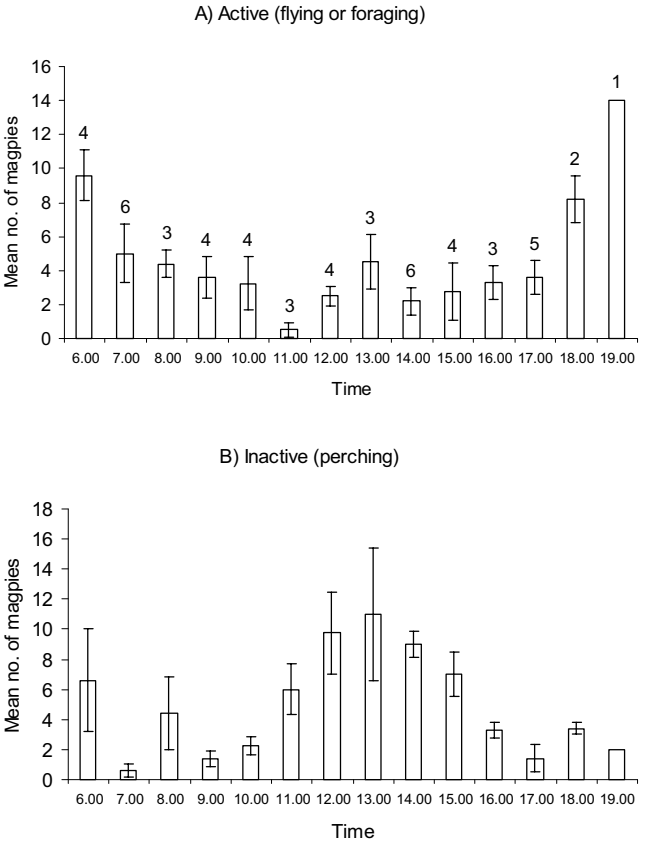

Fig. 3. Mean number of Magpies (±SE) observed during the 3 km walking transect. Active Magpies (A) include those that were flying or foraging. Perching Magpies (B) includes those perching in direct sunlight and in shade. The number of replicates for each hour of the day are shown in A.

3 km walking transect

Diurnal distribution of Magpie activity

A total of 54 walking transects were carried out between 13 August and 24 September 1996. This showed that the frequency of distribution of the four behavioural categories (see "Material and methods") during different times of the day was not equal (Chi-square test: $\chi^2_9 = 209.6$, $P < 0.01$). Indeed between 12:00 and 15:00 hrs (the hottest part of the day) 74% of Magpies were found perching in the shade. The mean number of Magpies observed which where either active (flying or foraging) or inactive (perching in direct sunlight or shade) are shown in Fig 3A–B. The distribution of the active Magpies shows a similar trend to those in Figs. 1 and 2, with a bimodal distribution, peaking at dawn and dusk. However, the inverse

is true of perching Magpies, with a peak between 11:00 and 15:00 hrs, which consisted almost entirely of birds perching in the shade. Another peak in perching birds is seen at 06:00 hrs, which consisted of birds mainly perching in the open. No Magpies were observed drinking from the supplied trough during any of the transects.

Temperature

The average daily (06:00–19:00 hrs local time) temperature recorded at Alagadi between 13 August and 24 September 1996 ranged from 33.3ºC to 41.4ºC (mean = 36.7±0.6ºC) while that in the shade ranged from 25.3°C to 31.6°C (mean = 28.4±0.5°C), Fig. 4. The difference between the average temperature in direct sunlight and that in the shade was 8.3ºC but ranged from 2ºC at 07:00 to 14ºC at midday. The difference between the average temperatures recorded in the shade and the average temperatures recorded in direct sunlight were found to be highly significant ($t_{52} = 21.6$, $P < 0.001$). The diel variation in temperature between 06:00 and 19:00 hrs is shown in Fig. 5.

The relationship between air temperature and Magpie behaviour

Fig. 6 shows that the proportion of Magpies found perching in the shade was positively correlated with the operative temperature in direct sunlight ($r = 0.21$, $F_{1, 32} = 8.0$, $P < 0.01$). A non-significant relationship was found between the proportion of Magpies recorded in the shade and the temperature in the shade ($r = 0.10$, $F_{1, 32} = 3.3$, $P > 0.5$). This suggests that it is the temperature in direct sunlight that determines whether Magpies seek shade during the hottest part of the day.

A relationship was also found between the overall proportion of Magpies that were active (i.e. flying or foraging) and the operative temperature (of the probe) in direct sunlight (Fig. 7). This negative correlation was found to be highly significant ($r_S = 0.62$, $P < 0.001$). Again a similar, but less pronounced relationship was found with the temperature in the shade ($r_S = 0.28$, $P < 0.05$). This would again suggest that temperature in direct sunlight is a more important determining factor than the temperature in the shade.

Discussion

Selection of an agreeable thermal environment is known in all groups of vertebrates (HAMMEL 1968). Fish respond to a temperature gradient to select a particular temperature (FRY & HOCHACHKA 1970), while amphibians and reptiles show diel and seasonal behaviour aimed at thermoregulation (BRATTSTROM 1970, TEMPLETON 1970). Mammals too, are known to select their thermal environment. Some primate species retreat to shade during the warmest times of the day (MYERS 1971) and many rodents depend on behavioural thermoregulation to survive, especially in harsh environments (HART 1971). This is also an important part of thermoregulation in birds (CALDER & KING 1974) but has been little studied.

The body temperature of passerines ranges from 39.2°C to 43.8°C (DAWSON & HUDSON 1970) but this may be influenced by many factors, such as time of day, activity and temperature. HAYWORTH & WEATHERS (1984) showed that the thermoneutral zone (TNZ) of Magpies ranged from 21°C to 32.5°C and that body temperature was independent of temperature between -10°C and 30°C, averaging about 39°C within this range. Above this temperature, hyperthermia developed progressively with body temperature rising exponentially. They

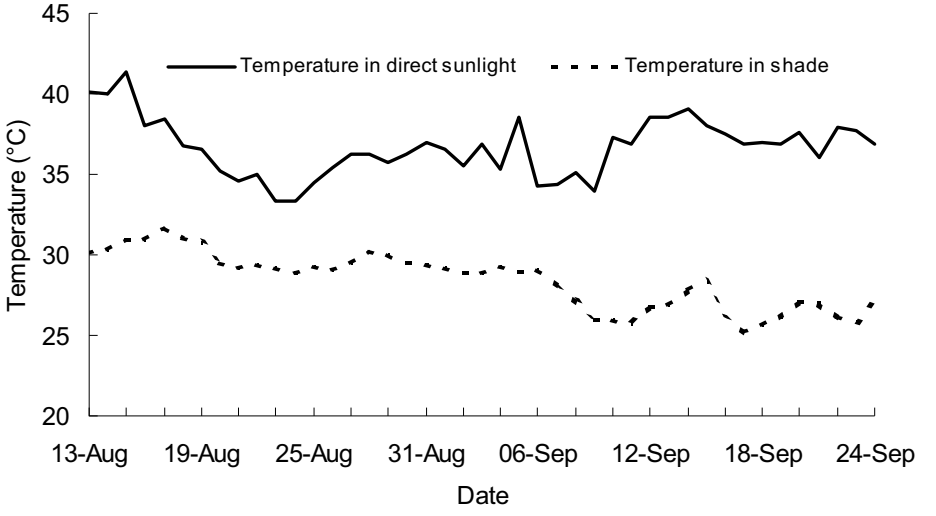

Fig. 4. The average daily temperatures recorded in direct sunlight and in the shade between 13 August and 24 September 1996, at Alagadi, northern Cyprus.

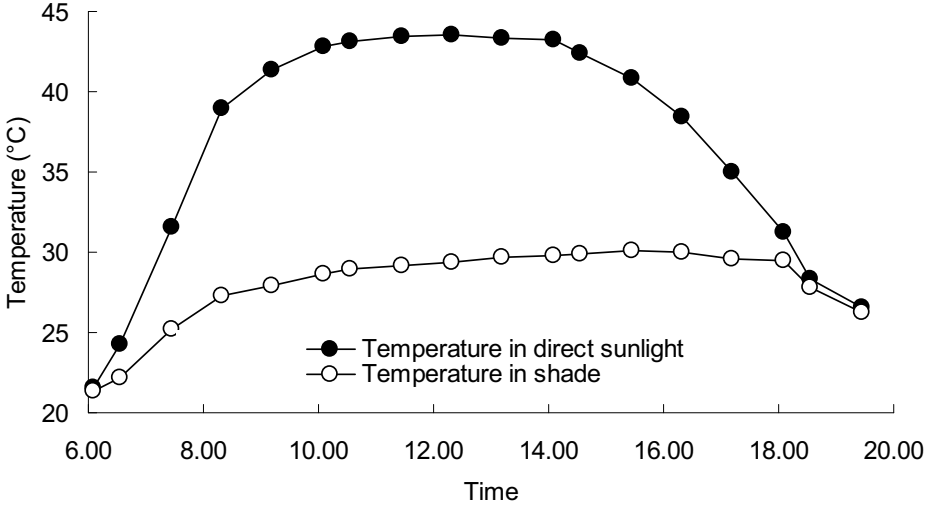

Fig. 5. The average diel variation in temperature recorded between 13 August and 24 September 1996, at Alagadi, northern Cyprus.

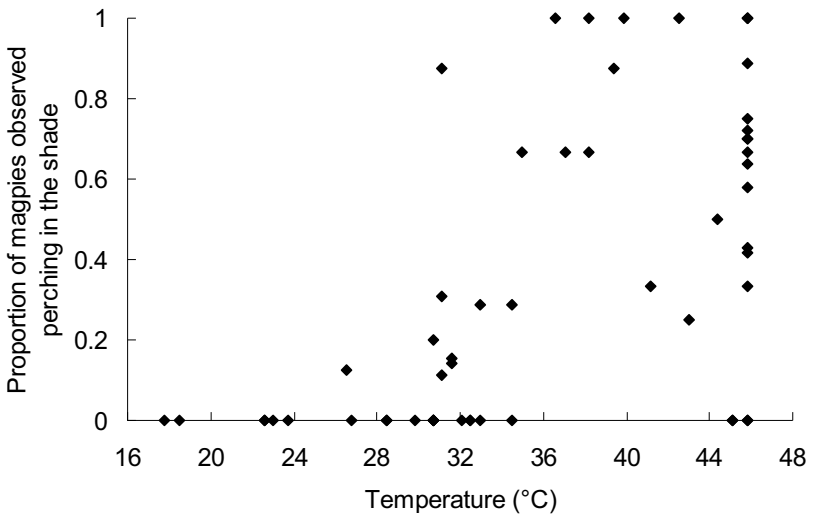

Fig. 6. Relationship between the temperature (°C) at the approximate time of observation and the proportion of Magpies recorded perching in the shade.

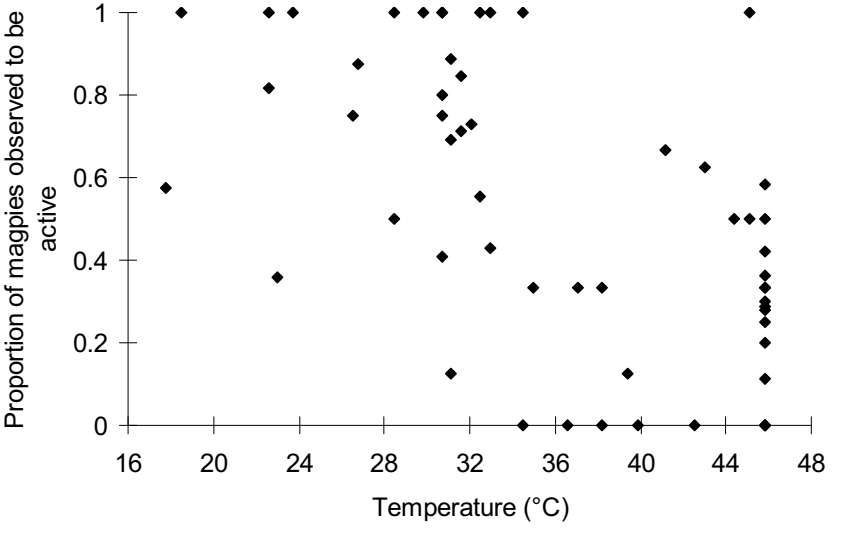

Fig. 7. Relationship between the temperature (°C) at time of observation and the proportion of Magpies recorded as being active (i.e. flying or foraging).

concluded that climate acted directly through its impact on physiological mechanisms to restrict Magpie distribution in North America. This was supported by earlier findings by STEVENSON (1971) and BOCK & LEPTHIEN (1975). It has also been suggested that heat stress should be more limiting than cold stress in this species (MUGAAS & KING 1981). During the study by HAYWORTH & WEATHERS (1984), three Magpies died at 40°C. Several died at 39°C in STEVENSON's (1971) study although, interestingly, no Yellow-billed Magpies died during these studies, presumably because they are better adapted to higher temperatures. These findings suggest that 40°C may be the upper critical temperature determining the limit of Magpie distribution. STEVENSON's results lead him to postulate that Magpies should therefore avoid temperatures of above 36°C and they are likely to confine their activities to the cooler times of the day. However these criteria may only apply to the North American subspecies *P. p. hudsonia* which may have evolved different physiological adaptations from the nominate sub-species *P. p. pica* which is found throughout much of Europe.

Magpies in Cyprus during the course of this study were faced with consistently high temperatures of up to 45°C and therefore must employ physiological or behavioural mechanisms to maintain their body temperature within the TNZ. The data presented here support STEVENSON's theory that Magpies should confine their activities to the cooler parts of the day with a bimodal distribution of flying and foraging behaviour (Figs. 1–3). HAYWORTH & WEATHERS' (1984) data suggest that Magpies should retreat to the shade when temperatures start to rise above 30°C and the data presented here tend to support this. Fig. 6 shows a distinct trend of movement into the shade of the majority Magpies at around 31°C. Conversely flying, foraging and perching in direct sunlight show a downward trend above this temperature. That Magpies seek shaded areas and reduce flying and foraging activities in response to high temperatures is perhaps not surprising. Similar results have been shown in several bird species including Red-winged Blackbirds, *Agelaius phoeniceus* (SANTEE & BAKKEN 1987), Starlings, *Sturnus vulgaris* (CLARK 1987), Chukars, *Alectoris chukar* (CARMI-WINKLER et al. 1987), the Verdin, *Auriparus flaviceps* and the Black-tailed Gnatcatcher, *Polioptila melanura* (WOLF et al. 1996).

While it could be argued that the reduction in Magpie foraging at high temperatures could be related to food availability rather than the effects of heat stress, the relationship between temperature and the number of birds retreating to shaded areas is strong (Fig. 6), suggesting that temperature is a more significant factor. Levels of activity and distribution of time between sun and shade were similar in captive Cactus Wrens (*Campylorhynchus brunneicapillus*) provided with food and water compared to birds observed in the field, suggesting that heat stress, rather than food availability was the principle determinant of shade seeking behaviour (RICKLEFFS & HAINSWORTH 1968). Magpies are active throughout the day at higher latitudes during the summer months (pers. observation) suggesting that the behaviour shown in northern Cyprus is not some general aspect of Magpie behaviour throughout their range. Indeed, MØLLER (1983) found that Magpies foraged for more than 600 minutes per day during the summer months in a population in Denmark. Time-energy budgets of Yellow-billed Magpies in California showed that these birds, which are subject to similar conditions as Magpies in northern Cyprus, spent a large proportion of their time resting in the shade during the hottest summer months (VERBEEK 1972).

A number of studies have shown that birds can dramatically reduce their standard operative temperature by retreating to the shade. Great Grey Shrikes (*Lanius excubitor*) using shade in the Negev desert reduced their standard operative temperature by 6°C (WARD & PINSHOW 1995) while Willow Warblers (*Phylloscopus trochilus*) migrating over the Sahara

desert can reduce their standard operative temperature by as much as 14°C by retreating to shade (BIEBACH 1986). In North America, WALSBERG (1993) showed that the upper critical temperature for Phainopeplas (*Phainopepla nitens*) in three different habitats including the Sonoran Desert was 43°C. By utilising shaded areas they reduced the amount of time exposed to the upper critical temperature by up to two-thirds. The magnitude of any reduction in standard operative temperature may be a function of size. As Magpies are amongst the largest of passerines, any reduction of standard operative temperature may be lower than that of the great grey shrike. In addition, the air temperature measured in this study was actually the operative temperature of the probe, which is dependent on the size, shape and colour of the probe. Magpies, being larger and darker are actually likely to experience higher temperatures than we measured. Therefore we believe the reduction in the standard operative temperature of the bird is likely to be substantial and an important contribution to the control of the birds' core temperature. Temperature in the shade in northern Cyprus never rose above 30°C during the study period giving an average difference between the two temperature regimes of 8.3°C but could be as high as 14°C. No Magpies were observed drinking from the water supply during the period of the study despite 54 transects being completed. In addition, four reservoirs were visited regularly during August and September as part of an avian diversity study and no Magpies were observed drinking or bathing despite the species being recorded as present at these sites on all visits (pers. observation). Although the physiological responses of Magpies in this area have not been studied, we suggest that retreating to the shade is one of the major factors involved in thermoregulation in this species whereas seeking drinking water is not. Panting was observed on only two occasions and gular fluttering was never observed. Therefore it is unlikely that Magpies rely on increasing respiratory evaporative heat loss. We believe that temperature determines the southern limit of the Magpie's range in Europe. Other corvids in Europe such as the Jay (*Garrulus glandarius*) the Jackdaw (*Corvus monedula*), the Hooded Crow (*C. corone cornix*) and Raven (*C. corax*) have a similar, although not identical distribution to that of the Magpie. Those that do extend into North Africa tend to be found at high altitudes (Magpies, Jackdaws and Ravens) coastal regions (Ravens) and along the Nile valley (Hooded Crows) (CRAMP & PERRINS 1994). European corvids have evolved to be adapted to the climate in the range they occupy and their niches are probably filled by other corvid species in North Africa such as the Brown-necked Raven (*C. ruficollis*) and the Fan-tailed Raven (*C. rhipidurus*) both of which occupy the arid areas of this region and are adapted to the climate they experience there (GOODWIN 1976).

Acknowledgements. The authors would like to thank all the members of Glasgow University Turtle Conservation Expedition (1996) for their assistance in data collection. Thanks also to Stuart BEARHOP for stimulating discussions and advice on statistical analyses. Brendan GODLEY is currently funded by a NERC Fellowship.

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