



Temperature acclimatization in the black-billed magpie (*Pica pica hudsonia*, Sabine)
by Robert Eugene Stevenson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of
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Abstract:

A study of temperature acclimatization of the black-billed magpie (*Pica pica hudsonia*) from southwestern Montana was done. One hundred eighteen birds were used in the study. The basal metabolic rate for newly captured birds in September and December was $1.71 \pm .52$ ccO₂/g hr. A significant difference ($P < .05$) was found between April birds caged outside and birds taken in September and December with regard to metabolic rates. Thermal conductivities were higher in birds taken in late August and early September than in the December birds. Also respiratory water loss was significantly higher in late summer birds than at any other time.

The lipid indices was highest in the spring, correlating with reduced oxygen consumption rate at that time. There were no significant differences among birds with regard to water index, protein bound iodine, corticosterone or hematocrit.

It is proposed that black-billed magpies are limited in their eastward distribution in the mid-western United States by the lethal combination of high ambient temperatures and high relative humidities.

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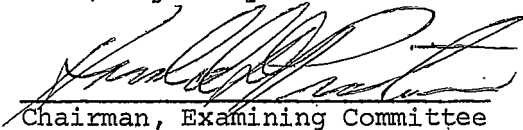
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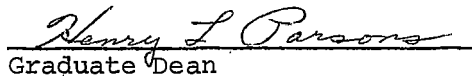
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ABSTRACT

A study of temperature acclimatization of the black-billed magpie (*Pica pica hudsonia*) from southwestern Montana was done. One hundred eighteen birds were used in the study. The basal metabolic rate for newly captured birds in September and December was $1.71 \pm .52 \text{ cc}^0_2/\text{g hr.}$ A significant difference ($P < .05$) was found between April birds caged outside and birds taken in September and December with regard to metabolic rates. Thermal conductivities were higher in birds taken in late August and early September than in the December birds. Also respiratory water loss was significantly higher in late summer birds than at any other time.

The lipid indices was highest in the spring, correlating with reduced oxygen consumption rate at that time. There were no significant differences among birds with regard to water index, protein bound iodine, corticosterone or hematocrit.

It is proposed that black-billed magpies are limited in their eastward distribution in the mid-western United States by the lethal combination of high ambient temperatures and high relative humidities.

INTRODUCTION

Avian adaptation to temperature has been studied by numerous investigators. Dawson and Hudson (1970) provide a comprehensive review of the available information on temperature regulation in various bird families.

My study involves a Corvid, the black-billed magpie (*Pica pica hudsonia* Sabine). Black-billed magpies are permanent residents of many areas in Montana and they must withstand temperature extremes from 41 C to -46 C (105 F to -50 F), occasional winds of high velocity and varying snow depths. Prime habitat for these birds is brushy, tree filled coulees and large bushes and trees along stream bottoms bordering open agricultural lands. They are seldom found in mountainous terrain or taiga and tend to avoid the open treeless prairie. The black-billed magpie was chosen for this study because of its apparent hardiness, abundance and relative accessibility.

Black-billed magpies from southwestern Montana showed no weight loss during the winter months according to Todd, 1968. Espino (1958), through thyroid histology of black-billed magpies from southern Wyoming, found no specific response to low temperatures.

The purpose of my study was to investigate the physiological and behavioral means whereby the black-billed magpie is able to accommodate itself to the temperature regime of this area. An effort was made to determine if photoperiod was important as a *Zeitgeber* for

thermal acclimatization. Oxygen consumption, respiratory water loss, thermal conductivity, lipid and water indices, hematocrit, thyroxine and corticosterone levels were determined from birds taken during late summer and throughout the winter and from those birds maintained on the artificial photoperiods. Finally, a preliminary analysis was made of the eastward distribution of the black-billed magpie as correlated with the combination of high temperature and relative humidity.

MATERIALS AND METHODS

Trapping, Housing and Blood Removal

A total of 118 black-billed magpies were collected within a twenty mile radius of Bozeman, Montana. The trap used for capturing the birds was $1\frac{2}{3}$ m square with a cone-shaped entry 18 cm in length resting on the ground (Brown, 1958). Bait consisted of cow and pig viscera and dead Japanese quail (*Coturnix coturnix*). Birds which were used in the photoperiod experiments were caged individually indoors in 70 cm x 70 cm x 45 cm wire cages. The light provided came from two 40 watt fluorescent lamps situated $1\frac{2}{3}$ m to 3 m from the cages. Light intensity at the nearest cage was 4 foot candles and at the most distant was 0.1 foot candle. The lights were turned on and off automatically.

Four birds caught on June 23, 1970 and eight birds taken on July 9, 1971 were maintained on a 16L 8D light schedule (16 hours of light and 8 hours of dark, beginning at 06:00 and ending at 22:00 daily) until late November and early December when they were killed. Control birds for all photoperiod experiments were kept individually outside in 25 cm x 40 cm x 18 cm wire cages. Nine birds captured on December 28 and 29, 1970 were used for the 9L 15D (08:00-17:00) light schedule. These birds were removed and killed at the end of March. Quail was used as food except during August, 1970 when chicken parts were substituted. Water was available *ad libitum*.

Blood was collected by lightly anesthetizing a bird and then severing the carotid artery about 2 cm above the base of the neck. The body of the bird was elevated above the head and a plastic tube placed at the site of the incision. Up to 6 ml of blood could be collected using this technique. Hematocrit values were obtained by centrifuging blood collected in heparinized micro-hematocrit tubes in a micro-hematocrit centrifuge for 20 minutes. Percentages were read on a mechanical hematocrit reader. Serum was collected by centrifuging whole blood at 3600 rpm for 20 minutes. The serum was stored in corked vials and kept frozen until used.

Oxygen Consumption and Respiratory Water Loss Measurements

Oxygen consumption was measured using an open circuit system. Two animal chambers were used. For temperatures above 10 C a cylindrical 18.9 liter plexiglass container surrounded by a 3 cm water jacket was used. One end of the chamber was sealed with plexiglass, the other end was sealed with a removable cork plug 4 cm thick. Temperatures in the chamber were reached and maintained by using water heated and circulated by a Brinkman ultra-thermostat. Chamber temperatures were measured using a mercury thermometer which was permanently installed in the cork end. The chamber was kept semi-darkened by covering it. An air pump was used to force air through the system. Air entering the chamber was dried by passing it first through Drierite. Outgoing

air from the chamber passed through a copper coil maintained at room temperature, a flow meter, and a drying tube filled with silica gel. A Servomex Oxygen Analyzer Type OA 150, designed for direct readings of oxygen percentages, was used to determine oxygen consumption. For oxygen consumption determinations at ambient temperatures below 10 C the low temperature animal chamber was an 18.9 liter metal can. This can was fitted with copper tubing for entering and exiting air. This apparatus was placed in a Cole-Parmer Instrument Company low temperature cabinet. Temperatures of -41 C could be reached with this apparatus. In the chambers birds rested on a 1 cm² mesh screen fitted on a rectangular plastic pan. The pan was filled with mineral oil to a depth of 1.5 cm. The mineral oil prevented fecal moisture from being added to the respiratory water. Moisture-free air was pumped through a copper coil placed in a freezer in order to reduce the air temperature entering the chamber to that of the freezer. Outgoing air passed through another copper coil maintained at room temperature. A pump produced an air flow between 600 and 1010 cc/min, usually around 805 cc/min. Humidity in both chambers was estimated by the method of Lasiewski, Acosta and Bernstein (1966). The mean relative humidity was 51% (range 26%-82%) based on 95 determinations at a chamber temperature above 20 C. The birds were held undisturbed in the chambers for at least one hour before the first readings were taken. After this period oxygen consumption was recorded at five minute intervals for

one half hour. These readings were averaged to determine the amount used by the bird at that ambient temperature. At least one hour was allowed to elapse before another set of oxygen consumption readings were taken. Temperatures were not changed by any set amount. All oxygen readings were converted to STP. Respiratory water loss was determined by weighing a drying tube filled with silica gel to 0.1 mg, passing outgoing air through the tube for 30 minutes and reweighing.

Body Temperature, Hormone and Lipid Analyses

Daily body temperature fluctuations were obtained using a small animal thermistor coupled to a two channel Rustrak automatic chart recorder. The thermistor was inserted two to three centimeters into the cloaca and held in place with pinch clamps attached to the rectrices. The second channel measured ambient temperature.

Birds were prepared for lipid analysis by plucking and then removing the manus, head and viscera. The carcass was weighed, homogenized in a blender or meat grinder and oven dried at 70 C or lower. The dried material was reweighed. A fraction of the dried material was placed in a Soxhlet extractor using petroleum ether (30-60 C boiling point) as the solvent. Extractions lasted for at least eight hours. The majority of the solvent was evaporated by flash evaporation and the remainder removed by drying under nitrogen. The lipids were then weighed. Thyroxine was assayed by the Hycel cuvette method for the determination of protein bound iodine (PBI). Serum corticosterone

was determined by the radio protein binding assay method of Murphy (1967) as modified by Adams and Wagner (1970).

Values for thermal conductivities were determined for all birds from the relationship (Murish, 1969):

$$\text{conductance} = \frac{(\text{heat produced} - \text{loss by evaporation})}{(\text{body temperature} - \text{ambient temperature})}$$

The caloric equivalent of O_2 was assumed to be 4.8 cal/ml O_2 and the latent heat of evaporation of water = 0.58 cal/mg H_2O .

RESULTS

Physiological Acclimatization

Thermoneutral ranges and the mean oxygen consumption values within the thermoneutral ranges for magpies tested at various times throughout the year and for those subjected to altered photoperiods are shown in Table I. The upper critical temperatures (T_C) were similar in all groups tested (35 C) except for the March birds (40 C) maintained on a 9L:15D photoperiod. The lower T_C varied with the season, being lowest (-10 C) in the December natural (those birds captured and immediately tested) and the December birds (-9 C) caged outside. It was intermediate (0 C) in the September natural, December inside birds (16L:8D) and the April outside caged birds. The highest lower T_C (10 C) was from March inside birds. The widest span enclosed by the thermoneutral range was 45° in December natural birds and the narrowest was 30° in March inside birds. Mean monthly temperatures recorded inside the unheated building which housed the experimental birds and outdoor temperatures from the Montana State University campus weather station are shown in Fig. 1.

Comparison of the mean oxygen consumptions from the thermoneutral ranges showed a significantly smaller difference ($P < .05$) between March birds and all other birds tested except for the April birds caged outside. The oxygen consumption of April birds was also significantly smaller ($P < .05$) than the December outside and December inside caged

Table I. Thermoneutral ranges, means of oxygen consumption rates within the thermoneutral ranges and regression coefficients of lines fitted by method of least squares.

	Sept. (12) ^{a/}	Dec. (6)	April (3) Outside	Dec. (7) Outside	Dec. (9) Inside 16L 8D	March (9) Inside 9L 15D
Thermo- neutral range (°C)	0 to 35	-10 to 35	0 to 35	-9 to 35	0 to 35	10 to 40
Means and sd (ccO ₂ /gmhr)	1.68±.48	1.74±.56	1.37±.45	1.98±.50	2.00±.80	1.19±.45
Regression coefficients	-.07870	-.02127	-.05825	-.04492	-.00730	-.06899

^{a/} sample size

computed average regression coefficient $\bar{b} = -.055$

Table II. Hematocrit, protein bound iodine and corticosterone mean values for black-billed magpies.

	Sept.	Oct.	Dec.	Jan.	Dec. 16L 8D Inside	Dec. Outside	March 9L 15D Inside
Hemato- crit	33.2±15.1 ^{a/}	37.2±12.6	42.5±8.2	43.7±8.3	41.4±5.2	39.6±5.2	43.2±7.7
(%)	(10) ^{b/}	(10)	(10)	(10)	(10)	(6)	(3)
Cortico- sterone	66.91±18.1	51.7±47.7	69.1±38.1	65.22±63.3	57.2±28.3	51.2±28.3	10.8±7.5
mg/ml	(11)	(10)	(11)	(8)	(9)	(6)	(5)
Protein bound iodine	3.7±1.1	4.3±1.3	4.4±1.8	5.1±2.7	5.9±3.6	3.3±1.8	4.0±0.8
µg/100 ml	(11)	(10)	(7)	(9)	(8)	(4)	(5)

^{a/} standard deviation

^{b/} sample size



Figure 1. Mean monthly temperature inside barn (1970-71) and mean monthly outside temperature at Montana State University campus, Bozeman, Montana based on 50 year record (1909-1958). Mont. Agric. Expt. Sta. (1967).

birds. Fig. 2 shows six oxygen consumption curves. The regression equations for the points below the lower T_c are included for each curve. The equality of the slopes of the regression lines (Sokal and Rohlf, 1969) was tested. Regression coefficients were found to be homogenous at the 95% level. The average computed regression coefficient was $\bar{b} = -.055$.

Data from each experiment on respiratory water loss (RWL) were fitted to a regression curve containing linear and quadratic terms (Fig. 3). The derived equations were then compared to see if significant differences existed between any group of determinations for the months or photoperiod treatments. RWL of September birds was significantly greater from all other groups ($P < .05$).

The thermal conductivity of black-billed magpies as related to T_a is shown in Fig. 4. In order to adequately compare groups of birds, the means of points above 20 C did not lend themselves to ordinary statistical analysis because no satisfactory linear or quadratic equations were found which truly represented these points. Thermal conductivity is most important during winter so analysis of points below 20 C should show changes due to season or photoperiod. An analysis of variance and a test for homogeneity of the means were conducted. The thermal conductivity of December inside caged birds was found to be significantly higher ($P < .05$) than all other groups (Table III).

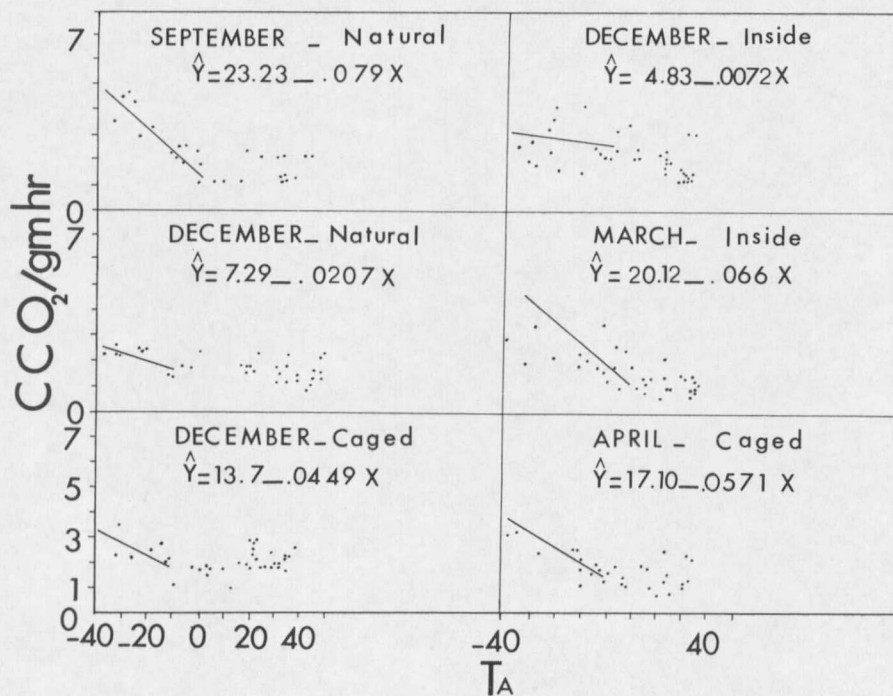


Figure 2. Variations in oxygen consumption vs. ambient temperature of black-billed magpies for different months and light schedules. Regression equations were determined by method of least squares.

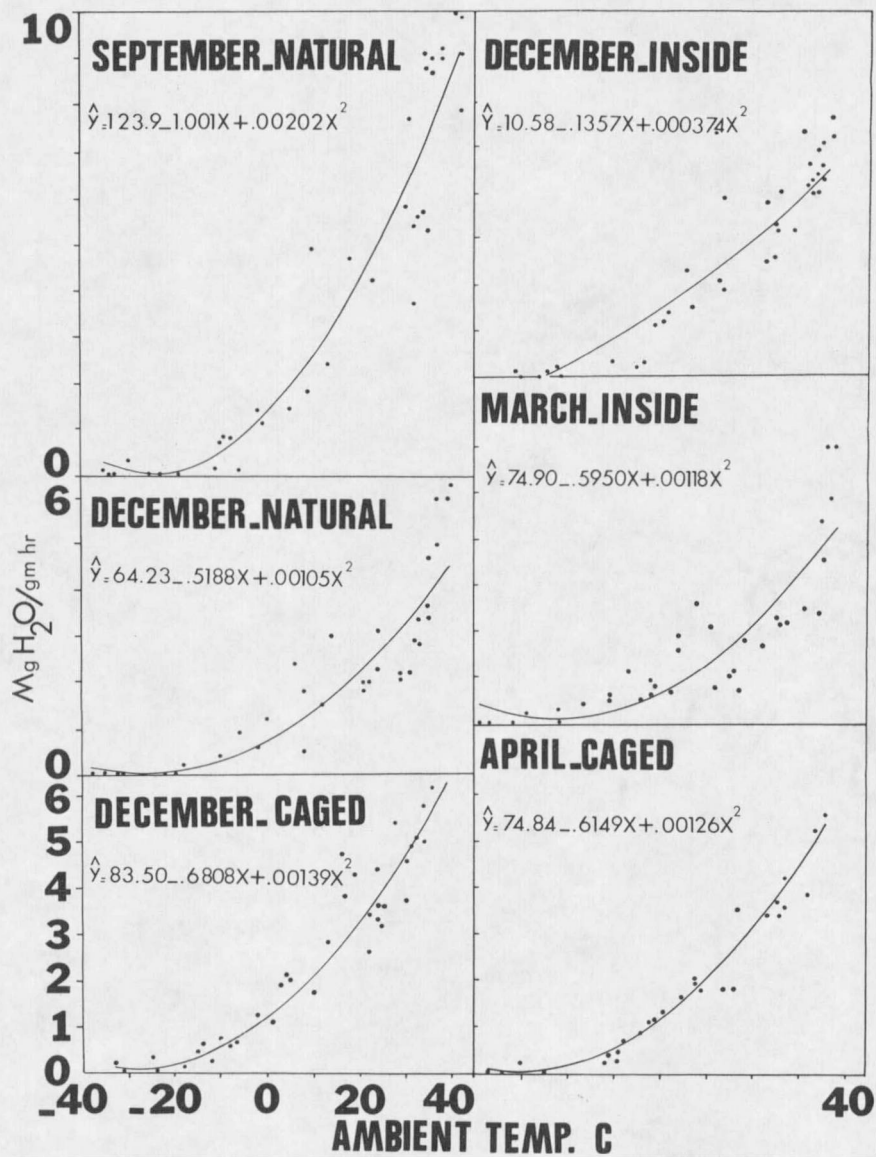


Figure 3. Variation in respiratory water loss vs. ambient temperature of black-billed magpies for different months and light schedules. Curvilinear regression equations are shown.

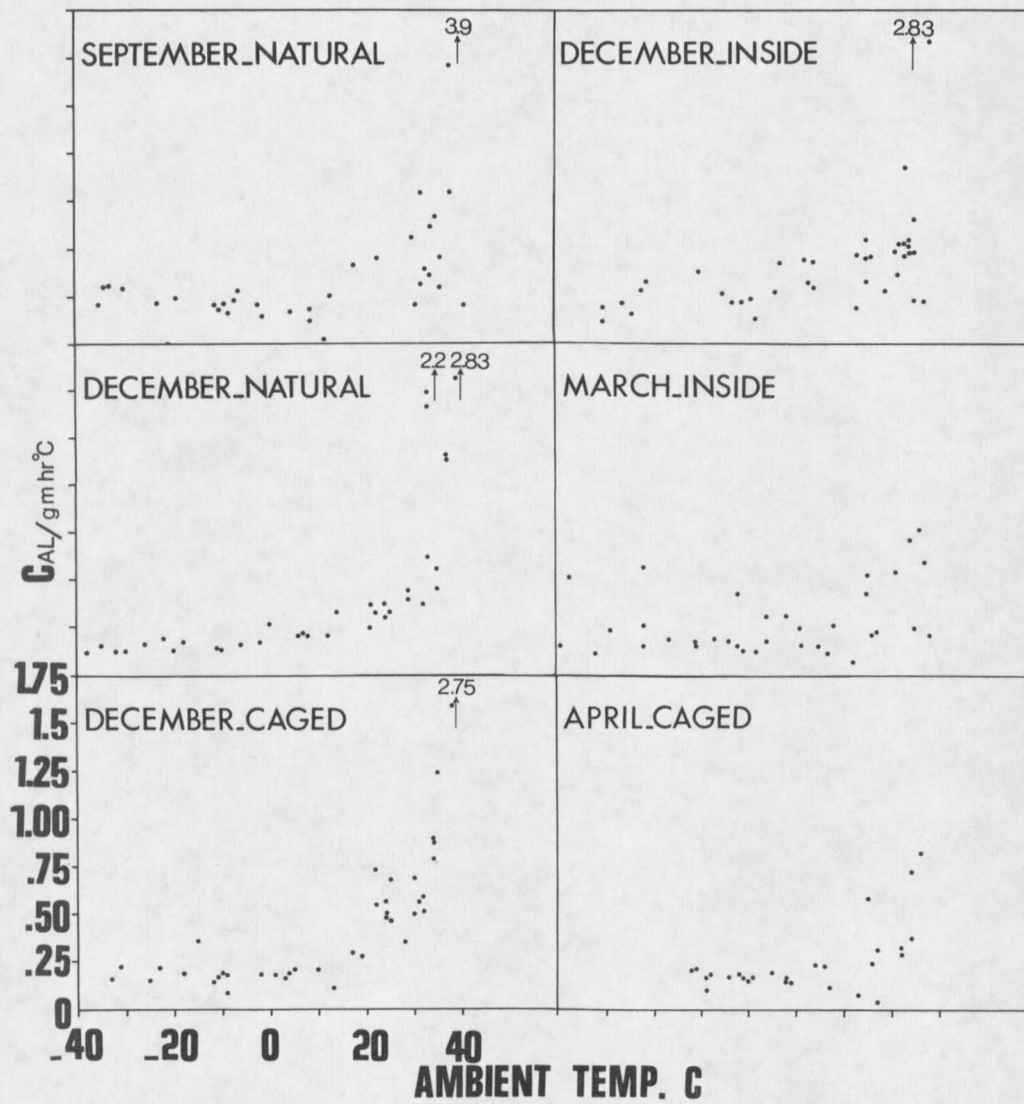


Figure 4. Variations in thermal conductivities vs. ambient temperature of black-billed magpies for different months and light schedules.

Table III. Mean thermal conductivity values of the black-billed magpie below ambient temperatures of 20 C.

Month or treatment	Sept. (20) ^{a/} Natural	Dec. (18) Natural	Dec. (20) Outside
Mean (Cal/ghr°C)	.2098	.1893	.1903
Month or treatment	Dec. (18) Inside	March (25) Outside	April (22) Inside
Mean (Cal/ghr°C)	.2798	.2337	.1873

^{a/} sample size; average computed mean = .2036

The lipid indices is plotted in Fig. 5. A significant difference exists ($P < .01$) between birds captured in September which have the lower index and those from October, December and April. No significant differences were found in the water indices (Fig. 6) between any birds. Todd (1968) measured the annual weight variation of black-billed magpies trapped in the Bozeman area. He found no significant decline in their weight during the winter months, thus indicating that food was readily available.

Table II lists the means, standard deviations and sample numbers for hematocrit, protein bound iodine and corticosterone. No significant differences were found among birds for hematocrit or the hormones. The mean corticosterone values for March were much lower than any of the other periods. However, large variations in values were present in all groups. The reason for this is unknown.

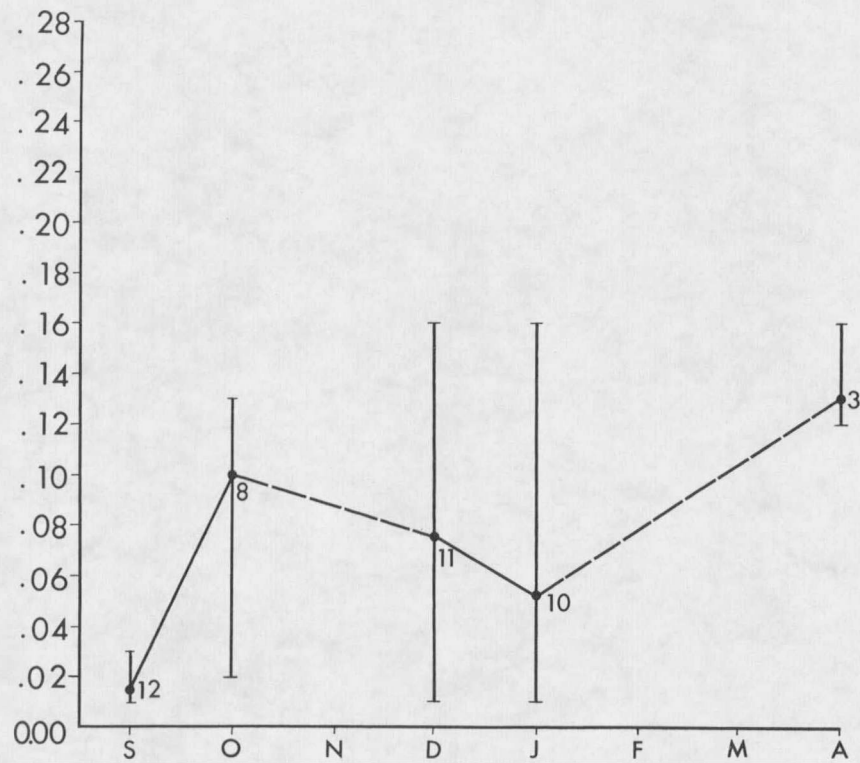


Figure 5. Seasonal changes in lipid index (weight of fat/fat-free dry weight) of black-billed magpies. Numbers at each point indicate sample size.

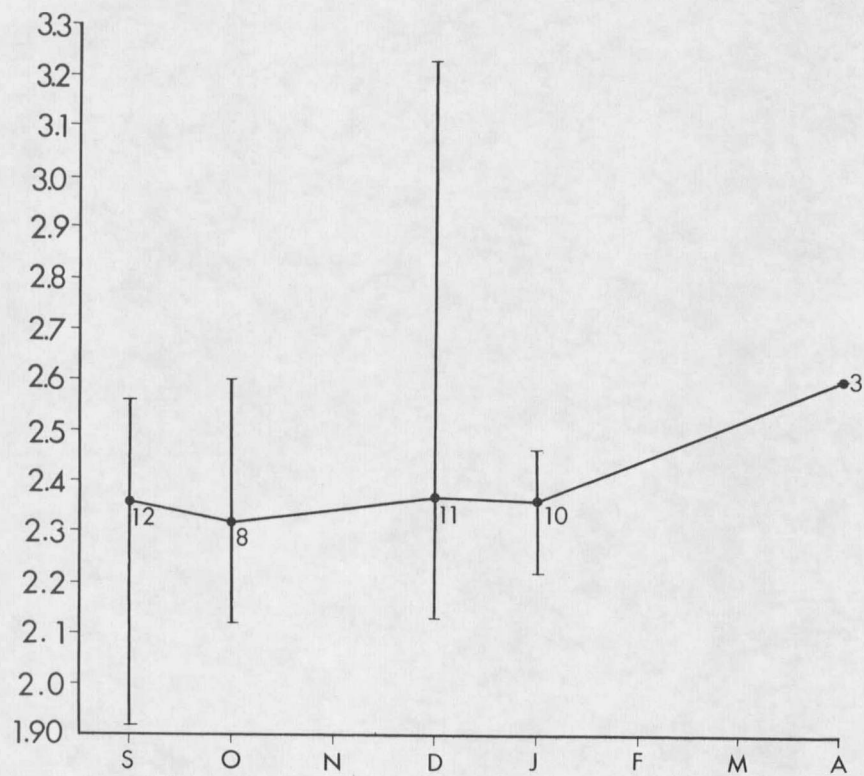


Figure 6. Seasonal changes in water index (grams water/fat-free dry weight) of black-billed magpies. Numbers at each point indicate sample size.

Changes in cloacal temperature (T_b) of two birds with increasing ambient temperature (T_a) are shown in Fig. 7. The T_b in each bird was different at the beginning as were the upper lethal temperatures. One bird was able to cope successfully with T_a up to approximately 38 C (Fig. 7A). From that T_a upward its T_b increased gradually to 46 C when the T_b abruptly jumped to 47 C and the bird died. The elevation in T_b occurred at a different T_a in Fig. 7B than Fig. 7A. In Fig. 7B the T_b began to rise from a T_a of 33 C and moved gradually to a T_b of 46 C when a sudden rise in the T_b occurred and death followed. The same general pattern occurred in both magpies: a T_a which has no effect on T_b followed by a gradually elevating T_a and finally a rapid rise in T_b and death. During oxygen consumption measurements signs of stress were exhibited by birds when T_a rose to 39 C. Some birds perished upon removal from the test chamber, whereas other birds could endure T_a near 41 C without apparent harm. Seven birds died during oxygen consumption testing at high T_a . The relative humidities in these seven tests were equal to or above 46% (46%-67%) and the T_a greater than 36 C with 42 C being the highest. It appears that the upper T_c of 35 C as shown in Fig. 2 correlates reasonably well with the black-billed magpie's ability to maintain thermoneutrality at relative humidities near 50%. In both Fig. 7A and B a T_a of 35 C is at or near a rise in the T_b .

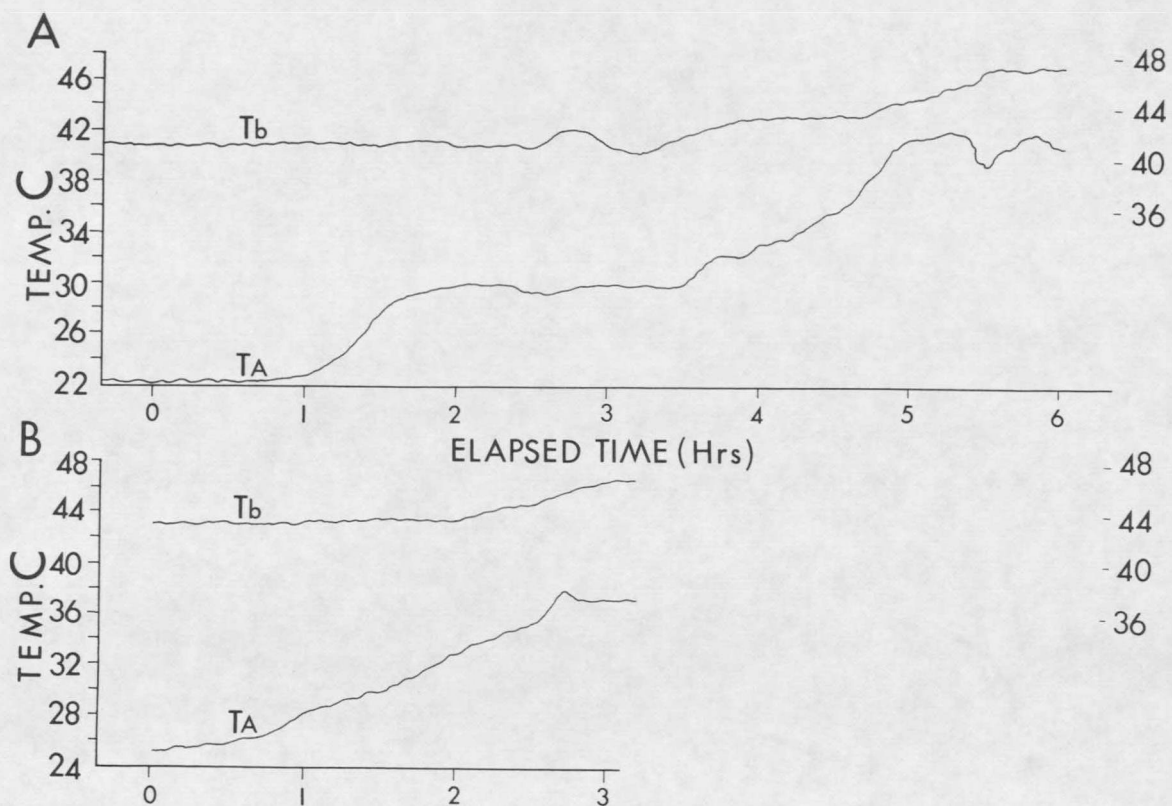


Figure 7. Cloacal temperature (T_b) vs. ambient temperature (T_a). Birds were dead upon termination of experiment.

Changes in T_b with increasing or decreasing light are shown in Fig. 8. The bird used in Fig. 8A was maintained inside on a 9L 15D photoperiod. The lights were abruptly turned on at 08:00 and off at 17:00. A drop of 1 C is evident within 15-20 minutes. During the night the T_b dropped (2 C) to a low of 40 C. The lights switched on at 08:00 and the T_b rose to 43 C within two hours. The T_b began to elevate within 15-20 minutes after the light came on and continued to increase to the daytime high. A black-billed magpie's T_b is not stable during the night but shows occasional rises which lasted up to 20 minutes. Birds caged outside (Fig. 8B) exhibited a similar change in T_b with light. Sunrise on 4/6/71 was at 05:56 MST. The T_b began to increase around 05:10 and was within 1 C of the daytime maximum by sunrise. Sunset on 4/6/71 was at 18:59 MST, the T_b of the bird began to drop within 25 minutes and decreased nearly 4 C.

Insulation

Two contour feathers of one bird were taken from each of three areas of the body. Measurements were made of the total length, the proportion of the rachis which was soft and fluffy or without hamuli and the aftershaft length (Table IV) in order to ascertain the percentage of the rachis with down-like qualities. The effectiveness of the black-billed magpie's insulation appears to be due in part to the fluffiness of the proximal portion of the rachis. The barbs and barbules (1 mm long) from the fluffy portion of the rachis are

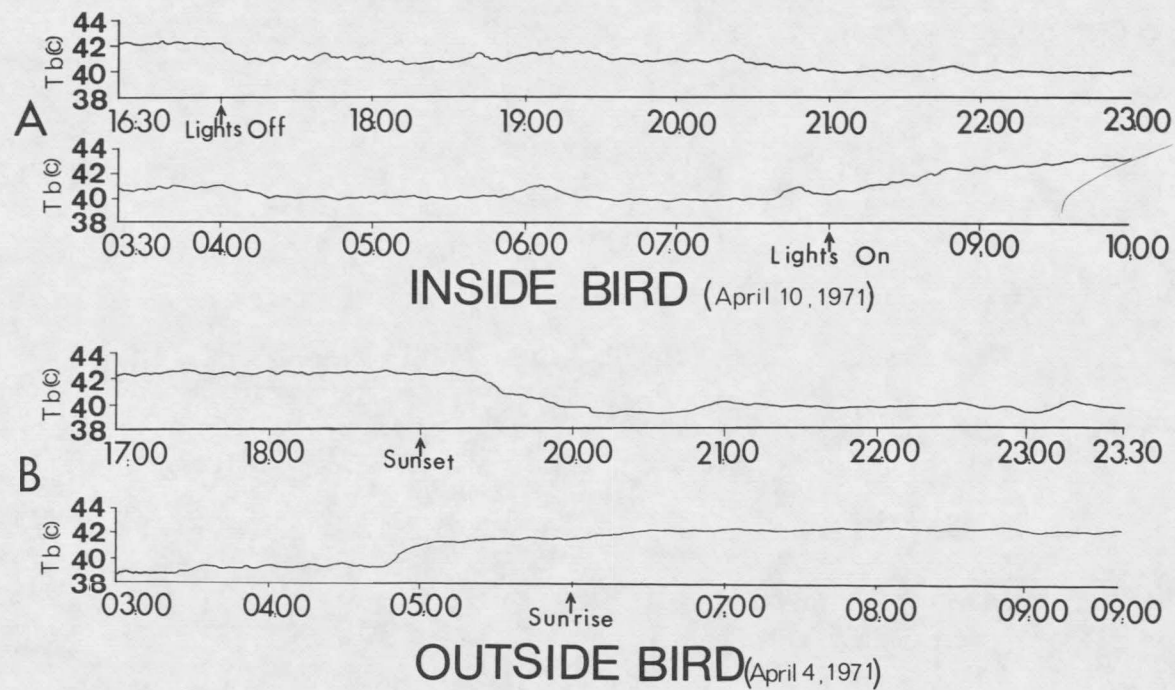


Figure 8. Cloacal temperature (T_b) vs. daylength. Twenty-four hour clock used for time.

Table IV. Measurements of contour feathers taken from three areas of the body of one black-billed magpie.

Feather location	Total feather length n = 2 (mm)	Length of rachis without hamuli, or has soft flexible barbs (mm)	Aftershaft length (mm)
Feather end of dorsal tract	34	27.5 (81%) ¹	31
Capital tract at base of neck	79	30.5 (39%)	52.5
Scapulars	86	55 (64%)	58

¹% of rachis with downy barbs.

interwoven with those of adjacent feathers. Three barbules arise at equidistant points about the circumference of each barb on the downy area of the rachis. The long aftershaft in each case is also interwoven with the barbs and barbules. Down feathers arise from both the pterylae and apterylae. Thus there is a basal layer of down overlain and interwoven with the soft lower portion of the rachis which in turn is overlain by the more rigid distal end of each contour feather.

Fat deposits in plucked birds were minimal with axillary, interclavicular and omentum depots being the only areas of accumulation. Negligible insulative value would be gained from fat in these locations. The lipid index is below that designated for non-migratory birds, thus the fat available probably functions as a short term energy supply rather than insulation.

Behavior and Temperature

Magpies exhibit the typical plumage fluffing posture of birds when subjected to cold temperatures. Birds observed at temperatures near -40 C were crouched on the bare tarsometatarsus areas, contour feathers were erected and in one instance a bird had placed its head under its left wing. This type of posturing is probably typical of roosting magpies since these observations were made on birds which had been in the dark for 6-8 hours. Free-roaming foraging birds during the day at T_a of -20 to -30 C showed plumage fluffing and some crouching while perching.

Avoiding air temperatures above 36-38 C at the relative humidities encountered in these tests is a must for the black-billed magpie. Birds which were in the high temperature chamber, panted at these temperatures, shook their plumage periodically and held their wings slightly away from their sides. Similar temperatures are common at midday in the range of the black-billed magpie and they probably restrict their activities to the cooler parts of the day.

DISCUSSION

Temperature Acclimatization

The black-billed magpie is a non-migratory bird. Fat was found to accumulate only during the breeding season with the highest lipid index (.13) occurring in the spring. Generally, non-migratory birds have a lipid index of 0.2 to 0.4 (Odum, 1965). The lipid index of the black-billed magpies studied here did not reach that level at any time (Fig. 5). The highest lipid index of the year corresponds with a lowering of the rate of oxygen consumption. This may allow for an accumulation of fat reserves (Kendeigh, 1949). Maintaining birds on a 9L 15D photoperiod from late December until late March did not prevent a lowering of the rate of oxygen consumption. In contrast to this was the work of Pohl (1971) who kept migratory bramblings (*Fringilla montifringilla*) for 18 months on a 10L 14D photoperiod. Under these conditions the birds failed to undergo seasonal changes in oxygen consumption rates at thermoneutrality. Bramblings maintained outside showed a decrease in the rate of oxygen consumption during the spring. The black-billed magpies caged inside (December and March) were not sexually active as indicated by gonadal size. Their gonads were no larger than those taken from birds in September, October and December. The gonads taken from birds caged outside in April were well developed. An endogenous rhythm may be involved in the vernal fat deposition in black-billed magpies.

Corticosterone, protein bound iodine or the hematocrit levels were not significantly different at any time of the year or in birds maintained under altered photoperiods. These physiological parameters did not increase the birds ability to adjust to climatic extremes. The downward shifting of the lower T_c is involved in winter acclimatization. The lower T_c dropped from 0 C in September birds to -10 C in December birds, to -9 C in December outside caged birds and shifted upward in April outside caged birds (0 C). This seasonal shifting of the lower T_c is an acclimatization which conserves energy during the winter months. It allows the birds to maintain basal oxygen consumption rates at lower ambient temperatures. The December birds which were caged inside had a significantly higher thermal conductance than the others. If the photoperiod length is used as a *Zeitgeber* to indicate the onset of long term temperature changes then the results from the December birds caged inside would have meaning. Since they were on a 16L 8D day indicating summer conditions, thermal conductivity should be at a high. Although the other conductivities were not significantly different they do fall into a general pattern. Winter thermal conductivities (in Cal/ghr°C), whether real or apparent, December natural (.2098) and December outside (.1903), April (9L 15D) inside (.1873) were lowest; September natural (.2098) and March outside (.2337) intermediate and the December inside (16L 8D) highest (.2098). Whether this changing is due to insulation or vasoconstriction, or a combination of both,

is unknown. Paralleling the higher thermal conductivities of the summer season was the higher RWL by late August and September birds. These birds were tested from 8/21/70 to 9/14/70 and had not experienced any cool fall weather. The combination of high thermal conductivities and high RWL is an effective means of cooling and would be of value during the warm summer. The gray jay (*Perisoreus canadensis*) has also been found to have a seasonal shift in the lower T_c (Veghte, 1964). Hart (1962) found a metabolic type of acclimatization to winter conditions, as reflected in high levels of heat production and greater cold resistance in the house sparrow, pigeon, evening grosbeak and the starling. Large seasonal changes in thermal conductivity were absent. Fig. 2 shows the greater variability in oxygen consumption exhibited by the December birds caged inside and maintained on a 16L 8D photoperiod. Even though there were no significant differences among all birds with regard to oxygen consumption below the lower T_c , the inside birds were affected somewhat by the altered photoperiod and higher T_a . This may be due to a response of the regulatory systems which when unchallenged periodically tend to give more variable or erratic results than systems used frequently. The lower T_c was designated as 0 C for the December inside caged birds for the purpose of obtaining a regression coefficient. Close analysis of the graph indicates, however, that it is risky to assign a lower T_c or a thermo-neutral zone to that set of points. The December birds caged inside

were sexually inactive, having been maintained in the refractory period since late June and early July. The two variables here (a T_a above the outside temperature and altered photoperiod) makes it difficult to assign one factor as being responsible for the variability.

The black-billed magpie is one of the larger passerines (average weight 180 g). Black-billed magpies winter in such geographically diverse areas as Fairbanks, Alaska; Alberta; Saskatchewan; Montana and Wyoming. Basal metabolic rates are equivalent to other non-migratory Corvids such as the gray jay and the blue jay (*Cyanocitta cristata*). Veghte (1964), working with the gray jay in Fairbanks, Alaska, reported the average annual resting metabolic rate as 1.75 ± 0.31 ccO₂/g hr or 13.7 Kcal/day per bird. Blue jays (Misch, 1960) tested in Michigan from 12/57 to 4/58 had a metabolic rate at rest of 1.89 ccO₂/g hr or 17.2 Kcal/day per bird. The black-billed magpie (September and December newly caught birds) consumed oxygen at the rate of $1.71 \pm .52$ ccO₂/g hr or 30.14 Kcal/day per bird. The equation derived by Lasiewski and Dawson (1967) would theoretically have the basal metabolic rate for a 180 g passerine as 37.27 Kcal/day. This is 19% higher than the 30.14 Kcal/day found experimentally for the black-billed magpie. These three Corvids are metabolically quite similar and differ by only 0.2 ccO₂/g hr in their rate of oxygen consumption.

Distribution and Climatic Factors

The average weight of an adult blue jay is 81 g and an adult gray jay weighs 68 g. The black-billed magpie is over 100% larger by weight than the other two Corvids and according to Kendeigh (1969) the total existence energy requirements must be increased by at least 44%. Since the rate of oxygen consumption at various T_a and the lowest temperatures encountered are similar for these three Corvids, it seems doubtful that their distribution is limited by low temperatures. More specifically, it is doubtful that low temperatures prevent the black-billed magpie from moving into the central and eastern United States. Since there are at least 12 subspecies of the black-billed magpie distributed in Europe, northwest Africa, Asia and the western part of North America (Dement'ev *et al.*, 1954) and all are considered to be omnivorous, a lack of a specific food requirement in eastern North America is improbable. Collins (1969) lists the food of the black-billed magpie from North America as consisting of 60% animal origin, mostly insects and 40% vegetable matter. Such flexibility in food habits offers an obvious advantage to the bird. A tabulation of the black-billed magpies occurrence during the annual Audubon Christmas bird count (American Birds, 1971; Audubon Field Notes, 1968, 1965) shows the eastward distribution ending usually between the 95°W and 100°W longitudinal meridian. Counts of over ten birds are not often

made east of the 100°W longitude. Linsdale (1937) described the black-billed magpies distribution as corresponding very closely with the region known as Cold Type Steppe Dry Climate of Russel (1931). Russel used records of temperature and precipitation as the fundamental basis for his classification. The easterly extent of this region is approximately through the center of the Dakotas, the western one third of Nebraska and the western one fourth of Kansas. Monthly maximum temperatures for eastern Montana, North Dakota and South Dakota in July and August average between 27 C-32 C (80 F-90 F) (U. S. Dept. of Interior, 1970). The extreme maximum temperatures range between 40 C and 43.5 C (Ward, 1925). Relative humidities in western North and South Dakota averages 60% in July, whereas the relative humidity averages 70% along the North Dakota-Minnesota boundary in July. As mentioned above, the upper T_c of the black-billed magpie is around 35 C and most of the birds exhibit signs of stress when the T_a approaches 39 C (102.2 F) at 50% relative humidity. Lasiewski *et al.* (1966) note that relative humidity has a marked influence on the effectiveness of evaporative cooling. I believe that the high relative humidity and T_a during the summer in the mid-western states presents an environmental barrier to the black-billed magpie. Lasiewski *et al.* (1966) comments on the data provided by Hudson and Brush (1964), support this hypothesis that the combination of high T_a and relative humidity limits the black-billed magpie in its eastward distribution in the United States. Hudson and Brush's experiments on

the mourning dove (*Zenaidura macroura*) show that doves are unable to withstand temperatures above 41 C at relative humidities exceeding 50%. However, Lasiewski *et al.* found that the same bird could withstand T_a of 45.2 C for two hours or more at low humidities.

Further experimentation on the black-billed magpie by varying the relative humidity and T_a up to the levels encountered in the mid-western United States should provide an insight into the peculiar distribution of this animal. Possibly research of this nature could be applied to the distribution and abundance of other organisms as well.

LITERATURE CITED

- Adams, W. M. and W. C. Wagner. 1970. The role of corticoids in partuition. Biol. of Reprod. 3: 223-228.
- American Birds. 1971. Seventy-first Christmas bird count. National Audubon Society in collaboration with the United States Fish and Game Department. A. D. Cruickshank, ed. 25: 121-514.
- Audubon Field Notes. 1965. Sixty-fifth Christmas bird count. National Audubon Society in collaboration with the United States Fish and Game Department. A. D. Cruickshank, ed. 19: 1-346.
- _____. 1968. Sixty-eighth Christmas bird count. National Audubon Society in collaboration with the United States Fish and Game Department. A. D. Cruickshank, ed. 22: 1-410.
- Brown, R. L. 1958. Magpie ups and downs. Montana Fish and Game Department, Helena, Mt. Information Bull. No. 3, 4 p.
- Collins, H. H., Jr. 1959. Complete Field Guide to American Wildlife - East, Central and North. Harper and Row, New York. 684 p.
- Dawson, W. R. and J. W. Hudson. 1970. Birds. In G. C. Whittow, ed. Comparative Physiology of Thermoregulation. Academic Press, New York. Vol. 1.
- Dement'ev, G. P., N. A. Gladkov, A. M. Sudilovskova, E. P. Spangenberg, L. V. Boehme, I. B. Volchanetskii, M. A. Voinstvenskii, N. N. Gorchakovskaya, M. N. Korelov and A. K. Rustamov. In G. P. Dement'ev and N. A. Gladkov (ed.) Birds of the Soviet Union. Israel Program for Scientific Translation, Jeursalem, 1970. U. S. Dept. of Commerce, Clearing House for Federal Scientific and Technical Information, Springfield, Va. Vol. 5.
- Erpino, M. J. 1968. Aspects of thyriod histology in Black-billed Magpies. Auk 85: 392-403.
- Hart, J. S. 1962. Seasonal acclimation in four species of small wild birds. Physiol. Zool. 35: 224-236.
- Hudson, J. W. and A. M. Brush. 1964. A comparative study of the cardiac and metabolic performance of the dove, *Zenaidura macroura*, and the quail *Lophortyx californicas*. Comp. Biochem. Physiol. 12: 157-170.

Kendeigh, S. C. 1949. Effect of temperature and season on the energy resources of the English Sparrow. Auk 66: 113-127.

_____. 1969. Tolerance of cold and Bergman's rule. Auk 86: 13-25.

Lasiewski, R. C., A. L. Acosta and M. H. Bernstein. 1966. Evaporative water loss in birds-I. Characteristics of the open flow method of determination and their relation to estimates of thermoregulatory ability. Comp. Biochem. Physiol. 19: 445-457.

_____. and W. R. Dawson. 1967. A re-examination of the standard metabolic rate and body weight in birds. Condor 69: 13-23.

Linsdale, J. M. 1937. The Natural History of Magpies. Pacific Coast Avifauna No. 25. 234 p.

Misch, M. S. 1960. Heat regulation in the Northern Blue Jay, *Cyanocitta cristata bromia* Oberholser. Physiol. Zool. 33: 252-259.

Murphy, B. E. P. 1967. Some studies of the protein-binding steroids and their application to the routine micro and ultramicro measurements of various steroids in body fluids by competitive protein-binding radioassay. J. Clin. Endocrinol. Metab. 27: 973-990.

Murrish, D. E. 1970. Responses to temperature in the dipper, *Cinclus mexicanus*. Comp. Biochem. Physiol. 34: 859-869.

Odum, E. 1965. Adipose tissue in migratory birds. In Handbook of Physiology, Sec. 5. (A. E. Renold and G. F. Cahil Jr., eds.). Washington, D. C., Amer. Physiol. Soc. p. 37-43.

Pohl, H. 1971. Seasonal variation in metabolic functions of Bramblings. Ibis 113: 185-193.

Russel, R. J. 1931. Dry Climates of the United States-I. Climatic Map. Univ. of Calif. Press, Berkeley, Calif. 41 p.

Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co. San Francisco. 776 p.

Todd, K. S. 1968. Weights of Black-billed Magpies from southwestern Montana. Auk 85: 508-510.

- United States Department of the Interior, Geological Survey. 1970.
The National Atlas of the United States of America. Washington,
D. C. 101-108.
- Veghte, J. H. 1964. Thermal and metabolic responses of the Gray Jay
to cold stress. *Physiol. Zool.* 37: 316-328.
- Ward, R. D. 1925. The Climates of the United States. Ginn and
Co. Boston. 518 p.

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