



Operative Temperature Reduces Habitat Space for Northern Bobwhites

Author(s): N. David Forrester, Fred S. Guthery, Steven D. Kopp, Will E. Cohen

Reviewed work(s):

Source: *The Journal of Wildlife Management*, Vol. 62, No. 4 (Oct., 1998), pp. 1506-1511

Published by: [Allen Press](#)

Stable URL: <http://www.jstor.org/stable/3802017>

Accessed: 05/12/2011 19:01

Your use of the JSTOR archive indicates your acceptance of the Terms & Conditions of Use, available at
<http://www.jstor.org/page/info/about/policies/terms.jsp>

JSTOR is a not-for-profit service that helps scholars, researchers, and students discover, use, and build upon a wide range of content in a trusted digital archive. We use information technology and tools to increase productivity and facilitate new forms of scholarship. For more information about JSTOR, please contact support@jstor.org.



Allen Press is collaborating with JSTOR to digitize, preserve and extend access to *The Journal of Wildlife Management*.

<http://www.jstor.org>

OPERATIVE TEMPERATURE REDUCES HABITAT SPACE FOR NORTHERN BOBWHITES

N. DAVID FORRESTER, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363, USA

FRED S. GUTHERY,^{1,2} Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363, USA

STEVEN D. KOPP, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363, USA

WILL E. COHEN, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363, USA

Abstract: High operative temperatures may cause wild animals to avoid habitat space–time, leading to thermal fragmentation of habitat. We evaluated thermal fragmentation of habitat space for northern bobwhites (*Colinus virginianus*) in a subtropical–subhumid portion of Texas during June 1994–August 1995. Based on data from 606 random points, 405 flushing points, and 237 landing points, bobwhites avoided habitat space–time with operative temperatures >39°C during the hottest period (Jul–Sep). The estimated proportion of habitat space–time avoided exceeded 0.50 during all seasons and reached maximums of 0.65 for flushing points (Mar–Jun) and 0.74 for landing points (Jul–Sep). Habitat management that fosters lower operative temperatures near the ground may increase the abundance of bobwhites in tropical and subtropical environments.

JOURNAL OF WILDLIFE MANAGEMENT 62(4):1506–1511

Key words: *Colinus virginianus*, fragmentation, habitat selection, northern bobwhite, operative temperature, Texas.

High temperatures may influence the behavior of birds in subtropical and tropical environments. For example, Gambel's quail (*Callipepla gambelli*) and chukars (*Alectoris chukar*) forage less as temperatures rise during hotter seasons (Goldstein 1984, Carmi-Winkler et al. 1987). Verdins (*Auriparus flaviceps*) and black-tailed gnatcatchers (*Polioptila melanura*) show strong affinity to cool refugia in the deserts of Arizona (Wolf et al. 1996).

High temperatures may reduce the quantity of usable space, defined as habitat compatible with physical, behavioral, and physiological adaptations of northern bobwhites (Guthery 1997: 294), to those sites with nonstressful or minimally stressful thermal regimes. High temperatures may fragment habitat space for birds by rendering portions of that space thermally stressful or intolerable, despite otherwise acceptable habitat conditions. This phenomenon is well known for ectotherms (Porter and Tracy 1983) but poorly documented for endotherms.

We studied thermal fragmentation of habitat space for bobwhites in a subtropical portion of Texas. Our objectives were (1) characterize the randomly available thermal environment, and (2) determine bobwhite selection for tempera-

tures within this environment. From these results, we were able to estimate the proportion of space–time (Guthery 1997) avoided by bobwhites seasonally and annually because of high temperatures. Space–time (ha–days) is the sum or integral of usable space through time; densities of bobwhites may maximize when all space is usable for all time (Guthery 1997). Finally, we discuss the field results relative to empirical findings on the thermal biology of bobwhites and suggest management options.

STUDY AREA

We collected data on 6 study areas totaling 18,531 ha in the Gulf Coast Prairies and South Texas Plains vegetation regions (Gould 1975) during June 1994–August 1995. Two study areas were in Duval County and 1 each in Kleberg, Jim Wells, San Patricio, and Brooks counties. Climate of the study areas is subtropical–subhumid, with mean maximum daily temperatures ranging from 33 to 35°C in August (Larkin and Bomar 1983). Mean annual precipitation ranges from about 60 cm on study areas further from the Gulf of Mexico (Duval County) to about 90 cm nearer to the Gulf (San Patricio County). The study areas represented a variety of soils ranging from clay to sand on level to gently undulating topography. Plant communities included old fields, prairie, mixed brush, and closed-canopy live oak (*Quercus virginiana*) forest.

¹ Present address: Department of Forestry, Oklahoma State University, Stillwater, OK 74078, USA.

² E-mail: forfsg@okway.okstate.edu

METHODS

To obtain an unbiased image of the randomly available thermal environment in space and time, we attempted to sample study areas in proportion to their area; random sampling points were determined from *X-Y* coordinates of study areas. We sampled systematically through hour of day and seasons; that is, effort (time) devoted to sampling was equally distributed among morning, midday, and evening periods during the day, and among days during months. Biologically based seasons were pair-nest (Mar–Jun), nest-brood (Jul–Sep), and covey (Oct–Feb).

Two observers searched study areas for bobwhites in the vicinity of random points. Upon encountering a group of bobwhites, observers measured thermal conditions at the approximate point of first observation and at the approximate landing point of an individual, if the group flew and the landing point was seen. Thus, we obtained data from 3 types of points: random, flushing, and landing.

We measured operative temperature (T_e) at each point. Operative temperature is more meaningful in terms of heat flow than air temperature (T_a) because operative temperature adds the heating effects of solar radiation and deducts (usually) the cooling effects of wind from air temperature. We modeled operative temperature following Mahoney and King (1977). We assumed a spherical shape for bobwhites (0.25 of surface area exposed to solar radiation; Campbell 1977), a characteristic dimension (body diameter) of $d = 0.05$ m (White 1995), absorptivity (α) of 0.78 (Calder and King 1974), and emissivity (ϵ) of 0.95. We report operative temperatures measured at the height of a bobwhite (15 cm). We used a hand-held anemometer (Turbometer, Forestry Suppliers, Jackson, Mississippi, USA) to obtain wind speed (m/sec), a digital thermometer (Taylor, Forestry Suppliers, Jackson, Mississippi, USA) to obtain air temperature ($^{\circ}\text{C}$), a light meter (Eptech, Forestry Suppliers, Jackson, Mississippi, USA) to measure light intensity (lux), and a thermopile couple pyranometer (Kipp and Zonen, Division of Enraf-Nonius, Bohemia, New York, USA) to measure global solar radiation (W/m^2). Radiation measurements were taken with the pyranometer at a subset of total points. We developed an equation to predict solar radiation based on lux readings for other points. Each

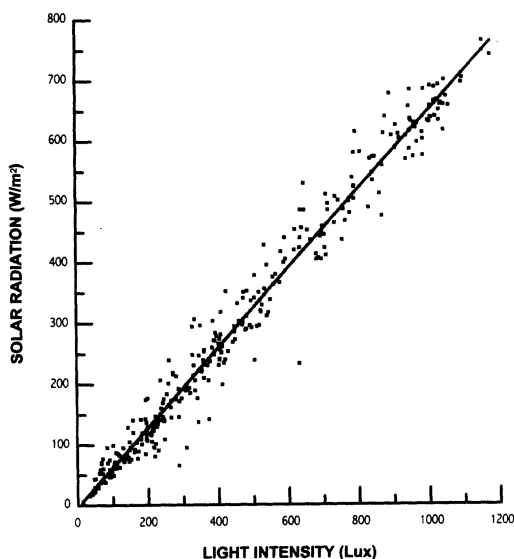


Fig. 1. Relation between solar radiation and light intensity as measured in southern Texas, 1994–95.

measurement was taken 3 times in succession, and the mean was used to estimate operative temperature; solar radiation (y in W/m^2) could be described as a linear function of light intensity (x in lux; Fig. 1) according to

$$Y = -3.43 + 0.657X,$$

where $r^2 = 0.97$, $P < 0.001$, and $n = 329$. Because the intercept was not different from zero ($P = 0.291$), we developed a zero-intercept model,

$$Y = 0.6518X,$$

where $r^2 = 0.99$, which was used for predictions. This result supported our use of light intensity to estimate global solar radiation.

Operative temperature data were analyzed for seasonal data from random, flushing, and landing points. We first constructed and modeled the cumulative frequency distribution by seasons for used (flush, land) and random points (Kopp et al. 1998). Models tested included the logistic, Gompertz, Weibull, confined exponential, and linear. We set the asymptote at $n + 2$ for the logistic, Gompertz, and Weibull, and confined exponential models. Banks (1991) gave methods of determining parameters in these models. Because all models were equally parameterized, we selected the model with the highest r^2 value for further analysis. We then differentiated the cumulative frequency distri-

Table 1. Mean operative temperatures (°C) at random points and at flushing and landing points of northern bobwhites during biological seasons in southern Texas, June 1994–August 1995.

Biological season ^a	Random			Flushing			Landing		
	\bar{x}	SE	n	\bar{x}	SE	n	\bar{x}	SE	n
Covey	27.1	0.52	187	25.1	0.70	106	24.0	0.88	86
Pair–nest	34.7	0.57	132	31.0	0.50	108	31.1	0.76	48
Nest–brood	36.1	0.30	287	32.3	0.35	191	32.4	0.58	103

^a Covey = October–February; pair–nest = March–June; nest–brood = July–September.

butions and scaled them to probability density functions (Mendenhall et al. 1990:145).

The above analysis resulted in density functions for used points, $f(x)$, and random points, $g(x)$. We defined a continuous selection function as

following Guthery (1997) and Kopp et al. (1998). The ratio indicates preference for operative temperatures if $u(x)$ is >1 , and avoidance if $u(x)$ is <1 . The area under $g(x)$ where $u(x)$ is <1 provides an estimate of the proportion of habitat space–time avoided because of operative temperature.

RESULTS

We obtained data at 606 random points, 405 flushing points, and 237 landing points (Table 1). Cumulative frequencies were best described by the logistic or Gompertz distribution for all seasons and point types ($r^2 = 0.96$ – 0.99 , $P < 0.001$ for 9 models).

The mean operative temperature at random points was higher than at flushing and landing points for all seasons (Table 1). Selection analyses revealed avoidance of operative temperatures $>30^\circ\text{C}$ during the covey season and for operative temperatures $>39^\circ\text{C}$ during the pair–nest and nest–brood season (Figs. 2–4). The estimated proportion of space–time avoided was ≥ 0.52 during all seasons for both types of points. The maximum proportion avoided occurred during the pair–nest season for flushing points (0.65) and during the nest–brood season for landing points (0.74). For the annually pooled data as appropriately weighted by length of season, the proportion of habitat space–time avoided was estimated at 0.57 for flushing points and 0.72 for landing points.

DISCUSSION

Our selection models (Figs. 2–4) for operative temperatures represent approximations of the random thermal environment on our study areas and of use of this environment by bobwhites. The continuous selection functions may be least trustworthy in the left and right tails, where the denominator, $g(x)$, may take values approaching zero. Nonetheless, the field results were consistent with empirically known features of the thermal biology of bobwhites.

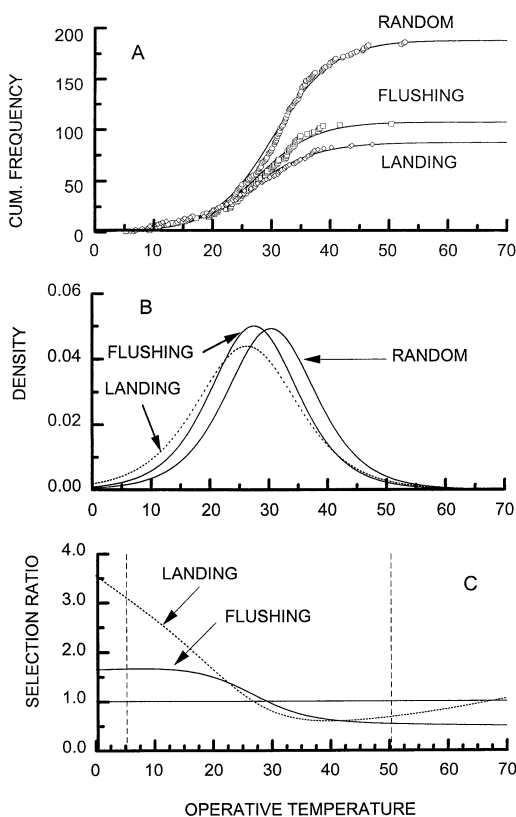


Fig. 2. Selection analysis for operative temperatures (°C) at points used by northern bobwhites in southern Texas during the covey season (Oct–Feb), 1994–95. (A) Cumulative (Cum.) frequency models ($r^2 \geq 0.97$, $P < 0.001$). (B) Probability distributions derived from cumulative frequency models. (C) Selection ratios for flushing and landing points. The horizontal line shows the break between preference (above) and avoidance (below), and the dashed vertical lines show the domain of observation.

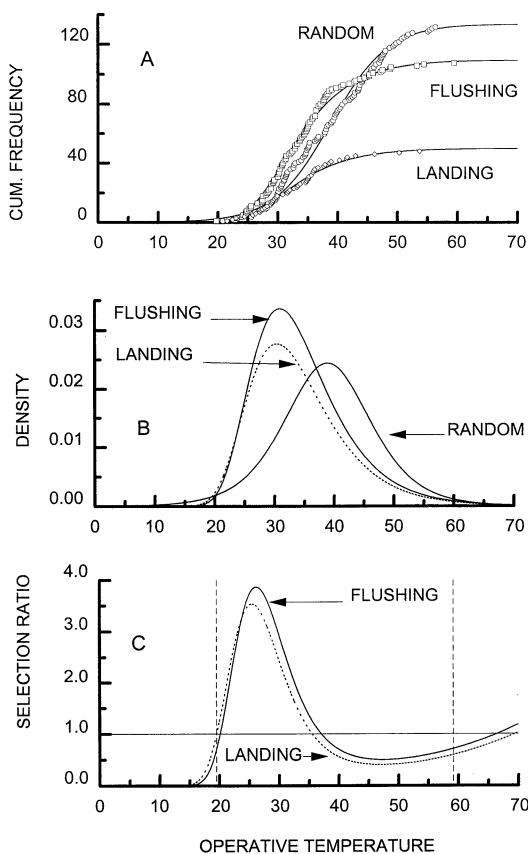


Fig. 3. Selection analysis for operative temperatures (°C) at points used by northern bobwhites in southern Texas during the pair-nest season (Mar–Jun), 1994–95. (A) Cumulative (Cum.) frequency models ($r^2 \geq 0.98$, $P < 0.001$). (B) Probability distributions derived from cumulative frequency models. (C) Selection ratios for flushing and landing points. The horizontal line shows the break between preference (above) and avoidance (below), and the dashed vertical lines show the domain of observation.

Lustick et al. (1972) placed the thermoneutral zone of bobwhites between 30 and 40°C. However, the upper critical temperature (40°C) may be too high because gular flutter occurs at 35.0–38.5°C (Case and Robel 1974, Spiers et al. 1983), and 40°C may be lethal if bobwhites are exposed to this temperature for long periods (Case and Robel 1974). Bobwhites can survive exposure to air temperatures of 44.1–45.1°C for 100 min, but such exposure elevates body temperatures above normal (Lasiewski et al. 1966). If the thermoneutral zone ranges between 30 and 35°C, then bobwhites tended to use thermoneutral portions of the environment during the pair-nest and nest-brood seasons. Mean operative temperature at flushing and landing points fell within the 30–35°C range during

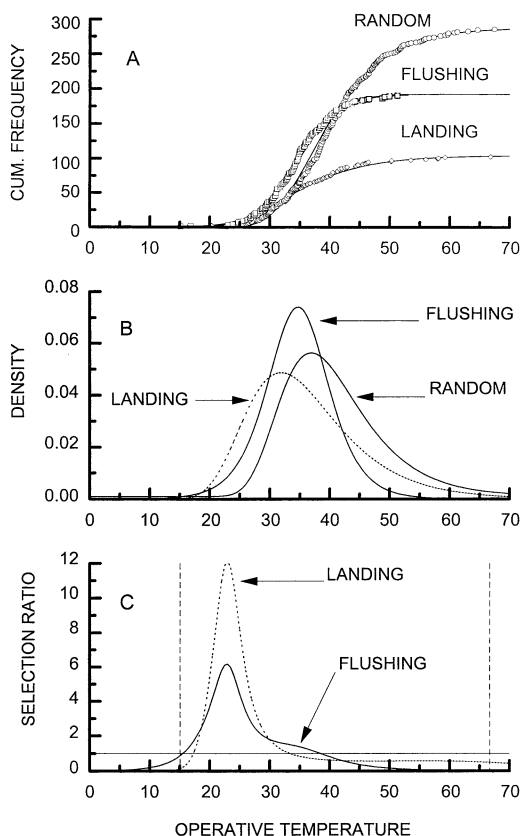


Fig. 4. Selection analysis for operative temperatures (°C) at points used by northern bobwhites in southern Texas during the nest-brood season (Jul–Sep), 1994–95. (A) Cumulative (Cum.) frequency models ($r^2 \geq 0.98$, $P < 0.001$). (B) Probability distributions derived from cumulative frequency models. (C) Selection ratios for flushing and landing points. The horizontal line shows the break between preference (above) and avoidance (below), and the dashed vertical lines show the domain of observation.

these seasons (Table 1). During the covey season, mean operative temperatures fell below the presumed thermoneutral zone at used points, when bobwhite occurrence in thermal space-time generally reflected the random availability of thermal space-time (Fig. 2).

The avoidance of habitat space-time with operative temperatures >39°C during the hottest season (nest-brood; Fig. 4) may have a basis in thermoregulation. Based on gular flutter at 35.0–38.5°C and possible death at 40°C (Case and Robel 1974, Spiers et al. 1983), 39°C may represent a borderline circumstance between normal body temperature and hyperthermia. At temperatures >39°C, heat dissipation mechanisms may not keep pace with body heat gain over an extended period.

The estimated degree to which operative temperatures fragmented habitat space on our study areas ($\geq 52\%$ of space-time avoided) was surprising. This outcome means that when one views an area of some size over some period of time in the region where we conducted research, more than half of potential space-time may be thermally unsuitable for bobwhites, especially during warmer seasons. Thermal issues are not a concern at night or in the morning.

We recognize that our findings on the response of bobwhites to the thermal environment are confounded with predator-avoidance issues. Kopp et al. (1998) demonstrated selection behavior for low exposure to terrestrial and aerial predators in another paper arising from the present research. However, the results reported herein suggest the thermal environment in subtropical-subhumid regions may commonly reach levels that are nearly as hazardous to bobwhites as predators, because bobwhites are vulnerable to incapacitation or death from hyperthermia. Goldstein (1984) measured temperatures high enough to kill Gambel's quail in minutes if individuals began moving in full sunlight in the deserts of Arizona. The relative importance of predator avoidance and heat avoidance will have to be determined in future research. Our results merely challenge predator-avoidance as an omnibus explanation for the field behavior of bobwhites.

MANAGEMENT IMPLICATIONS

Taking 39°C as an approximation of the operative temperature that leads to hyperthermia in bobwhites, we find that large portions of the randomly available thermal environment may be intolerable to bobwhites during warmer seasons in semiarid-subtropical environments (Figs. 3, 4). Habitat management that fosters lower operative temperatures near the ground may increase the abundance of bobwhites in these environments. Generally, bobwhite populations increase as space-time is added to a management area (Guthery 1997). Based on Klimstra and Roseberry (1975), lower operative temperatures may also increase the length of the laying season, which would increase the number of opportunities for renesting and multiple brooding, and hence annual production.

Management of the thermal environment involves the structure, composition, and dispersion of vegetation. Woody plants provide thermal cover for loafing, and bobwhites in sub-

tropical environments select taller woody cover during hotter days, presumably for cooling effects (Johnson and Guthery 1988). Thus, taller woody cover should be well dispersed on a management area. Herbaceous ground cover reduces operative temperatures via shading from solar radiation and via the cooling effects of evapotranspiration. Schroeder's (1985) habitat suitability indices indicate optimum herbaceous cover has these properties: 40–60% canopy coverage, 40–60 cm tall, and 40–60% grasses. Managers might apply the upper extremes of these ranges in subtropical environments.

ACKNOWLEDGMENTS

The Caesar Kleberg Foundation for Wildlife Research and the Quail Research Fund supported this study. We thank J. C. Laurenz and B. O. Wolf for reviewing the manuscript. The Welder Wildlife Foundation, Texas A&M University-Kingsville, Texas A&M University System, and private landowners granted access to study areas. This paper is Welder Wildlife Contribution 512 and Caesar Kleberg Wildlife Research Institute manuscript 97-108.

LITERATURE CITED

- BANKS, R. B. 1991. Growth and diffusion phenomena. Springer-Verlag, New York, New York, USA.
- CALDER, W. A., AND J. R. KING. 1974. Thermal and caloric relations of birds. Pages 259–413 in D. S. Farner and J. R. King, editors. Avian biology. Academic Press, New York, New York, USA.
- CAMPBELL, G. S. 1977. An introduction to environmental biophysics. Springer-Verlag, New York, New York, USA.
- CARMİ-WINKLER, N., A. A. DEGEN, AND B. PINSHOW. 1987. Seasonal time-energy budgets of free-living chukars in the Negev Desert. *Condor* 89:594–601.
- CASE, R. M., AND R. J. ROBEL. 1974. Bioenergetics of the bobwhite. *Journal of Wildlife Management* 38:638–652.
- GOLDSTEIN, D. L. 1984. The thermal environment and its constraint on activity of desert quail in summer. *Auk* 101:542–550.
- GOULD, F. W. 1975. Texas plants: a checklist and ecological summary. Texas Agricultural Experiment Station Miscellaneous Publication 585 (revised).
- GUTHERY, F. S. 1997. A philosophy of habitat management for northern bobwhites. *Journal of Wildlife Management* 61:291–301.
- JOHNSON, D. B., AND F. S. GUTHERY. 1988. Loafing coverts used by northern bobwhites in subtropical environments. *Journal of Wildlife Management* 52:464–469.
- KLIMSTRA, W. D., AND J. L. ROSEBERRY. 1975. Nesting ecology of the bobwhite in southern Illinois. *Wildlife Monographs* 41.
- KOPP, S. D., F. S. GUTHERY, N. D. FORRESTER, AND

- W. E. COHEN. 1998. Habitat selection modeling for northern bobwhites on subtropical rangeland. *Journal of Wildlife Management* 62:884–895.
- LARKIN, T. J., AND G. W. BOMAR. 1983. Climatic atlas of Texas. Texas Department of Water Resources, Austin, Texas, USA.
- 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. *Comparative Biochemistry and Physiology* 19:445–457.
- LUSTICK, S., T. VOSS, AND T. J. PETERLE. 1972. Effects of DDT on steroid metabolism and energetics in bobwhite quail (*Colinus virginianus*). *Proceedings of the National Bobwhite Quail Symposium* 1:213–233.
- MAHONEY, S. A., AND J. R. KING. 1977. The use of the equivalent black-body temperature in the thermal energetics of small birds. *Journal of Thermal Biology* 2:115–120.
- MENDENHALL, W., D. D. WACKERLY, AND R. L. SCHEAFFER. 1990. *Mathematical statistics with applications*. PWS-Kent Publishing, Boston, Massachusetts, USA.
- PORTER, W. P., AND C. R. TRACY. 1983. Biophysical analyses of energetics, time-space utilization, and distributional limits. Pages 55–83 in R. B. Huey, E. R. Pianka, and T. W. Schoener, editors. *Lizard ecology*. Harvard University Press, Cambridge, Massachusetts, USA.
- SCHROEDER, R. L. 1985. Habitat suitability models: northern bobwhite. U.S. Fish and Wildlife Service Biological Report 82 (10.104).
- SPIERS, D. E., T. ADAMS, AND R. K. RINGER. 1983. Temperature regulation in adult quail (*Colinus virginianus*) during acute thermal stress. *Comparative Biochemistry and Physiology* 74A:369–373.
- WHITE, S. L. 1995. Comparative anatomy of Texas and masked bobwhites. Thesis, Texas A&M University-Kingsville, Kingsville, Texas, USA.
- WOLF, B. O., K. M. WOODEN, AND G. E. WALSBURG. 1996. The use of thermal refugia by two small desert birds. *Condor* 98:424–428.

Received 21 December 1997.

Accepted 22 May 1998.

Associate Editor: Porter.