Herpetological Conservation and Biology 5(1):143-148.
Submitted: 1 June 2008; Accepted: 26 May 2009.

ENVIRONMENTAL FACTORS AFFECTING SAMPLING SUCCESS OF ARTIFICIAL COVER OBJECTS

***LUCAS N. JOPPA*[1], *CHRISTOPHER K. WILLIAMS*[2], *STANLEY A. TEMPLE*[3], *AND GARY S. CASPER*[4]**

[1]Nicholas School of the Environment, Box 90328 LSRC, Duke University, Durham, North Carolina 27708, USA, e-mail: lnj@duke.edu.
[2]Department of Entomology and Wildlife Ecology, 253 Townsend Hall, University of Delaware, Newark, Delaware 19716, USA, e-mail: ckwillia@udel.edu.
[3]Department of Forest and Wildlife Ecology, A221 Russell Labs, University of Wisconsin-Madison, Madison, Wisconsin 53706, USA, e-mail: satemple@wisc.edu.
[4]University of Wisconsin-Milwaukee Field Research Station, PO Box 375, Slinger, Wisconsin 53086, USA, e-mail: gcasper@charter.net.

***Abstract*.—Artificial cover objects (ACOs) can be useful for surveying an area for snake abundance. However, very little is known about the correlation between environmental conditions, time of day, and ACO capture success rates. We studied the effects of time of day, temperature, humidity, wind speed, and sky cover variables in relation to ACO sampling capture rates of two colubrid species, *Thamnophis butleri* and *Thamnophis sirtalis*. We found that time of day, temperature, and sky cover best explained capture with a quadratic function of temperature being a significant variable. An optimal temperature of 26°C with increasing cloudiness was found to produce the highest ACO sampling capture rate. These observations provide some of the first quantitative information regarding temporal and environmental correlates of ACO methodology, and may help improve the efficiency of the ACO technique for surveying snake abundance.**

Key Words.— capture rates; cover object; environmental effects; Garter Snake; *Thamnophis butleri; Thamnophis sirtalis*

INTRODUCTION

Reptiles often seek shelter under naturally occurring cover objects, and introducing artificial cover objects (ACOs) into areas with scarce natural cover is a useful method for sampling herpetofauna during inventory or monitoring (Parmelee and Fitch 1995). The primary advantages of ACO sampling are low cost and labor intensity (Englelstoft and Ovaska 2000; Kjoss and Litvaitis 2000) while providing a better measure of abundance than quadrant and transect sampling (Monti et al. 2000). When compared to other methodologies, ACO sampling is a relatively nonintrusive procedure from the perspective of the sampled species, as no contact with the animal is needed.

Although the literature on sampling with ACO methodology is biased towards amphibians (Bonin and Bachand 1997; Monti et al. 2000; Houze and Chandler 2002), there has been increased use of ACOs to sample snakes (Parmelee and Fitch, 1995; Englelstoft and Ovaska 2000; Kjoss and Litvaitis 2001). Fitch (1992) found ACOs produced higher capture rates than live traps or random encounters. This improved success may occur because shelters provide reduced mortality during ecdysis and during digestion of food items (Fitch 1992). The result may also be observed because snakes seek such shelters for conductive and radiant heat gain as ACOs collect and store solar radiation when the rest of the environment begins to cool from a lack of sunlight (Kjoss and Litvaitis 2001). Importantly, temporal and environmental conditions such as time of day, temperature, rainfall, cloud cover, and humidity may affect the capture success of ACOs (Fellers and Drost 1994).

The purpose of this study was to investigate the influence of temporal and environmental variables on the sampling success of the ACO methodology for snakes. We examined combined sampling success for two garter snake species, the Common Gartersnake (*Thamnophis sirtalis*) and the Butler's Gartersnake (*Thamnophis butleri*), relative to ambient environmental conditions and time of day. Our results lend insight into the thermal biology of the two study species, and should help researchers increase the efficiency of ACO sampling by identifying temporal and environmental conditions (time of day, ambient temperature and humidity, sky, and wind) most conducive to increased snake detections.

MATERIALS AND METHODS

ACOs are often made of many different materials (e.g., asphalt roofing, corrugated tin, plywood; Parmelee and Fitch 1995; Englelstoft and Ovaska 2000; Kjoss and Litvaitis 2001). We used plywood boards for this study because metal boards may overheat and reduce capture success (Parmelee and Fitch 1995) and because previous use of plywood cover boards proved successful for detecting *T. butleri* and *T. sirtalis* in Wisconsin (Gary Casper, pers. obs.). We combined data from two prior

FIGURE 1. Map of south-eastern Wisconsin, USA, where the study of capture rates of cover objects took place.

studies conducted simultaneously. In the first, we placed 2 cm x 122 cm x 81 cm plywood boards every 7.6 m along 122 m transects perpendicular to wetland edges for a total of 16 ACOs per transect. We established 30 transects at seven different sites, comprising 480 ACOs. In the second study, we randomly placed 21 or 42 ACOs around wetland edges at 11 sites, resulting in 273 ACOs (753 ACOs in total). The majority of ACOs were in place by the first week of May 2003, and sampling began 2 weeks later to allow sufficient time for snakes to occupy the ACOs. The study areas were in Milwaukee, eastern Waukesha, southeastern Washington, and southern Ozaukee counties, Wisconsin, USA (Fig. 1). The sites had typical southeastern Wisconsin wetlands (i.e., cattail marsh, wet and wet-mesic prairie, southern sedge meadow, lowland old-field, shrub-carr; Eggers and Reed 1997), and were quite similar to one another (Jeff Lorch, pers. comm.). All transect sites had at least 122 m of upland habitat ascending a slope adjacent to a wetland. Sampled habitat at each site had < 50% tree canopy cover and well established ground cover dominated by grasses. All sampling areas were continuous habitat without transecting roads, buildings, or fences. Very few natural cover objects were present. We cleared all vegetation from under each ACO site, laid the ACO flat on the ground, and covered it lightly with nearby vegetation. We did this to avoid the production of rotting vegetation underneath ACOs, which may discourage snakes (Parmelee and Fitch 1995). We avoided laying an ACO on substrates such as ant mounds that discourage *T. butleri* or *T. sirtalis* use of the ACO as shelter.

We checked sites twice a week for the duration of the 7-week study period, 19 May – 6 July 2003. Although several severe weather events prevented us from checking every site exactly twice per week, these were rare occurrences. We ended the study in the mid-July because data from prior years showed a decline in capture rates beginning at this time (Gary Casper, pers. obs.). Three sites were checked during each morning and evening sampling period. We normally checked the ACOs no earlier than two hours before sunset during the evening data collection and no more than two hours after sunrise for morning data collection. However, when rain was forecast, we checked the ACOs before precipitation occurred, regardless of time of day. Over the course of this study, we recorded 1,279 snake captures during 9,058 ACO samplings across 753 ACOs and 18 field sites.

During the duration of the study, we recorded time of day, temperature, relative humidity, wind speed, and sky conditions immediately prior to checking the first ACO at each site. All subsequent ACOs at the site were assigned equal values. We used a 0–6 ranking basis according to the Beaufort scale to record wind speed. We used a 0-5 scale, with 0 = clear, 1 = partly cloudy, 2 = cloudy, 3 = fog, 4 = drizzle, 5 = rain or thundershowers to report sky conditions.

To determine if temporal (time of day and Julian date) or environmental variables (temperature, humidity, sky, and wind) affected the use of ACOs by either *T. sirtalis* or *T. butleri*, we *apriori* identified a set of candidate models to possibly explain this relationship. Before we entered parameters into possible candidate models, we first identified whether each variable influenced snake use of ACOs via a linear or quadratic relationship, and whether any variables strongly correlate and could be removed. We then conducted a multiple linear regression on all candidate models and used Akaike Information Criteria (AIC; a measure of model fit corrected for the number of parameters in the model) and Akaike weights (the relative proportion that each model is the best model out of 100%) to find the best descriptive model (Burnham and Anderson 2002; Johnson and Omland 2004). The model with the lowest AIC value and the highest AIC weight indicates the most likely explanation of observed variation in snake use of ACOs.

RESULTS

During the study period, we recorded 286 captures of *T. sitalis* and 993 captures of *T. butleri*. The average number of snakes recorded per transect per day produced 208 unique data points to conduct modeling analysis.

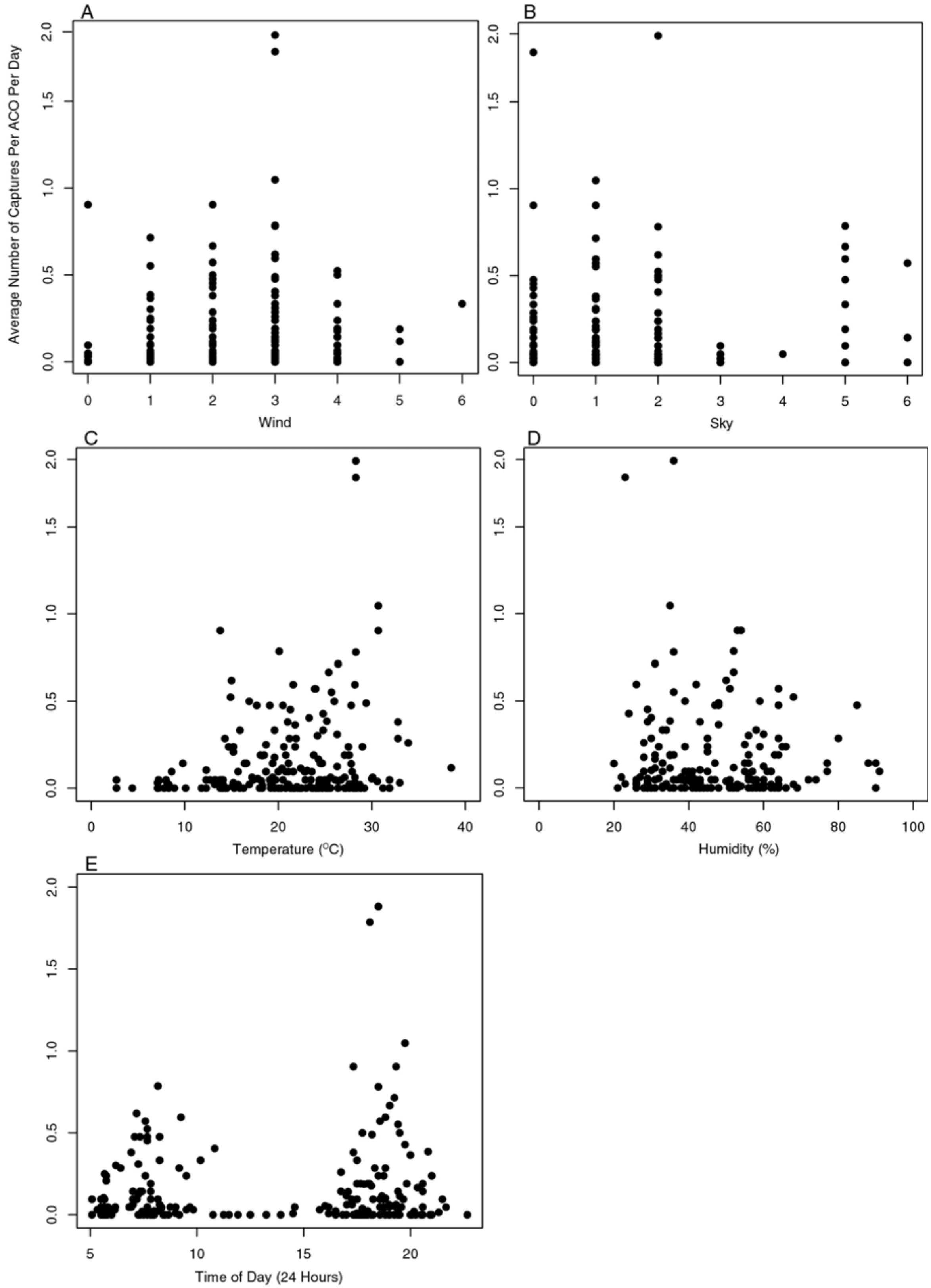

FIGURE 2. Average *Thamnophis butleri* or *T. sirtalis* captures per artificial cover object (ACO) per day (Y-axis) for the five measured variables in this study conducted in Wisconsin, USA: (A) Wind Speed; (B) Sky; (C) Temperature (^{O}C); (D) Humidity (%); and (E) Time of Day (24 h clock). Wind speed and Sky (a measure of cloudiness) appear on an increasing scale from 1 to 6.

Because temperature and Julian date were strongly correlated (Pearson correlation Coefficient = 0.519, P < 0.01), we selected temperature as the variable of choice for subsequent modeling. Additionally, of the six variables considered, only temperature more strongly influenced snake occurrence via a quadratic relationship rather than a linear relationship ($P < 0.05$) to account for a curvilinear structure in the daytime values. For example, temperature is lower in the morning, increases throughout the day, and then decreases at the end of the day. Explanatory models must include this variability. Therefore, for further model selection, we examined the following terms: (temperature)^2, humidity, wind, sky, and time.

We performed multiple linear regression analysis on 19 possible models of the five variables (Table 1). We found the main effects of quadratic temperature and time of day were the best predictors of the number of snakes per ACO ($F_{2,205} = 5.958$, $P = 0.003$) with a final regression model of: Number of snakes/ACO = 0.001(temp^2) + 0.006(time) + 0.013(constant). Although the best-fit model (model 1) was 9.4% better than the 2nd best model, and therefore a superior fit (Burnham and Anderson, 2002), we acknowledge the top 3 models were similar. The second best model ($F_{1,206} = 8.942$, $P = 0.003$) only contained the main effect of quadratic temperature (Number of snakes/ACO = 0.001(temp^2) + 0.057(constant) and the third best model ($F_{2,205} = 5.371$, $P = 0.005$) contained main effects of quadratic temperature and sky (Number of snakes/ACO = 0.001(temp^2) + 0.017(sky) + 0.042(constant). Therefore we also conducted model averaging of these three models (following Burnham and Anderson 2002) producing a revised, although essentially similar, regression model of: Number of snakes/ACO = 0.001(temp^2) + 0.003(time) – 0.004(sky) + 0.033(constant). In all models the quadratic function of temperature is most critical to observing snakes under ACOs. A linear interpolation of the best fit model predicted a peak in snakes captured per ACO at an optimal temperature of 26°C. Additionally, at this optimal temperature, the odds of capturing snakes improved as the sky became partly or fully cloudy.

DISCUSSION

The results of this study are reasonable based on snake physiology and the hypothesis that snakes seek cover objects in part for the object's heat retention properties. Thus, the significance of temperature dependence on ACO capture rate is understandable. Above the observed optimal capture temperature of 26°C, reptiles may be less dependent on additional heat sources to maintain a critical body temperature (Beauchat and Ellner 1987). Encounter rates for reptiles are greatest at ambient temperatures of 20-25°C, but this can vary with local climate and species assemblages (Grant et al. 1992). Why our capture rates were lower at temperatures below 26°C is unknown. Cooler temperatures may reduce overall activity, or snakes may seek other retreats.

In recent years, there has been concern as to an appropriate method to estimate population abundances of herpetofauna (Monti et al. 2000). Many authors describe how count indices obtained from ACO studies may not accurately represent population size (Marsh and Goicochea 2003). This bias could occur from intense sampling as well as from differing preferences in cover objects between size and age classes of a species (Marsh and Goicochea 2003). While this study did not

TABLE 1. Multiple regression models of five variables predicting number of *Thamnophis butleri* or *T. sirtalis* per board in Wisconsin, USA.

Model	AICc	Δ_i	w_i	No. of Parameters	r^2
Temp^2 + time	-569.34	0.00	25.7%	2	0.26
Temp^2	-568.47	0.91	16.3%	1	0.24
Temp^2 + sky	-568.21	1.13	14.6%	2	0.25
Temp^2 + wind	-566.68	2.66	6.8%	2	0.24
Temp^2 + wind	-566.68	2.66	6.8%	2	0.24
Temp^2 + humid	-566.43	2.91	6.0%	2	0.24
Temp^2 + wind + sky	-566.24	3.04	5.6%	3	0.25
Time	-565.32	4.05	3.4%	1	0.23
Temp^2 + humid + wind + sky + time	-564.84	4.26	3.1%	5	0.26
Sky + time	-565.02	4.32	3.0%	2	0.24
Temp^2 + humid + wind + sky	-564.81	4.39	2.9%	4	0.25
Wind + time	-563.78	5.56	1.6%	2	0.23
Humid + time	-563.44	5.90	1.3%	2	0.23
Humid + sky	-562.60	6.74	0.9%	2	0.22
Sky	-562.53	6.85	0.8%	1	0.21
Wind + sky	-560.97	8.36	0.4%	2	0.22
Wind	-560.58	8.80	0.3%	1	0.21
Humid	-559.84	9.53	0.2%	1	0.20
Humid + wind	-558.79	10.55	0.1%	2	0.21

Notation follows that of Anderson et al. (2000): AIC_c = Akaike Information Criterion, second order; Δ_i = AIC_c differences; w_i = Akaike weight specifically address those problems, understanding how to maximize capture rates is an important step towards a better understanding of ACO-based study results. Although previous studies approached the efficacy of ACOs and their design, this study adds to the quantitative information available on the correlation of temporal and environmental variables (time, temperature, humidity, wind speed, sky cover) with the success of ACOs as a sampling procedure for snakes. As ACOs gain more acceptance and use in the field of herpetology, the results of our study will help researchers decide when to monitor ACOs in the field, thereby increasing sampling success. An increase in sampling success is necessary if important biological information (such as population parameters critical for success conservation efforts) is to be gathered about cryptic species. By understanding that temperature and sky condition were significant variables affecting capture rate at our sites, while humidity and wind speed were not, sampling success should be improved.

Acknowledgments.—We conducted this work with support from the Wisconsin Department of Natural Resources-Bureau of Endangered Resources, a Garden Club of America research award, Wisconsin Academy of Arts and Science's Lois Almon award, and the University of Wisconsin-Madison Holstrum Environmental Fellowship. We are extremely grateful to Bob Hay for getting this project off the ground, as well as for his continued help throughout this study. We thank the Max McGraw Wildlife Foundation for their support. We also thank Jeff Lorch for his efforts in collecting field data. This is Contribution Number 210 of the University of Wisconsin - Milwaukee Field Station, one of our research sites. The University of Wisconsin Animal Use and Care Committee approved all research protocols in this study (NIH approval #A3368-01, protocol #A01120-1-04-03).

LITERATURE CITED

Beauchat, C.A., and S. Ellner. 1987. A quantitative test of life history: thermoregulation by a viviparous lizard. Ecological Monographs 57:45–60.

Bonin, J., and Y. Bachand. 1997. The use of artificial covers to survey terrestrial salamanders in Québec. Pp. 175–179 *In* Amphibians in Decline. Green, D.M. (Ed.). Canadian Studies of a Global Problem. Herpetological Conservation No. 1. Society for the Study of Amphibians and Reptiles. St. Louis, Missouri, U.S.A.

Burnham, K.P., and D.R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-theoretic Approach. Springer, New York, New York, USA.

Eggers, S.D., and D.M. Reed. 1997. Wetland Plants and Plant Communities of Minnesota and Wisconsin. 2nd Edition. U.S. Army Corps of Engineers, St. Paul, Minnesota, USA.

Englelstof, C., and K.E. Ovaska. 2000. Artificial cover-objects as a method for sampling snakes. Northwestern Naturalist 81:35–43.

Fellers, G.M., and C.A. Drost. 1994. Sampling with artificial cover. Pp. 146–150 *In* Measuring and Monitoring Biological Diversity: Standard Methods for Amphibians. Heyer, W.R., M.A. Donnelly, R.W. McDiarmid, L.C. Hayek, and M.S. Foster (Eds.). Smithsonian Institution Press, Washington, D.C., USA.

Fitch, H.S. 1992. Methods of sampling snake populations and their relative success. Herpetological Review 23:17–19.

Grant, B.W., A.D. Tucker, J.E. Lovich, A.M. Hills, P.M. Dixon, and J.W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pp. 379–403 *In* Wildlife 2001. McCullough, D.R., and R.H. Barrett (Eds.),.Elsevier Science Publications, London, UK.

Houze, C.M., Jr., and C.R. Chandler. 2002. Evaluation of coverboards for sampling terrestrial salamanders in Georgia. Journal of Herpetology 36:75–81.

Johnson, J.B., and K.S. Omland. 2004. Model selection in ecology and evolution. Trends in Ecology and Evolution 19:101–108.

Joppa, L.N., and S.A. Temple. 2005. Use of upland habitat by the Butler's Garter Snake (*Thamnophis butleri*). Chicago Herpetological Society Bulletin 40:221–227.

Kjoss, V.A., and J.A. Litvaitis. 2000. Community structure of snakes in a human-dominated landscape. Biological Conservation 98:285–292.

Kjoss, V.A., and J.A. Litvaitis. 2001. Comparison of methods to sample snake communities in early successional habitats. Wildlife Society Bulletin 29: 153–157.

Marsh, D.M., and M.A. Goicochea. 2003. Monitoring terrestrial salamanders: biases caused by intense sampling and choice of cover objects. Journal of Herpetology 37:460–466.

Monti, L., M. Hunter, and J. Witham. 2000. An evaluation of the artificial cover object (ACO) method for monitoring populations of the Redback Salamander *Plethodon cinereus*. Journal of Herpetology 34:624–629.

Parmelee, J.R., and H.S. Fitch. 1995. An experiment with artificial shelters for snakes: effects of material, age, and surface preparation. Herpetological Natural History 3:187–191.

LUCAS JOPPA is a Post-doctoral Researcher in the Nicholas School of the environment at Duke University. His interests include protected area planning and design, community ecology, and herpetological conservation. (Photographed by Will Cook).

CHRISTOPHER WILLIAMS is an Assistant Professor of Wildlife Ecology at the University of Delaware. He is primarily interested in population ecology with special interest in upland game birds and waterfowl. (Photographed by Anonymous).

STANLEY TEMPLE retired in 2007 from the University of Wisconsin-Madison Wildlife Ecology Department as the Beers-Bascom Professor in Conservation, and now continues his life work as Senior Fellow and Science Advisor with the Aldo Leopold Foundation. He has worked in 28 different countries and with some of the world's most endangered species. He is a founding member, and past president, of the Society for Conservation Biology. (Photographed by Anonymous).

GARY CASPER is a Research Scientist at the University of Wisconsin-Milwaukee Field Research Station. His lifelong interest in herpetology and 20 years of service as the Collection Manager of Herpetology and Ichthyology at the Milwaukee Public Museum led to his recognition as one of the foremost experts on herpetological conservation in the Midwest of the United States. (Photographed by Gary Casper)