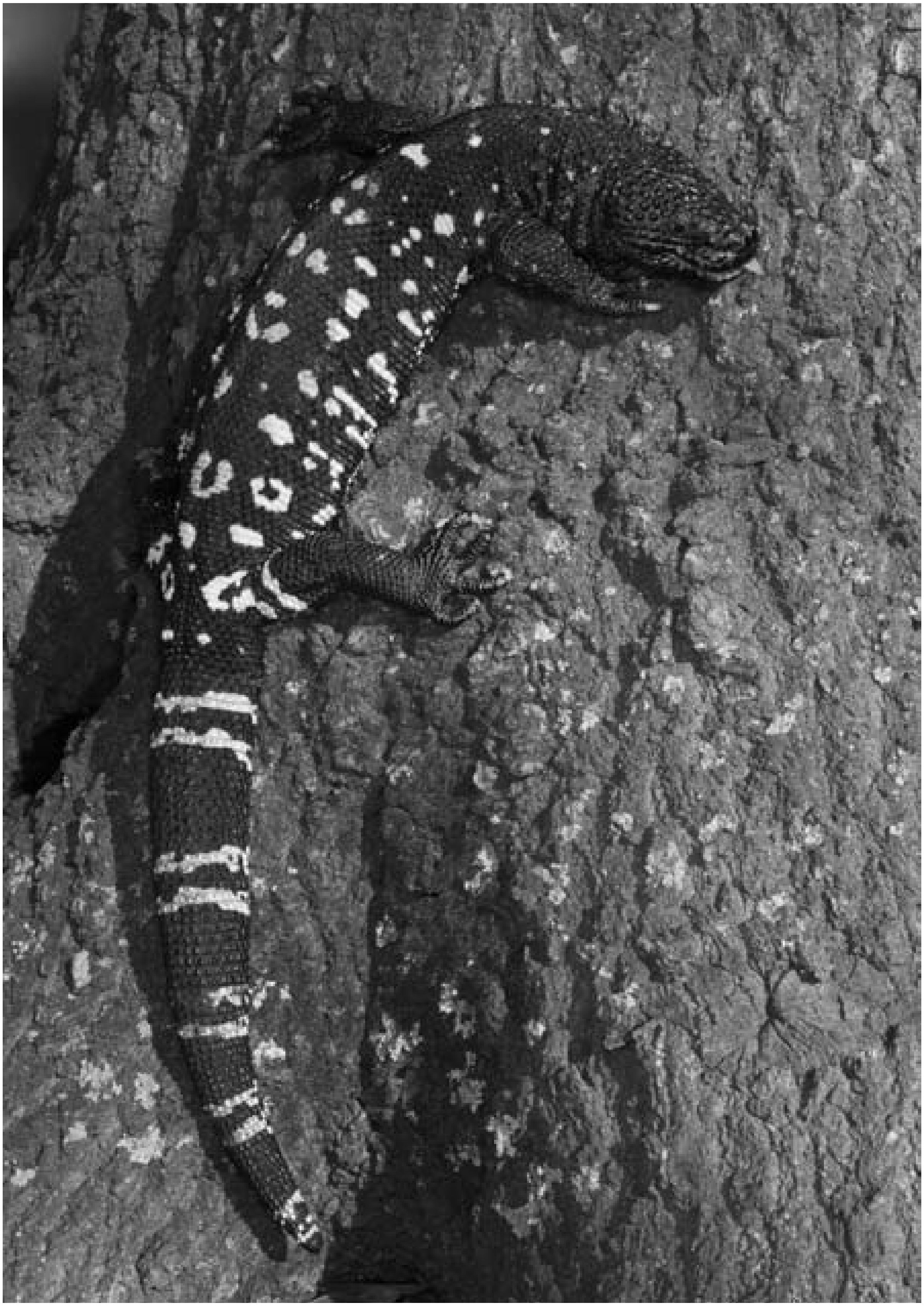


MICHAEL KERN

With powerful limbs and claws, the Guatemalan Beaded Lizard (*Heloderma horridum charlesbogerti*) is well equipped to climb trees in search of nestling prey.

Notes on the Distribution of the Endangered Lizard, *Heloderma horridum charlesbogerti*, in the Dry Forests of Eastern Guatemala: An Application of Multi-criteria Evaluation to Conservation

Daniel Ariano[1,2] & Gilberto Salazar[2]

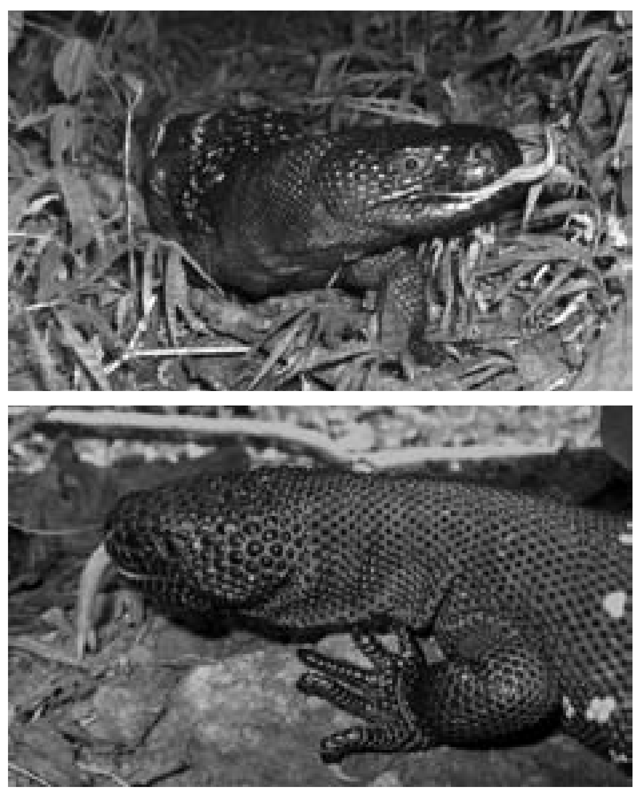
[1]Postgrado de Biología, Universidad de Costa Rica, San Pedro-San José, Costa Rica (darianosanchez@gmail.com)
[2]Asociación Zootropic, 12 calle 1-25 z. 10. Edif. Geminis 10, Torre Sur nivel 18, Of. 1801, Ciudad Guatemala, Guatemala

The Helodermatidae belong to the reptile clade possessing toxin-secreting oral glands (Fry et al. 2006). Lizards of this family are specialized vertebrate nest predators (Pianka 1966). The two species of *Heloderma* that comprise the Helodermatidae are *Heloderma suspectum* and *H. horridum* (Campbell and Lamar 2004). The former is commonly known as the "Gila Monster," whereas the latter is known as the "Beaded Lizard," "scorpion," or "sleeping baby" (Ariano 2003, Beck 2005). The coloration of *H. horridum* is both cryptic and aposematic (Beck 2005). This species reaches an average total length of about 650 mm (Beck and Lowe 1991), and the tail is short in relation to the size of the rest of the body (Álvarez del Toro 1982). The average weight of an adult is around 800 g (Beck and Lowe 1991).

Four subspecies of *H. horridum* have been described: *H. h. horridum, H. h. exasperatum, H. h. alvarezi* (Bogert and Martín del Campo 1956), and *H. h. charlesbogerti* (Campbell and Vannini 1988). *Heloderma h. charlesbogerti*, the Guatemalan Beaded Lizard, represents an isolated and distinctive population at the southern limit of the species' distribution (Beck 2005). *Heloderma h. charlesbogerti* differs from the other subspecies in body proportions and color patterns (Campbell and Vannini 1988). Recent molecular studies suggest that this taxon (in conjunction with *H. h. alvarezi*) may actually represent a distinct species (Douglas et al. 2003).

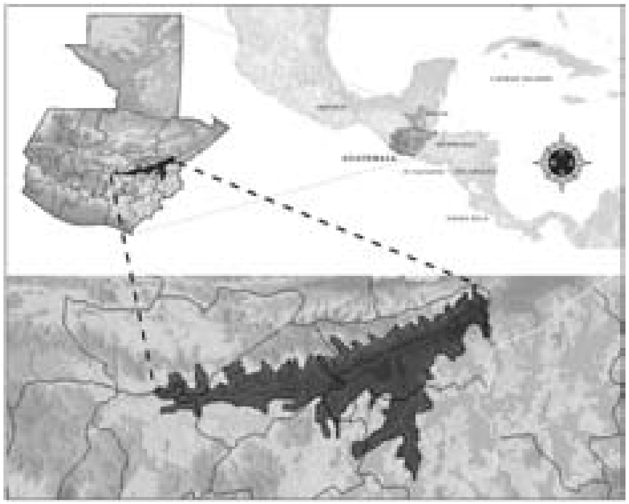
The Guatemalan Beaded Lizard inhabits the dry forests of the semiarid region of the Motagua Valley in eastern Guatemala (Ariano 2003) at elevations of 300–900 m above sea level (Campbell and Vannini 1988, Ariano 2003). Studies have revealed that the species can be found along rocky hills with steep slopes associated with dry forest vegetation including *Bucida macrostachya*, *Pereskia autumnalis*, *Moringa oleifera*, *Licania hypoleuca*, *Cephalocereus maxonii*, *Bursera simarouba*, *Leucaena diversifolia*, and *Bursera bipinata* (Ariano 2003).

The holotype of *H. h. charlesbogerti* is in the vertebrate collection of the University of Texas, Arlington (UTA R-15000), and comes from the region of Espíritu Santo, El Jícaro, El Progreso. Most of the paratypes also are in the UTA collection, and others in the collection of vertebrates at the University of Costa Rica (UTA R-15001–3, UTA R-18693, UCR 9602–3). These were collected in 1984 and 1985 in the region of Gualán, Zacapa, and from the region of Espíritu Santo in the Motagua Valley (Campbell and Vannini 1988). The distribution of the Guatemalan Beaded Lizard in Zacapa has been reduced drastically in recent years as a result of extensive loss of forest cover, persecution by local people afraid of its venom, and extraction from the wild for illegal trade (Ariano 2006).



DANIEL ARIANO

Guatemalan Beaded Lizards (*Heloderma horridum charlesbogerti*) in the wild.



JOHN BINNS

Semiarid region of the Motagua Valley in northeastern Guatemala (from Nájera 2006).

Geographic Information Systems (GIS) have been useful tools for identifying conservation priorities for species in changing landscapes (Bojorquez et al. 1995). Multiple criteria frequently need to be evaluated as part of this process. Such procedures are called "Multi-criteria Evaluation" (MCE; Carver 1991, Eastman et al. 1995). MCE is most commonly achieved by Boolean overlay. In this approach, all criteria are reduced to logical statements of suitability and then combined by means of one or more logical operators such as intersection (logical AND) or union (logical OR) (Gutierrez and Gould 2000). This study seeks to determine the potential distribution of *H. h. charlesbogerti* in the semiarid region of the Motagua Valley in order to prioritize conservation areas and develop better conservation strategies for this population.

Methods

Study Site.—The analysis was conducted in the semiarid region of the Motagua Valley (RSAVM) in northeastern Guatemala. Dry forests are among the most endangered ecosystems in the world (Janzen 1988). This region comprises about 200,000 ha in the departments of El Progreso and Zacapa; it has the lowest average annual rainfall in Central America (500 mm) and is characterized by many endemic species (Nájera 2006). Currently, the region is heterogeneous, characterized by agricultural lands, grass lands, thornscrub, and very dry deciduous forest remnants, and includes zones of tropical thorn scrub, very dry tropical forest, and dry tropical forest (Holdridge 1967). The meteorological records of this area indicate that average maximum and minimum temperatures are 34.1 °C and 17.9 °C, respectively, absolute maximum and minimum temperatures are 45.0 °C and 4.4 °C, average annual precipitation ranges from 400–1200 mm, and average relative humidity ranges from 60–80% (INSIVUMEH 2006). Elevations in the region range from 180–900 m, with some peaks reaching 1,200 m. The area is hot and is characterized by seasonal rains; but, in general, the evaporation-transpiration is greater than the total rainfall (Nájera 2006). The rare combination of conditions occurring in RSAVM has contributed to its designation as a "unique ecoregion of the world" in the classification developed by the WWF (Dinerstein et al. 1995).

Multi-criteria Evaluation.—Seven digital maps were used for the Multi-criteria Evaluation. These maps represented conditions of forest cover, actual land use, geology, average rainfall, human population centers, life zones, and slopes of the semiarid region of the Motagua Valley in northeastern Guatemala. The maps were in UTM coordinates with NAD 27 zone 16 datum in raster system (MAGA 2002).

The multi-criteria analysis used a Boolean approach of the type "AND," employing the macro-modeler interface of Idrisi 32 version I32.2. This means that only the pixels that have all of the specific characteristics defined in the analysis will be chosen as potential distribution pixels. The decision rules for this MCE were based on the 2004–2006 collecting sites of *H. h. charlesbogerti.* Categories chosen for each specific layer taking into account these collecting sites were: deciduous forest, shrubscrops, and shrubs for the forest-cover layer; forest-shrubs for the land-use layer; below 800 mm for the average rainfall layer; PZM, Pi, and I categories for the geology layer; thorn scrub and dry forest for the life-zone layer; and above15% for the slopes layer. A buffer zone of 500 m was defined around each human population center.

The final MCE (suitability map of potential distribution of *H. h. charlesbogerti*) was constructed by overlaying all the Boolean maps obtained for each layer, and then adding the constraint that the suitable areas not be within the human population centers and the 500-m buffer zone. The area of the resultant polygons was measured and classified as: < 100 ha; > 100 but < 500 ha; > 500 but < 1000, and > 1000 ha. The patches greater than 1000 ha were defined as the extant populations of the species in its natural habitat.

The characteristics of collecting sites were obtained from base maps (A, B), for which a Boolean transformation was made, assigning value 1 to pixels with the desired characteristics, and value 0 to pixels without those characteristics. Then, all the resultant Boolean maps (C, D) were overlaid to obtain a final potential distribution map (E). Map A represents forest cover and map B represents hill slopes.

Finally, the suitability map was tested by overlaying the historical collecting sites of *H. h. charlesbogerti* from 1984–2001. These historical collecting sites were obtained by reviewing the literature (Campbell and Vannini 1988, Ariano 2003) and the data for specimens in local Guatemalan collections (both live and preserved animals), such as that of the Natural History Museum of the Universidad de San Carlos de Guatemala, National Natural History Museum "Jorge Ibarra," "La Aurora" National Zoo, Zootropic Collection, and the Collection of Universidad del Valle de Guatemala.

The accuracy of the suitability map was measured as the percentage of historical locations predicted correctly by the suitability map. Additionally, each area was visited and surveys were distributed to local inhabitants asking them about the presence of *H. h. charlesbogerti* in surrounding forests. As proposed by Ariano (2003), they also were asked to distinguish the species from a set of six photographs depicting the species *Ctenosaura similis, Coleonyx mitratus, Aspidoscelis managuae, Ctenosaura* *palearis, Hemidactylus tuberculosus*, and *Heloderma horridum charlesbogerti*.

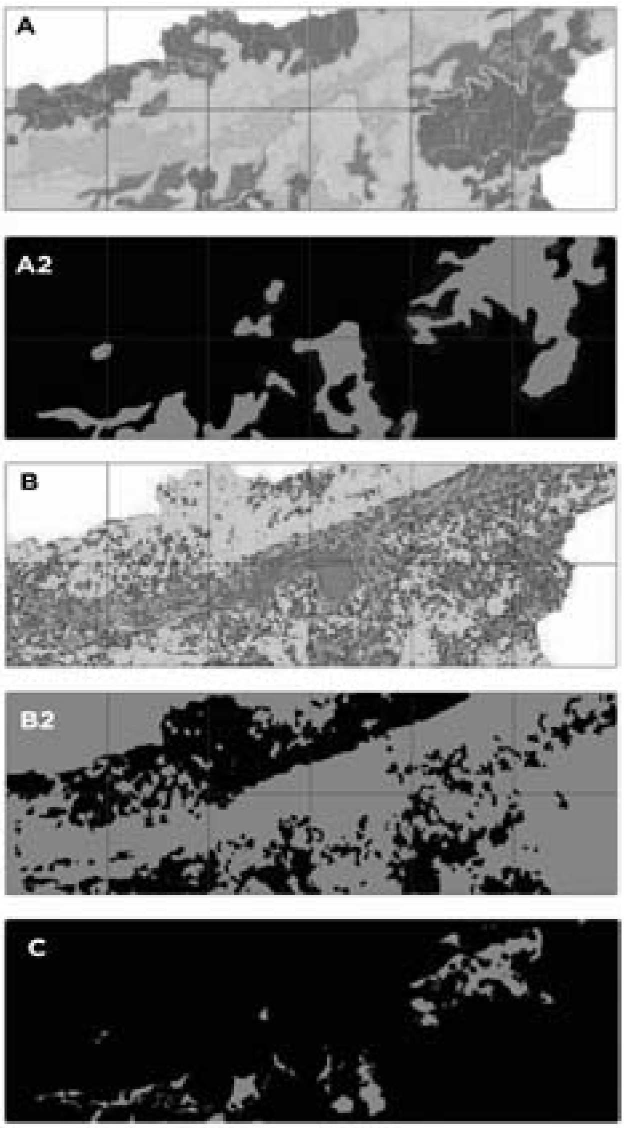
Results

The analysis generated a total of 60 polygons of potential distribution of *H. h. charlesbogerti*. Polygons were aggregated according to geographic proximity in seven areas of potential distribution of the species. These 60 polygons made up a total area of about 25,108 ha of suitable habitat. Of these 60 polygons, only 23 are in the > 100 but < 500 ha category, seven areas are in the > 500 but < 1000 category, and only three areas are > 1000 ha.

The resultant suitability map has an accuracy of 100% because all historical collecting points (1984–2001) were within the polygons predicted by the MCE analysis as potential habitat for *H. h. charlesbogerti*. Also, surveys confirmed the presence of the species in these seven major areas. For these reasons, we believe that the resultant suitability map is a good predictor of the actual distribution of the species according to actual land use, forest cover, rainfall, slopes, and distance to human population centers.

Area #3 contains the collecting sites of the holotype of the species (UTA R-15000) and one paratype (UCR 9602) (Campbell and Vannini 1988). Area #4 contains the more recent collecting sites (Ariano 2003) and is the study site in which six individuals of the species have been radio-tracked. Data from these localities were the basis for determining conditions and constraints established for the Boolean type MCE. This area also contains the collecting sites of the six individuals kept in captivity in the National Natural History Museum "Jorge Ibarra," the pair of individuals kept in the "La Aurora" National Zoo, and one of the two individuals kept in captivity in the Natural History Museum of Universidad de San Carlos de Guatemala. Area #7 contains the collecting sites of five paratypes (UTA-R-15001–3, UTA-R-18693, UCR 9603) and the collecting sites of the individual in the Zootropic collection and one of the individuals in the Natural History Museum of Universidad de San Carlos de Guatemala.

According to the definitions of this study, we identified only three extant populations of *H. h. charlesbogerti*. These populations were in areas #4 (Cabañas-El Jícaro), #5 (San Jorge-Zacapa), and #7 (Gualán-La Cartuchera-Los Jutes), all areas > 1000 ha of continuous potential habitat. The presence of *H. h. charlesbogerti* in these areas was confirmed by the surveys and by sightings in the wild by the authors.



DANIEL ARIANO

Schematic representation of Boolean MCE for determining the potential distribution of *Heloderma horridum charlesbogerti* in the semiarid region of the Motagua Valley, Guatemala. **A:** Shades of gray represent the different types of vegetative cover found in the semiarid region of the Motagua Valley. **A2:** Gray areas represent portions of the same region that match the vegetative cover suitable for *Heloderma* (deciduous forest, shrub-crops, or shrubs) based on *Heloderma* collection sites from 2004–2006. **B:** Shades of gray indicate the degree of incline of slopes in the semiarid region of the Motagua Valley. **B2:** Gray areas represent slopes that correspond to 2004–2006 *Heloderma* collection sites (slopes > 15°). **C:** This map is the final product of the MCE showing the entire potential distribution area of *Heloderma horridum charlesbogerti*. Gray areas represent the cumulative overlay of all Boolean maps for each of the selection criteria (forest cover, actual land use, geology, average rainfall, human population centers, life zones, and slopes) appropriate for *Heloderma* according to actual collection sites from 2004–2006.

Discussion

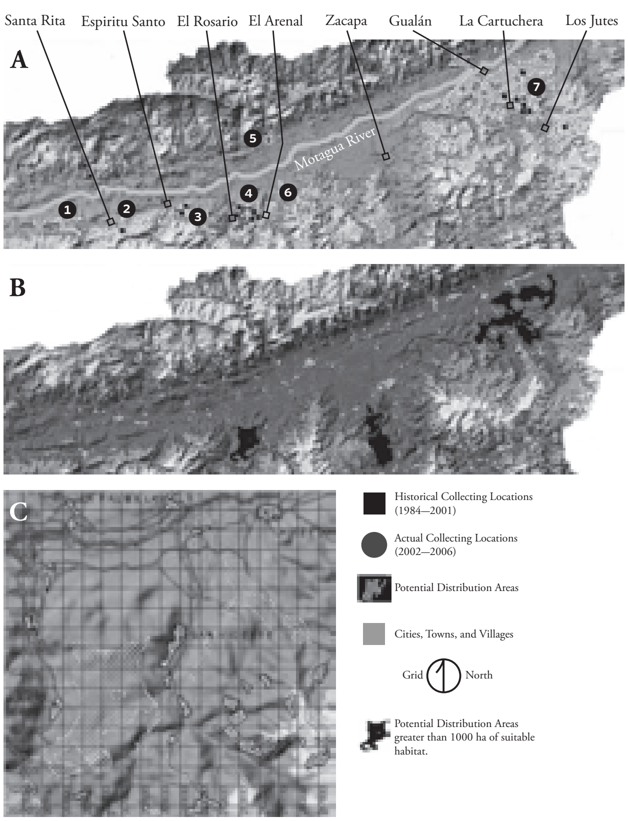
The three areas > 1000 ha are conservation priority areas for the species. According to Ariano (2003), the most relevant threats for the Guatemalan Beaded Lizard are loss of forest cover, illegal extraction for collectors, and persecution by local people, who consider it to be dangerous. As a means of mitigating these threats, we propose the development of strong environmental education programs for the human populations in the surrounding areas and promotion of the establishment of private natural reserves within these areas. These actions may help to eliminate the persecution of this species by local people and diminish the loss of forest cover in the area.

The present study will help to prioritize the human communities that need to be targeted by an educational program promoting the conservation of the species. This is a way to optimize the effectiveness of scarce resources (human and monetary) available for developing any educational program in the area. It also may be of great value in directing overall land conservation efforts to ensure that the protected areas proposed for the region also preserve thorn scrub-very dry forest habitat and the extant populations of *H. h. charlesbogerti*.

Excluding the areas < 100 ha from the analysis, the potential habitat for the species extends across only 17,534 ha. These data illustrate the critically endangered status of this taxon in its natural habitat, which is threatened by a considerable and ongoing loss of forest cover. For these reasons, the implementation of conservation policies and prompt short-term action are critical to ensure the conservation of the Guatemalan Beaded Lizard.

The historical distribution of *H. h. charlesbogerti* extended across the dry forests of the semiarid region of the Motagua Valley in northeastern Guatemala (Campbell and Vannini 1988), an area of about 200,000 ha (Nájera 2006). Presently, only about 0.01% (25,108 ha) of the natural habitat remains. Our data suggest that *H. h. charlesbogerti* is one of the most endangered species in Guatemala.

All but one of the polygons of potential distribution were along the southern bank of the Motagua River. This lends support for the hypothesis proposed originally by Stuart (1954) that a Pacific subhumid corridor was the route by which *H. horridum* gained access into the middle Motagua Valley. This hypothesis has been considered the most plausible explanation for the present distribution of *H. horridum* and many other xeric-adapted species of reptiles in the Motagua Valley (Campbell and Vannini 1988). If true, we would expect that the major distribution of *H. h. charlesbogerti* in the Motagua Valley would be along the southern bank of the Motagua River, because the river has proven to be an effective biogeographic barrier for other taxa (Schuster et al. 2003).



DANIEL ARIANO

Historical and recent collecting localities and potential distribution of the Guatemalan Beaded Lizard (*Heloderma horridum charlesbogerti*) in the semiarid region of the Motagua Valley.

The only way to ensure the conservation of this taxon in its natural habitat is by protecting the last forest remnants harboring populations, and by implementing an educational program for the human populations that inhabit the towns surrounding these areas. The conservation efforts made along the southern versant of the Motagua Valley have to be strengthened, because almost every conservation effort so far has been made along the northern versant of the Motagua Valley. Fortunately, these actions are now in progress, principally through the efforts of the Guatemalan NGO Zootropic and its partners, the International Reptile Conservation Foundation and Zoo Atlanta (Ariano 2006). The governmental authority for biodiversity conservation, the National Council of Protected Areas (CONAP) also has a strong interest in promoting the conservation of the last dry forest remnants in the Motagua Valley, and in developing national policies for the conservation of *H. h. charlesbogerti*. An educational program was initiated recently by Zootropic, with the financial support of the National Fund for Nature Conservation (FONACON). These actions provide reasonable hope for the conservation of the Guatemalan Beaded Lizard. Another positive is the first successful captive breeding of this species after years of failed attempts (Owens 2006).

Taking into account that most of the suitable habitat for the species is made up of patches of forest < 100 ha in a highly fragmented matrix of crops and cattle lands, the area should be managed at a landscape level to ensure the conservation of the species within its habitat (Bennet 2004, Ferrier et al. 2004). Only with a combination of education, land protection, and landscape management will the conservation of *H. h. charlesbogerti* be ensured for the long term.

Acknowledgments

We thank the community in the Cabañas region, Zacapa, Guatemala for their willingness to preserve this species for future generations. Thanks to Luis Alvarado and Rodrigo Botrán of Zootropic for supporting this project since its inception in 2002. Thanks to Juan Aguilar, Priscilla Zamora (in memoriam), Alejandro Muñoz, Blanca Arauz, Sabrina Amador, Ana Guzmán, and Juan Palavicinni of the Universidad de Costa Rica for their help in the early attempts to digitize the base maps. CONAP provided permits to conduct this project. Thanks to Zootropic, IRCF, Zoo Atlanta, and Universidad de Costa Rica for support. Financial assistance for this part of the project was provided by the German Academic Exchange Service (DAAD), Zootropic, Idea Wild, and The Nature Conservancy. Special thanks to Brad Lock (Zoo Atlanta) and John Binns (IRCF) for their support of "Project Heloderma." The present paper is part of D. Ariano's Master of Science thesis in the Department of Biology of Universidad de Costa Rica.

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DANIEL ARIANO

Guatemalan Beaded Lizard habitat in the Motagua River Valley during winter and spring (left) and during the summer (right).

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This Guatemalan Beaded Lizard is part of the captive breeding program at Zoo Atlanta.

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Guatemalan Beaded Lizard Elevated to CITES Appendix I

At the 12-day meeting of the 171 signatory nations of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in The Hague (The Netherlands), the Guatemalan Beaded Lizard (*Heloderma horridum charlesbogerti*) was elevated from Appendix II to I, affording it a higher level of legal protection. The committee considering species proposals requires a two-thirds vote of those present and voting to list a species initially, transfer, or delist a species.

Appendix I lists species that are the most endangered and threatened with extinction. CITES prohibits international trade in these species except when the purpose of the import is not commercial, for instance for scientific research. In these exceptional cases, trade may be permitted — provided that it is authorized by the granting of both an import permit and an export permit (or re-export certificate).

The Proposal Leading to the Change in Status

Summary: *Heloderma horridum charlesbogerti* is a subspecies of the Beaded Lizard, a large, venomous lizard that occurs in Mexico and Guatemala. This subspecies is endemic to the Motagua Valley in eastern Guatemala, where it is restricted to small, dispersed patches of forest in semi-arid areas. The species *H. horridum* was categorized as “Vulnerable” in the IUCN Red List in 1996. The range of the subspecies has been reduced to 24,000 ha, its wild population is currently estimated at 170–250 individuals, and it is regarded as threatened with extinction due to loss of its habitat, collection for local and foreign collectors, the effects of hurricanes, and persecution by local people, who fear it because of its poisonous nature. A National Conservation Strategy has been developed and will attempt to counteract the threats. The subspecies has apparently been traded, both nationally and internationally, and, although the numbers are small, they are significant in relation to the total population. Collection and trade in this subspecies is illegal in Guatemala. Four subspecies of *H. horridum* are recognized, and *H. h. charlesbogerti* differs from the others in various details of morphology and coloration, making it relatively easy to distinguish live animals when adult, although juveniles are said to be difficult to tell apart. *Heloderma suspectum*, the only other species in the genus, is very distinctive. Captive-breeding has so far been unsuccessful, despite many attempts. *Heloderma* species have been included in Appendix II since 1975. The proposal seeks to transfer the population of the subspecies of *Heloderma horridum charlesbogerti* from Appendix II to Appendix I.

Analysis: *Heloderma horridum charlesbogerti* appears to meet the biological criteria for listing in Appendix I. Its habitat has been severely reduced, it is restricted to dispersed patches of forest, the population is very small and localized, and a population decline can be inferred from the difficulty in finding the species currently, compared with the 1980s.

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Iguana

Conservation, Natural History, and Husbandry of Reptiles

International Reptile Conservation Foundation www.IRCF.org

MICHAEL D. KERN

This Panther Chameleon (*Furcifer pardalis*) in Ankify was a highlight of a trip to Madagascar. See article on p. 184.