Monitoring Gila Monster (*Heloderma suspectum*) Populations in Southeastern Cochise County, Arizona.

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Abstract --*Gila Monsters (Heloderma suspectum) are symbolic species of the desert landscapes of the southwestern United States and Mexico. These large, venomous lizards appear to be rather uncommon throughout their range, but our understanding of their population status is complicated by the fact that they spend most of their lives underground rather than actively moving through their preferred upland habitat. Personnel and volunteers from the U.S. Fish and Wildlife Service have opportunistically monitored Gila Monsters in the vicinity of San Bernardino and Leslie Canyon National Wildlife Refuges in southeastern Cochise County, Arizona, from 2000-2017. Lizards were captured, measured, weighed, sexed, photographed, PIT-tagged, and then released at the capture site. Data from 222 different Gila Monsters (313 total captures, including 91 total recaptures) provided insight into seasonal and daily activity periods, individual movement, home range size, habitat use, life history traits, growth and longevity, mortality, and food habits. Such basic population ecology information was easily and economically gathered by Service staff. It contributed to the overall knowledge of Gila Monster population ecology.*

INTRODUCTION

Gila Monsters (*Heloderma suspectum*; Helodermatidae) are one of the most iconic creatures of the American Southwest and adjacent Mexico. They are characterized by their relatively large body size; small eyes covered by moveable eyelids; beadlike osteoderms on the tops of their head, limbs, body, and tail; venom glands in their lower jaw; long, recurved teeth (some being grooved to help deliver venom); thick, forked tongues; and a substantial, sausage-shaped tail used to store fat reserves (Ernst and Ernst 2011, Lowe et al. 1986).

While immediately recognizable as a species, the color pattern of Gila Monsters varies from population to population, is subject to ontogenetic change (Bogert and Martin del Campo 1956), and is described as having irregular, reticulated patches of black blotches on a rose, orange, or yellow background (Beck 2005).

The geographic range of Gila Monsters includes portions of Sonora, Chihuahua, and Sinaloa in the Republic of Mexico, and portions of Arizona, New Mexico, California, Nevada, and Utah in the United States (Beck 2005). Within their habitats, Gila Monsters are highly sedentary for most of the year, spending >92% of the annual cycle at rest in their shelters (Beck 2005). Gila Monsters appear to be rather uncommon throughout their range. Determining their exact population status is complicated by the fact that they spend most of their lives underground and very little of their time actively moving through their preferred upland habitats (Lowe et al. 1986). The species' secretive behavior through most of the year is also responsible for our relatively limited knowledge of their natural history and conservation status.

Here, I describe the results of long-term opportunistic monitoring conducted by the U.S. Fish and Wildlife Service in Cochise County, Arizona. The data from this monitoring have been efficiently gathered during other work. It sheds new light on several aspects of Gila Monster natural history.

Description of Monitoring Site: The Cochise County, Arizona monitoring site, centered around San Bernardino National Wildlife Refuge (SBNWR) and Leslie Canyon National Wildlife Refuge (LCNWR), is characterized by Chihuahuan desert-scrub, influenced by limestone and volcanic soils, relatively high elevations, cold winters, and hot summers. Refuge elevations range from about 1,134-1,195 m (3,719-3,919 ft) on SBNWR to about 1,402-1,722 m (4,600-5,650 ft) on LCNWR. Mean maximum temperatures in this area ranged from about 13-38 ° C (55-100.5 ° F), mean minimum temperatures ranged from -4.8-21 ° C (23.3-68.9 ° F), and temperature extremes ranged from -18-43 ° C (0-109 ° F) (http://www.rcc-acis.org/) during the time of this monitoring effort.

Annual precipitation, measured at three separate rain gauges located on the two refuges, is bimodal. Mid to late summer thunderstorms comprise the majority of the annual rainfall, which ranged from 15.11 cm (5.95 in) during 2003 to 57.94 cm (22.81 in) during 2014 and averaged 31.67 cm (12.47 in) during the 18-year monitoring effort.

Vegetation: Characteristic plants include velvet mesquite (*Prosopis velutina*), whitethorn acacia (*Acacia constricta*), creosote bush (*Larrea tridentata*), littleleaf sumac (*Rhus microphylla*), sandpaper bush (*Mortonia scabrella*), prickly pear cactus (*Opuntia engelmannii*) and (*O. santa-rita*), banana yucca (*Yucca baccata*), soaptree yucca (*Yucca elata*), sotol (*Dasilyrion wheeleri*), ocotillo (*Fouquieria splendens*), and multiple annual and perennial grass species. Narrow riparian corridors containing Fremont cottonwood (*Populus fremontii*), Goodding's willow (*Salix gooddingii*), velvet ash (*Fraxinus velutina*), netleaf hackberry (*Celtis reticulata*), and other species, are more widely spaced across the landscape.

METHODS

Gila Monsters within the general landscape surrounding SBNWR and LCNWR were opportunistically monitored by U.S. Fish and Wildlife Service (Service) personnel between 2000-2017. When we encountered an individual Gila Monster, we captured and temporarily removed it from the environment; measured the length, weighed, sexed (when possible; see discussion below), photographed, PIT-tagged it to provide positive individual identification, and then released it at the original capture site. PIT-tags were injected subcutaneously on the underside of the abdomen with no problems involving tag retention or injury to the lizards. Sexing was accomplished following Beck (2005), Lowe et al. (1986), and Seward (2000), which indicate males generally have larger, wider heads and a more squared body shape, while females generally had narrower heads and a more pear-shaped body. Smaller individuals are not able to be accurately sexed.

This monitoring was accomplished under the conditions prescribed in an annual Arizona Game and Fish Department Scientific Collecting License. Coordinates for capture sites were recorded with GPS devices when available, or using mapping software when necessary, and mapped. Such basic population ecology information was easily and economically gathered by Service staff working at the refuges, and the data adds to the wealth of information already documented for this lizard and can ultimately help wildlife managers make more informed decisions regarding this species.

RESULTS

Refuge staff and volunteers captured and processed 222 different Gila Monsters (313 captures, including 91 total recaptures) between 2000-2017. This includes 26 individuals that were collected as road kills, which were processed and included in this database before they were donated to museums or university collections. Information gained from this long-term monitoring effort has provided data regarding seasonal and daily activity periods, home range/movement, habitat use, life history traits, growth and longevity, mortality, and limited food habits.

Many of the Gila Monsters in our monitoring area typically have more dark than light color patterns (are darker) than those found in other areas of Arizona, perhaps conforming to the principle of Gloger's rule (Bogert and Martin del Campo, 1956), or perhaps providing a greater degree of favorable cryptic coloration in areas dominated by the dark volcanic rock within this landscape. Dark adults have also been discovered in black basaltic lava flows in Southwest Utah (Beck 1985).

Activity Periods **-** Gila Monsters become active when they search for food, water, mates, or shelters, are very familiar with the terrain that they inhabit, and exhibit fidelity to familiar sites (Beck 2005). We observed active individuals from March through December, with two peaks of activity (Figure 1). The earliest lizards were observed at the entrances of their shelters in rocky areas on March 20 and March 23. The shelters (n=2) located during this effort were shallow burrows under rock roofs; one facing east and the other facing west.

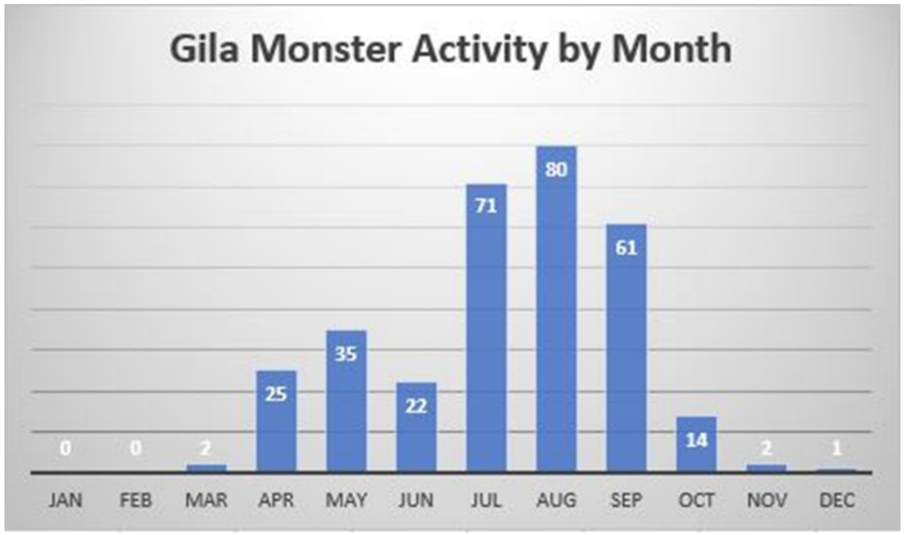

Figure 1. Gila Monsters in southeastern Cochise County, Arizona, have two activity peaks during the year, with the larger peak associated with the summer rainy season. The bars show the number of lizards per month (n=313), including both living and dead individuals.

Gila Monsters were periodically observed thermoregulating at these shelter entrances during March, and their activity away from these burrows generally began during April, with an activity pulse (26% of captures) during spring (April-June). Maximum activity (68% of captures) occurred during the summer rainy season (July – September), when lizards take advantage of opportunities for rehydration and foraging. Most lizard activity tapered off quickly in October with the onset of cooler temperatures.

Our data depicts Gila Monster activity between 6:28 AM and 8:15 PM local time, with most activity (~68%) occurring in the morning between 7 AM - Noon, some activity (~10%) occurring during the middle of the day, and another smaller pulse of activity (~23%) occurring in the afternoon between 4-8 PM (Figure 2). Gila Monsters are likely more tolerant of cold temperatures than of heat, which allows them to use resources during times when other options for maintaining higher activity temperatures are not available (Beck 2005). Nocturnal activity by Gila Monsters was likely underestimated by our efforts because Service staff were generally present on the landscape between 5 AM – 5 PM, and were largely absent outside of that time. However, some staff did spend evening hours conducting inventory and monitoring work, and Gila Monsters were rarely observed during those periods. The higher elevation and overall cooler temperatures of the monitoring site likely influence daily activity periods.

We captured 15 young (<165mm SVL; <67g Mass) Gila Monsters during this effort, but so far none have been recaptured to help determine growth rate or survivorship. This is not completely surprising because the species' conservative energy-use strategy permits them to subsist for long time periods with limited activity, and because smaller Gila Monsters are more secretive than adults and may show greater nocturnal activity (Beck 2005). We captured 60% (n=9) of the young reptiles between 7:20 AM – 11:50 AM, and 40% (n=6) between 4:30 PM – 7:35 PM. While juveniles may utilize warm summer nights for foraging in the area, we have not observed this pattern. However, it would be inaccurate to assume that all Gila Monster age classes have an equal probability of being encountered.

Movement **-** Home range (HR) is an area within an organism's habitat through which it moves to fulfill its resource needs, which may include foraging, rehydration, reproduction, and other needs (Beck 2005). Recapturing the same Gila Monster over time allowed limited determination of apparent HR use by an individual. We calculated HR sizes by constructing the smallest convex polygon that encompassed all of the

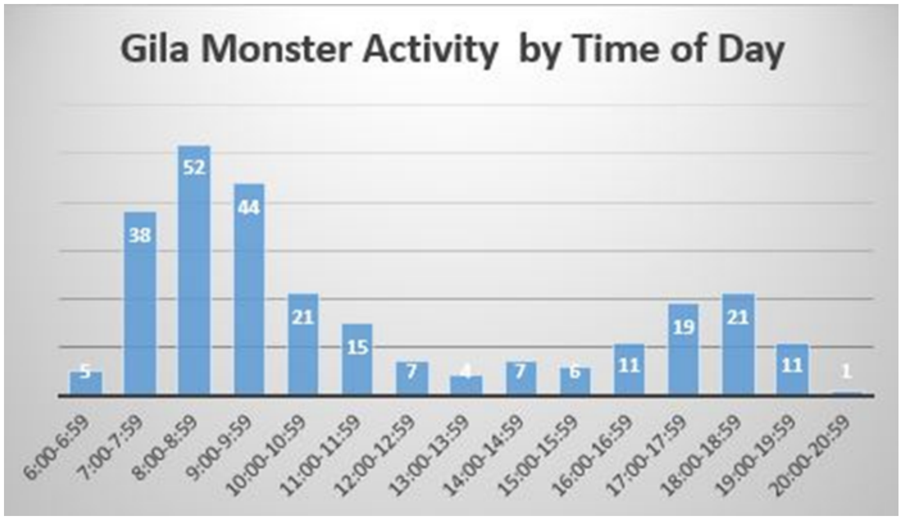

Figure 2. Gila Monsters in southeastern Cochise County, Arizona, have two daily activity peaks, with most activity in the morning hours. The bars show the number of live captures (n=262) over a 24-hour period. Note that personnel tended to be in the field more in the morning than in the evening, which may have affected the distribution of documented captures.

observed locations (Jennrich and Turner 1969). The accuracy of HR calculations is based on having an adequate number of accumulated relocation points (minimum of three), and this was limited by our opportunistic monitoring, but does not influence an animal's movement in the way that tracking a radio-tagged individual may impact an animal's behavior (Millspaugh et al. 2012). The maximum distance between capture points of individual lizards (n=55) during this monitoring effort ranged from 11-3,842 m (37-12,606 ft), and a mean of 563 m (1,847-ft), with nearly half (47%) of the lizards exceeding 402 m (1,320 ft) between maximum capture points. The size of the HR of Gila Monsters (n=18) in this effort varied from 0.03-37.7 ha (0.07-93.2 a), and a mean gross HR of 6 ha (14.85 a). This compares with the HR size ranging from about 6-147 ha (14.8-363.2 a) determined for Gila Monsters by Beck (2005), a mean gross HR of 48.1 ha (116.4 a) for adults and 13.4 ha (33.1 a) for subadults at a site in Arizona (Gallardo et al. 2002), and 6-68 ha (14.8-168.0 a) at another site in Arizona (Sullivan et al. 2004). I anticipate that our estimates of Gila Monster HR in southeastern Cochise County will increase as the number of recaptures continues to grow.

Habitat Use - Habitat use by Gila Monsters in Arizona has been described as desert-scrub, semi-desert grassland, and sometimes woodland areas (Beck 2005). Our monitoring area, characterized by extensive elevation complexity and topographical relief, and composed of small canyons, foothills, and rocky slopes, provides different directional aspects, rock outcroppings, drainages, and flatlands. Elevation range of the Gila Monsters captured during this effort ranged from 1,138 m (3,732 ft) to 1,490 m (4,888 ft), and the average elevation where Gila Monsters were captured (n=313) was 1,278 m (4,193 ft).

Gila Monsters were not found across the landscape in equal numbers, rather their occurrence often existed as "clusters" within the more limited microenvironments that may be necessary to allow the animal to avoid its limits of physiological tolerance (Beck 2005). For example, within their habitats, Gila Monsters spend the vast majority of their time within shelters, taking advantage of the cooler, more humid microclimates located underground (Beck and Jennings 2003). Most of our captures occurred on or immediately adjacent to rugged, rocky areas with substantial vegetative cover, especially velvet mesquite. We occasionally (n=5) found individual Gila Monsters in grassland valley bottoms or at other locations that were far from rocky habitats or other captures. These "wanderers" may represent pioneering individuals or lizards utilizing microenvironments that are not completely recognized or understood. Thus, while Service personnel spent considerable time in a variety of habitats across the monitoring area, Gila Monsters appeared to select rocky habitat over flat and grassland habitats. Within even the areas with the highest capture rates, population densities of the species appear to be low.

Life history - In nature, mating by Gila Monsters occurs during April – June (Beck 2005), which was supported when Gila Monsters captured during our effort mated on May 7, 2007. Captive Gila Monsters lay eggs within 5-8 weeks following copulation (Eidenmuller and Reisinger 2011, Shaw 1968). Free ranging Gila Monsters lay 2-13 eggs (mean 5.7) during the summer rainy season (Ernst and Ernst 2011, Goldberg and Lowe 1997), which appears crucial for establishing the necessary moisture conditions required for successful hatching (Beck 2005, Goldberg and Lowe 1997, Seward 2000). This was supported during our monitoring by a female laying a clutch of 13 eggs on August 12, 2012. Eggs hatch about 120-152 days later (Eidenmuller and Reisinger 2011), and hatchlings overwinter in their underground nest before emerging during the following spring/summer (Ernst and Ernst 2011, Roger A. Repp, personal communication, Tucson, AZ, May 2018).

Hatchling sized Gila Monsters have been variously described as ranging from 110-141 mm (4.33-5.55 in) SVL, ranging from 150-186 mm (5.9-7.32 in) TL, and having a body mass ranging from 23.1-44 g (0.81-1.55 oz) (Beck 2005, Eidenmuller and Reisinger 2011, Lowe et al. 1986, Shaw 1968). Five presumed hatchlings captured during our monitoring efforts ranged from 115-142 mm (4.53-5.59 in) SVL, ranged from 175-203 mm (6.89-7.99 in) TL, and ranged in weight from 23.5-47.1 g (0.83-1.66 oz). Hatchlings have been observed in nature between April – August (Beck 2005), and this was supported by hatchlings (n=5) captured during our monitoring effort between June 23 – July 25.

Growth and Longevity – Gila Monsters have reached over 30 years of age in captivity, and frequently exceed 20 years in nature (Beck 2005). Growth rates are variable among individuals and size classes, with Gila Monsters taking 10.1-12.8 years to reach 325 mm (12.80 in) SVL, and taking at least 17.6 years to reach over 360 mm (14.17 in) SVL (Beck 2005). Based on this information, I estimate that 65 (29%) of the 222 Gila Monsters encountered during our monitoring effort were at least 10.1-12.8 years old, including five (2%) that were at least 17.6 years old when they were originally captured. Subsequent recaptures of some of those lizards documented two individual females reaching between at least 18.3-21 years old when they were last recaptured, and one female that was between 19.8-22.5 years old when last recaptured.

During our monitoring efforts in Cochise County, the Gila Monsters having the greatest length included a female captured in July 2012 measuring 404 mm (15.9 in) SVL and 445 mm (17.5 in) TL, and a male captured in August 2009 measuring 369 mm (14.5 in) SVL and 531 mm (20.9 in) TL. The Gila Monster having the shortest length was an individual captured in June 2013 measuring 115 mm (4.5 in) SVL and 175 mm (6.9 in) TL. The Gila Monsters having the greatest mass included a female captured in May 2008 that weighed 1,100 g (38.8 oz) and a male captured in May 2007 that weighed 1,085 g (38.3 oz). The Gila Monster having the smallest mass was the individual captured in June 2013 that weighed 23.5 g (0.83 oz). These values are all consistent with size information reported by other authors (Beck 2005, Goldberg and Lowe 1997).

Recaptured lizards demonstrated considerable variation in their weights between captures that were not correlated with significant changes in their length, ranging from 295 g (10.4 oz) gains to 585 g (20.6 oz) losses. In some cases, these changes reflected their reproductive condition (e.g., gravidness), but more often they likely represented gains and losses in association with annual and seasonal changes in food and water availability. *Heloderma* have relatively high rates of evaporative water loss when compared with other lizards (DeNardo et al. 2004, Lowe et al. 1986), which would affect body mass. These fluctuations in their body conditions likely mirror changing ecological conditions such as drought, precipitation, food availability, population dynamics of prey species, and other conditions upon which they depend for their survival.

Mortality - Vulnerability to predation was not adequately assessed by our monitoring. During our efforts, four Gila Monsters were captured that were missing various portions of their tails from prior injuries, several lizards were missing toes, and others exhibited scars on their body or face. While a ringtail cat (*Bassariscus astutus*) was documented by remote trail camera photos as showing an interest in a Gila Monster (Figure 3),

Figure 3. Remote trail camera photos documented this ringtail cat (Bassariscus astutus) showing an interest in a Gila Monster at Leslie Canyon National Wildlife Refuge in southeastern Cochise County, Arizona, but the outcome of the interaction is unknown.

no actual predation was identified. The only Gila Monster fatalities documented during our effort - 26 individuals were collected as road kills - resulted from vehicles.

Food habits – Gila Monster food habits were not studied as part of this monitoring effort. However, a 61 g (2.2 oz) recently consumed baby cottontail rabbit (*Sylvilagus auduboni*) was regurgitated by a captured 351 mm (13.8 in) SVL, 885 g (31.2 oz) female lizard on June 30, 2009.

SUMMARY

Data collected during this long-term monitoring effort are generally consistent with studies of Gila Monsters in other locations, with some important differences. These differences include daily and seasonal activity periods, which are likely influenced by the higher elevation and overall cooler temperatures of the monitoring area compared to other locations and may reflect the lizard's adaptation to meeting optimal thermoregulation requirements. Additionally, home range sizes are generally smaller than those determined by other researchers. This may reflect an abundance of resources within the area we monitored, or a potential sampling bias.

Our data add to the overall knowledge of Gila Monster population ecology, and may inform management decisions. Consider two examples. First, knowing that activity is highest in mid-spring and during the summer rainy season, local managers can focus potential Gila Monster habitat disturbance, e.g., with heavy equipment, during those times because individuals are most likely to be able to disburse and avoid mortality. Second, the measurement and mark-recapture data provide an important baseline against which future measurements may be compared. If future data indicate a systematic decline in body size or condition, or if recaptures suddenly begin to decline with similar effort in the field, managers may develop a structured research program to identify the causes of the changes. In brief, while the data do not provide answers to every question, they provide key insights that can advance Gila Monster conservation.

There are advantages and disadvantages to long-term monitoring work being accomplished opportunistically by staff or "citizen scientists." Perhaps the greatest advantage is that long-term monitoring of a fixed area can be accomplished cost effectively; it can be done opportunistically while employees are engaged in their other duties. Importantly, participants build comradery that promotes teamwork, and participation builds interest in principles of conservation ecology, population dynamics, behavioral patterns, and other ecological values. There are also limitations to opportunistic monitoring compared to structured, intensive monitoring by more qualified researchers. These include employee turnover and participants having differing levels of interest and expertise, which requires continual training, oversight, and error checking. There is also a potential bias relating to any monitoring occurring only during established employee working hours. Accounting for these benefits and costs over the 18 years of the Gila Monster monitoring effort, I believe the benefits have far outweighed any costs as we have learned more about this animal and taught many others a greater appreciation of it.

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