Evaluation of the distribution and conservation status of the Gila Monster (*Heloderma suspectum*) in southwestern New Mexico

Final Report

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Project Summary

The Gila Monster (*Heloderma suspectum*) is an iconic venomous lizard of the southwestern U.S., yet little is known about its distribution in New Mexico. While widespread and relatively common elsewhere, this species is known from only a few scattered and disjunct areas in southwestern New Mexico, and it is categorized as endangered by the New Mexico Department of Game and Fish. Gila Monsters are threatened by multiple factors, including illegal collection for commercial and private trade, habitat fragmentation, changes in land use, and increased temperatures and drought conditions associated with climate change. In the spring and summer of 2017, we conducted surveys throughout four target areas in southwestern New Mexico, which were identified from previous records and a preliminary distribution model. While we detected Gila Monsters at all of the four areas, detection probability varied significantly among them; furthermore, these lizards were most prevalent near the Gila River. To evaluate the vulnerability of the populations at a landscape scale, we built suitability models for current and future landscapes based on data gathered from various sources. While the potential extent of Gila Monster occurrences in New Mexico is larger than previously known, our models suggest that occupied areas are likely small and their delineation is complicated by varying detection probabilities, thus further sampling is needed to improve model estimates. This will be necessary in designing a comprehensive Gila Monster conservation strategy in New Mexico, where this charismatic lizard's future is complicated by the increased pressures from a changing climate and the effects of pet-trade harvesting.

Project Purpose and background

The Gila Monster (*Heloderma suspectum*) is categorized as an endangered species in New Mexico by the New Mexico Department of Game and Fish (NMDGF) and has a relatively limited distribution within the southwestern portion of the state (NMDGF 2006). Its occurrence in New Mexico consists of disjunct populations in Hidalgo, Grant, Luna, and Doña Ana counties (Degenhardt et al. 1996). Current knowledge about Gila Monster populations in New Mexico is poor, primarily due to the lack of a large scale approach to study this species. Much of the data on distribution consists of historical records, which are often imprecise and decades old. Anecdotal reports provide additional information on distribution in New Mexico. This lack of knowledge limits the ability to determine any conservation or management actions that might be needed, despite the species being threatened by a variety of factors.

Gila Monster populations face threats from a wide range of factors, although some evaluations suggest that New Mexico populations are stable (e.g., NMDGF 2006). Illegal collection of Gila Monsters by commercial and private collectors has been cited as a serious concern for local populations in New Mexico (NMDGF 1985; USDA 1990; Beck 2005). Urbanization, fragmentation, and land-use changes may contribute to threat risks by reducing the extent of suitable habitat, limiting dispersal and foraging area, and increasing mortality from roads (Beck 2005). Furthermore, reductions in extent and quality of habitat can be especially damaging to Gila Monsters because the species requires specialized microhabitat shelters (Beck & Jennings 2003). The use of specialized shelters acts as a means for lizards to conserve water and energy, and as a buffer against drought conditions (Beck & Jennings 2003; Davis & DeNardo 2007; Gienger et al. 2014). Climate change, especially drought and long-term drying trends, poses a significant physiological threat to Gila Monsters, which experience decreased foraging activity and body condition stress during dry periods (Davis & DeNardo 2010). Evaluations of extinction risk based on thermal stress, following the methodology developed by Sinervo et al. (2010), also suggest that Gila Monsters are particularly vulnerable to climate change (Giermakowski & Snell 2011). Thus, in the case of Gila Monsters, the additive effects of habitat modification and climate change can negatively affect their populations.

Although understanding of the coarse scale distribution of Gila Monsters in New Mexico is poor, the population of Gila Monsters at Red Rock Wildlife Management Area is one of the best-studied populations in the United States (i.e., Beck 2005). The population structure and habitat use of Gila Monsters at Red Rock was investigated from 1992 to 1998 (Beck 1994; Beck & Jennings 2003). Beck (1994) reported densities of 5 lizards/km^2, one of the highest reported densities for the species. However, outside of the Red Rock and Granite Gap areas, little is known about the distribution and density of Gila Monsters in New Mexico (Figure 1). The area between Red Rock in Grant County and Granite Gap in Hidalgo County includes BLM Wilderness Study Areas that are expected to contain Gila Monsters but no records exist in this area (Figure 1). This distribution gap is likely due to a lack of surveys. Presence of Gila Monsters in this gap would support population connectivity, which provides the opportunity for dispersal and long-term population persistence (Hanski & Gilpin 1997). Failure to detect Gila Monsters in this gap would potentially indicate that the north and south populations are isolated and are at an increased risk of local extirpation from stochastic events (Fischer & Lindenmayer 2007).

This project focused on areas in western Hidalgo and Grant counties with verified native populations that have the highest number of records and observations (Degenhardt et al. 1996; Figure 1). The records from Doña Ana County and east of Silver City are suspected pet releases or escaped individuals and likely do not represent natural populations (NMDGF 2006). The distribution of Gila Monsters in Hidalgo and Grant counties consists of two disjunct areas of high incidence, separated by approximately 75 miles (Figure 1).

The primary goal of this project was to evaluate the current distribution of the Gila Monster in southwestern New Mexico. In addition, we evaluated the environmental constraints of the Gila Monster in the state by modeling current and future landscape suitability for this species. Our approach was based on estimating detection and occupancy rates through time-constrained visual encounter surveys (VES). We focused on four different areas: Gila Lower Box Wilderness Study Area (WSA), Peloncillo WSA, Granite Gap, and Antelope Pass. We subsequently used the survey results, and other information obtained through databases, to build and refine distribution models.

Methods

Survey of populations

We conducted visual encounter surveys to search for Gila Monsters during their highest activity periods, both annually and daily. We concentrated our survey efforts during the months of April, May, August, and September. During each day of the surveys, we focused our efforts in the mornings and afternoons, when activity is highest. To record the time spent searching and the distances covered while searching, all observers relied on Garmin GPS units (different models) and their track-recording feature that stores the observer's position every 15 seconds. Time and distances covered were calculated from those positions. All Gila Monsters encountered were captured, weighed, measured, photographed, and released at the site of capture. When possible, we collected a blood sample that was then deposited at the Museum of Southwestern Biology, University of New Mexico.

Habitat modeling

We compiled 53 historical records of Gila Monsters in New Mexico. These records were mostly based on well-documented observations and museum specimen records. However, we also used data gathered from several partners, including local experts, retired biologists, and governmental agency personnel.

To model the potential suitability of the landscape for Gila Monsters, we used the maximum entropy algorithm (Maxent; Elith et al. 2010) because it is useful for evaluating relationships between predictor variables and species records that are based on presence-only data. We used Maxent (Phillips et al. 2006; Phillips & Dudík 2008) to calculate the probability that Gila Monsters would be present on the landscape using the built-in functions for random seeds, background selection, cross-validation, and model averaging (Phillips & Dudík 2008). We obtained biotic variables for modelling from the WorldClim database, but also used data on geology and surface properties (such as rock type) from the New Mexico Resource Geographic Information System hosted at the University of New Mexico.

We produced binary maps using two different thresholds to define the landscape suitable for Gila Monsters. We used the "maximum sensitivity plus specificity logistic (MSS)" and the "10 percentile training presence logistic (10PL)" thresholds. We used these parameters as they are among the two most commonly used thresholds for creating binary suitability maps for species distributions with MaxEnt (e.g. Pearson et al. 2007). The final binary map was made by overlaying the two results and only considering areas where the two thresholds overlap.

To evaluate potential changes in suitability under a future climate change scenario, we projected the model generated for current conditions using a set of climate variables for the years 2050 (average for 2041-2060) and 2070 (average for 2061-2080). We used the climatic projections from the General Circulation Model (GCM) from the United Kingdom Meteorological Office Hadley Centre known as HadGEM2-ES. The future climate layers were downscaled and calibrated (bias corrected) using WorldClim 1.4 as baseline "current" climate (Hijmans et al. 2005). We used the moderate representative concentration pathway (RCP; RCP 6.0) of greenhouse gases as it is considered the most plausible scenario under the current conditions (Moss et al. 2010). We used the same variables used to build the landscape suitability model under the current climatic conditions. Binary maps for potential future distribution were generated using the same thresholds and approaches used to build maps of current conditions.

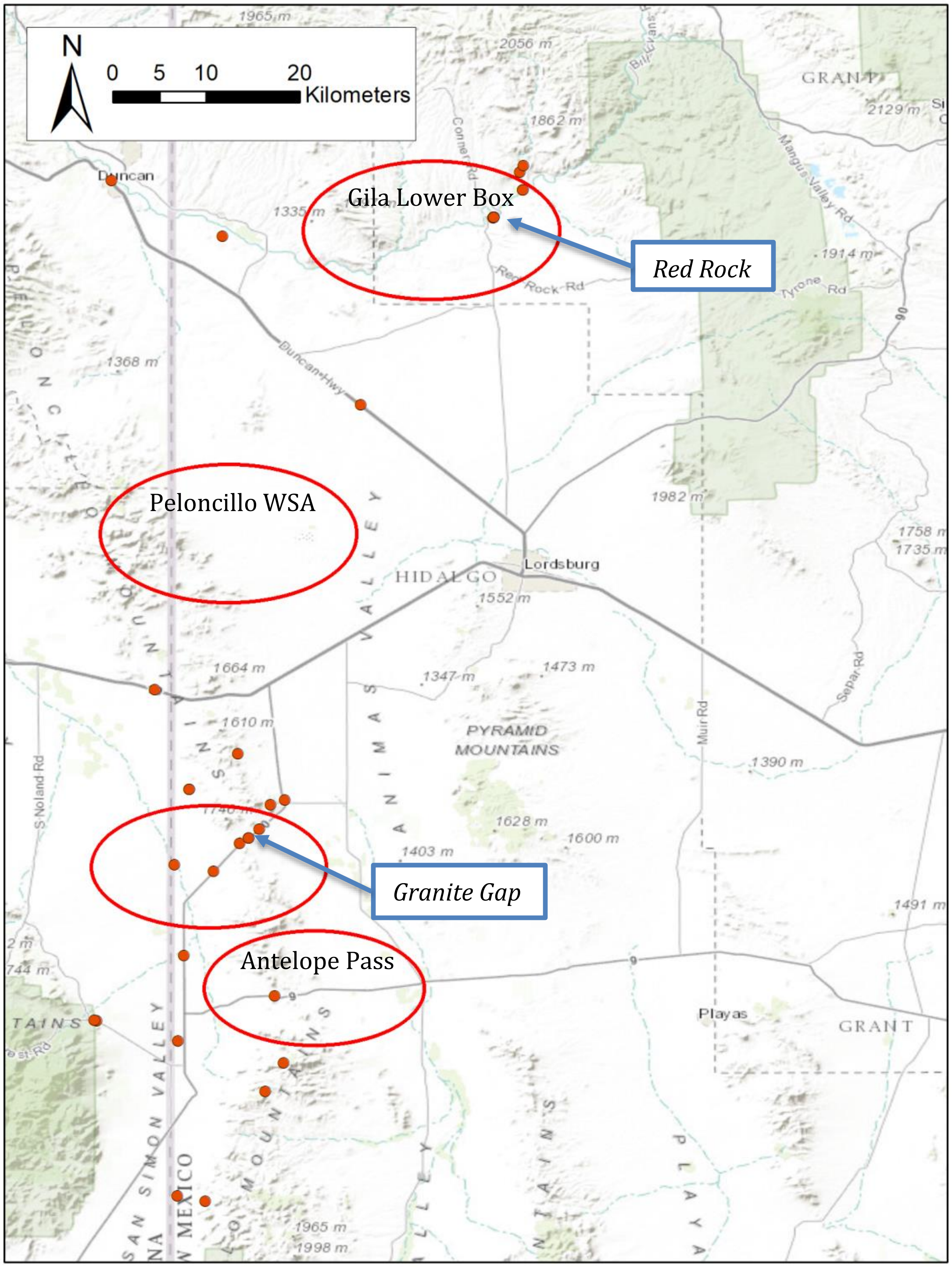

Figure 1. Map of southwestern New Mexico indicating previous records of Gila Monsters (dots) and focused areas of surveys (ellipses) based on preliminary distribution models that considered topography and landscape features (geology, rocktype, etc.).

Results

Visual encounter surveys

We completed 61 visual encounter surveys over the course of the sampling period between 7 April and 21 September 2017. All observers logged a total of 115.5 hours of survey effort while walking 253.7 km and bicycling 68.5 km (Tables 1 and 2). There was a significant difference in survey duration between morning and afternoon (t-test with equal variances assumed, $p<0.02$), as well as the distance covered (t-test with equal variances assumed, $p<0.02$). However, these differences did not have a significant influence on detectability (see subsequent analyses). During the course of the study, we were able to detect seven Gila Monsters across all four areas of interest (Tables 3 and 4). Five of the seven Gila Monsters were found in August and only in one instance were two individuals found during the same survey. In addition to direct visual encounters, we observed Gila Monster tracks within canyons of the Gila Lower Box Wilderness Study Area (WSA), the only area where we found large flat patches of sand where tracks were easily detected.

Table 1. Effort during visual encounter surveys: time spent moving per study area and month sampled.

Study area	**Time (HH:MM:SS)**				**Total**
	April	May	August	September	
Gila Lower Box	5:09:21	32:48:34	9:34:34	2:37:45	50:10:14
Granite Gap	2:46:15	6:30:43	2:49:45	4:53:42	17:00:25
Antelope Pass	2:44:03	1:06:30	15:03:34	3:59:00	22:53:07
Peloncillo WSA	0:00:00	18:06:19	3:12:45	4:06:53	25:25:57
Total	10:39:39	58:32:06	30:40:38	15:37:20	115:29:43

Table 2. Effort during visual encounter surveys: distance walked per study area and month sampled.

Study area	**Distance (km)**				**Total**
	April	May	August	September	
Gila Lower Box	14.5	87.3	12.9	5.9	120.6
Granite Gap	4.9	16.5	5.0	8.4	34.8
Antelope Pass	4.7	2.0	15.9	10.5	33.1
Peloncillo WSA	0.0	48.3	6.6	10.3	65.2
Total	24.1	154.1	40.4	35.1	253.7

Table 3. Number of Gila Monsters found during the study per study area and month sampled.

Study area	**Month of sampling**			
	April	May	August	September
Gila Lower Box	0	1	3	0
Granite Gap	0	1	0	0
Antelope Pass	0	0	1	0
Peloncillo WSA	NA	0	1	0

Table 4. Data collected for each Gila Monster observed during the study (n=7).

Study area	**Date**	**Time**	**SVL (mm)**	**Tail (mm)**	**Mass (g)**	Blood sample
Gila Lower Box	24 May	19:35	326	127	575	Yes
Gila Lower Box	16 Aug	18:00	285	126	430	Yes
Gila Lower Box	16 Aug	19:05	258	115	198	Yes
Gila Lower Box	17 Aug	9:30	143	42	25	Yes
Granite Gap	12 May	8:55	302	137	530	No
Antelope Pass	18 Aug	15:50				No
Peloncillo WSA	11 Aug	9:20	135	54	34.75	Yes

Analysis of occupancy and detection

We detected Gila Monsters at all four of the selected study areas in 2017 via VES. The number of Gila Monsters detected varied between sites with time of the year (TOY; Table 3; which in analyses we treated as an ordinal variable that represents week of the year). We only surveyed four areas and used a single-season occupancy model to evaluate the effect of several variables on detectability and occupancy. Specifically, we were interested in the effect of weather and effort (distance and time spent searching) on detectability and the effect of the type of habitat on occupancy.

For variables affecting detectability, we standardized effort, time of year (TOY), and calculated distance covered during each survey. We also obtained maximum and minimum temperatures and total precipitation for three days prior to each survey from the Daymet project database (Thornton et al. 2018). As a variable affecting occupancy, we used the most detailed vegetation classification from the GAP/LANDFIRE National Terrestrial Ecosystems project and available from USGS (Homer et al. 2015). We used AIC (Akaike's Information Criterion) to rank models and select the most parsimonious combination of covariates that accounted for the variation in detectability and occupancy. The top models do not indicate that occupancy is being influenced by habitat type and identifies detectability as being best explained by TOY, effort, and distance (Table 5). Furthermore, none of the top five models includes habitat type as significant in assessing occupancy or weather in influencing detectability. The overall detectability calculated with the top model is 0.227. However, these analyses are based on a small sample size of only four study areas, and the null model (where no factors are included) is the next most parsimonious model for detectability.

Table 5. Ranking of top five models of detectability and occupancy for sites surveyed. (.) indicates null model.

Model	Number of parameters	AICc	Delta_AICc
Ψ(.),p(TOY+Effort+Distance)	5	-31.92	0
Ψ(.),p(.)	2	33.58	65.50
Ψ(.),p(Effort)	3	49.80	81.71
Ψ(.),p(Distance)	3	51.65	83.56
Ψ(.),p(TOY)	3	52.80	84.72

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Current distribution

The model of current distribution performed well with training data (AUC=0.987) as well as with test data (AUC=0.977). The composite map of two binary layers indicates continuous suitable patches along the western boundary of New Mexico, as well as within the Gila River valley and the extreme southeast corner of Hidalgo county (Figure 1). In addition, nearly all observations used in the model were identified as occurring within the core suitability areas (identified in binary maps). The bioclimatic variables that were identified by the Maxent models as to contributing significantly to the suitability of the landscape for Gila Monsters in New Mexico were "Late spring precipitation (May-Jun)", "Maximum winter temperatures (Nov-Mar)", and "Monsoon precipitation (Jul-Sep)". The percent contribution of each variable to the present day model of Gila Monster distribution were 35.6%, 30.1%, and 19.1%, respectively.

Future distribution

Results from projecting the distribution to 2050 and 2070 under a single climate change scenario show that the latitudinal (north-south) range for Gila Monsters is not expected to change drastically when compared to the distribution under current climate conditions (Figures 3 and 4). Compared with the model for the present time, there is an overall decrease in the area of suitable landscape: 18.8% by 2050, growing to a 22.5% decrease by 2070. Suitability decreases most in the eastern edges of the present day range and becomes more fragmented with time.

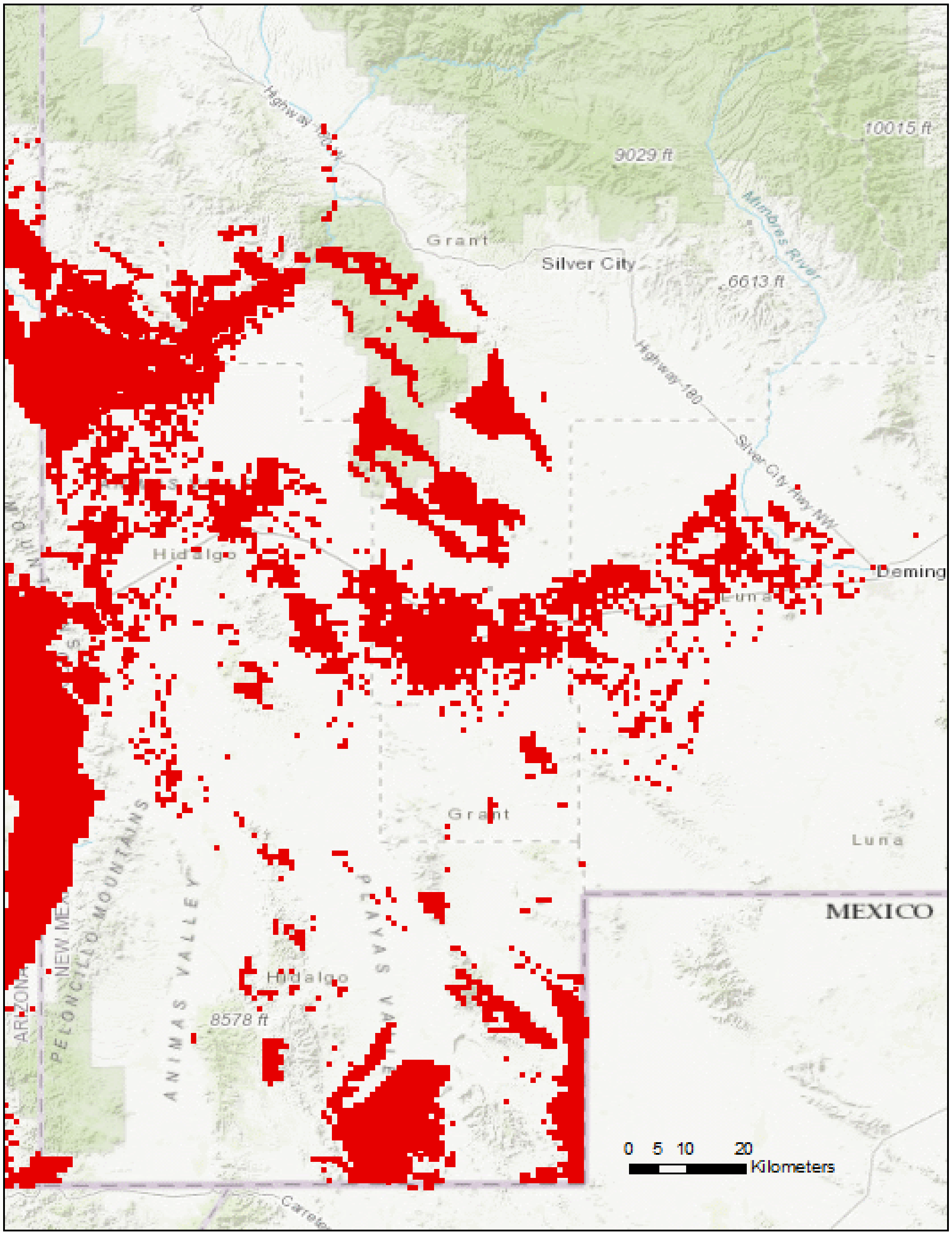

Figure 2. Map of extreme southwestern New Mexico indicating current landscape suitability for Gila Monsters based on distribution models that rely predominantly on climatic variables related to spring and summer precipitation and winter temperatures.

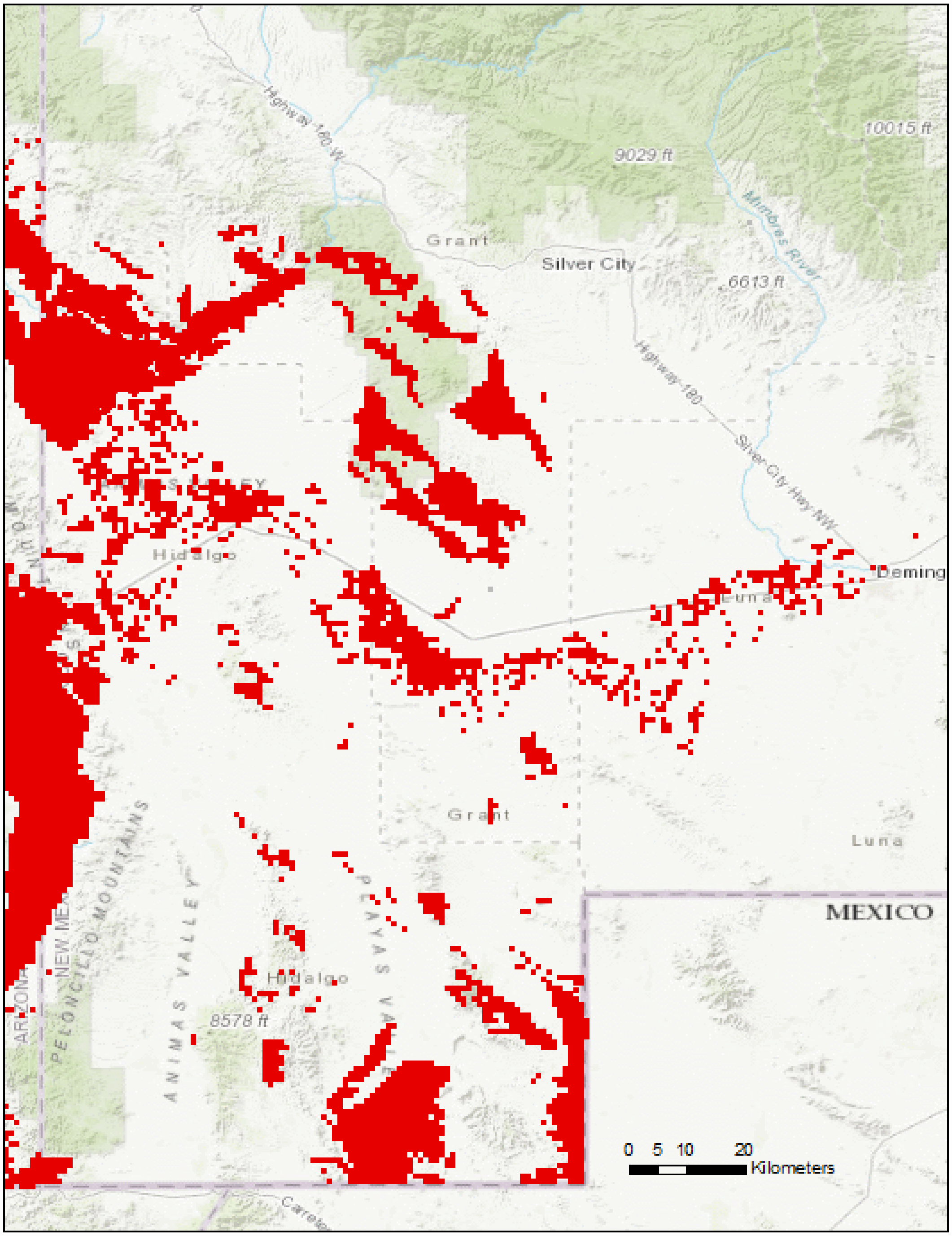

Figure 3. Map of extreme southwestern New Mexico indicating landscape suitability for Gila Monsters by 2050 (average for 2041-2060) based on a distribution model that relies predominantly on climatic variables related to spring and summer precipitation and winter temperatures.

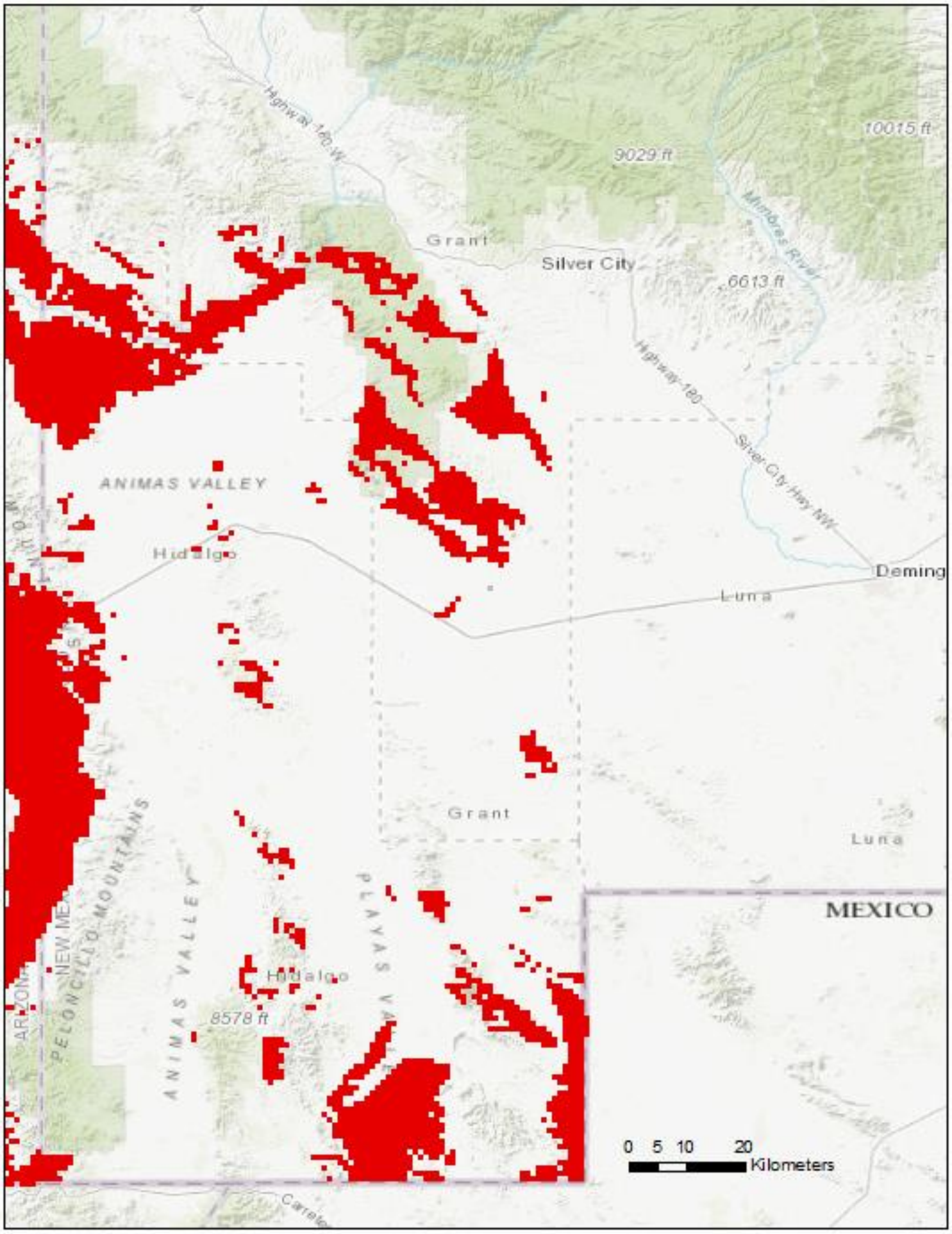

Figure 4. Map of extreme southwestern New Mexico indicating landscape suitability for Gila Monsters by 2070 (average for 2061-2080) based on a distribution model that relies predominantly on climatic variables related to spring and summer precipitation and winter temperatures.

Discussion

We detected Gila Monsters at all of the four survey areas, including the area between the Gila River valley and Granite Gap in Hidalgo County where Gila Monsters have not been documented previously (i.e., Peloncillo Wilderness Study Area). Four of the seven detections were near the Gila River, supporting anecdotal evidence from observations of biologists and residents of the area that the Gila Monsters are commonly seen close to the river. The overall detectability throughout the study areas was less than 25%; accordingly, a lot of effort is required to detect Gila Monsters using visual encounter surveys. In addition, time of the year, as well as survey effort (both time spent and distance covered during the survey), played a significant role in detection of Gila Monsters.

Our coarse scale analyses suggest that current distribution of Gila Monsters in New Mexico is mostly influenced by climatic variables related to spring and summer precipitation and winter temperatures. The extent of suitable landscape is limited to the very southwestern corner of the state, and it is likely to decrease in the future, particularly along the eastern edge of the distribution. This is in addition to becoming more fragmented in response to future changes in climate. The major caveat to species distribution models generated here is that they are based on limited data. This is because current knowledge about Gila Monster populations in New Mexico is poor, primarily due to the lack of a large scale approach to studying this species. In this study, we have documented Gila Monsters at the Peloncillo WSA, at least 25km away from the nearest known record. During the same year as this study, we became aware of two more sightings in eastern Hidalgo county, and those were also at least 25km away from the nearest known record. Thus, there is still much to be learned about the distribution of populations of Gila Monsters in New Mexico. Undoubtedly, further surveys will greatly improve our distribution models, and thus aid in delineating more precisely the extent of occurrence of Gila Monsters in the state.

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References

Beck, DD. 1994. A field study of the Gila Monster in southwestern New Mexico. Progress Report to NMDGF, #93-516.6-3.

Beck, DD & RD Jennings. 2003. Habitat use by Gila Monsters: the importance of shelters. Herpetol. Monogr. 17:111-129.

Beck, DD. 2005. Biology of the Gila Monsters and Beaded Lizards. University of California Press.

Davis, JR & DF DeNardo. 2007. The urinary bladder as a physiological reservoir that moderates dehydration in a large desert lizard, the Gila Monster *Heloderma suspectum*. J. Exp. Biol. 210:1472-1480.

Davis, J & DF DeNardo. 2010. Seasonal patterns of body condition, hydration state, and activity of Gila Monsters. *Heloderma suspectum*. at a Sonoran desert site. J. Herpetol. 44:83-933.

Degenhardt, WG, CW Painter, & AH Price.. 1996. Amphibians and Reptiles of New Mexico. University of New Mexico Press.

Fischer, J & DB Lindenmayer. 2007. Landscape modification and habitat fragmentation: a synthesis. Glob. Ecol. Biogeogr. 16:265-280.

Gienger, CM, CR Tracy, & KA Nagy. 2014. Life in the slow lane: Gila Monsters have low rates of energy use and water flux. Copeia 2014:279-287.

Giermakowski, JT & HL Snell. 2011. Final report: Evaluating the potential extinction of selected New Mexican lizards due to climate change. Final report to New Mexico Department of Game and Fish; Share with Wildlife, State Wildlife Grants T-32-P-2, 32

Hanski, IA & ME Gilpin. 1997. Metapopulation Biology: Ecology, Genetics, and Evolution. Academic Press.

Homer, CG, JA Dewitz, L Yang, S Jin, P Danielson, G Xian, J Coulston, ND Herold, JD Wickham, and K Megown. 2015. Completion of the 2011 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing 81(5):345-354.

Moss, RH, JA Edmonds, KA Hibbard, MR Manning, SK Rose, DP Van Vuuren, TR Carter, S Emori, M Kainuma, T Kram, and GA Meehl. 2010. The next generation of scenarios for climate change research and assessment. Nature, 463(7282), p.747.

NMDGF. 1985. Handbook of Species Endangered in New Mexico.

NMDGF. 2006. Threatened and Endangered Species of New Mexico, 2006 Biennial Review.

Pearson, RG, CJ Raxworthy, M Nakamura, and AT Peterson. 2007. Predicting species distributions from small numbers of occurrence records: a test case using cryptic geckos in Madagascar. Journal of Biogeography, vol. 34(1):102–117.

Sias, DS & CW Painter. 2002. Natural history data from reptile and amphibian trapping in Guadalupe Canyon, New Mexico and Arizona. Report to NMDGF.

Sinervo, B, et al.. 2010. Erosion of lizard diversity by climate change and altered thermal niches. Science 328:894-899.

Phillips, SJ, RP Anderson, and RE Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecol. Modeling 190:231-259.

Thornton, PE, MM Thornton, BW Mayer, Y Wei, R Devarakonda, RS Vose, and RB Cook. 2018. Daymet: Daily Surface Weather Data on a 1-km Grid for North America, Version 3. ORNL DAAC, Oak Ridge, Tennessee, USA. https://doi.org/10.3334/ORNLDAAC/1328

USDA. 1990. Conserving Endangered Species: A Commitment to the Future. U.S. Forest Service SW Region.