# Status Assessment of Arizona Black Rattlesnake (*Crotalus cerberus*) in New Mexico

## Final Report to Share w/ Wildlife Program

### 2021 Report

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**Project Objective**

The objective of this study is to assess the current status and distribution, habitat associations, and prey availability of the Arizona Black Rattlesnake (*Crotalus cerberus*) in New Mexico.

**Project Need**

There are currently ten recognized species and subspecies of rattlesnakes in New Mexico. *Crotalus cerberus* (Figure 1) is known from Catron and Grant counties from at least 19 confirmed locations (Figure 2 and Table 1).

**Figure 1.** Arizona Black Rattlesnake (*Crotalus cerberus*), adult male, Strawberry Canyon, San Francisco Mts.

These locations are currently (2021) represented by 26 museum specimens, 27 captured and released individuals, a live specimen in captivity, and four observations. In addition, Klauber (1972, 1997) mentions a specimen from Steeple Rock as another locality (without data, but see comments below). These limited data indicate that *C. cerberus* has a relatively small extent of known occurrence within New Mexico, despite the prevalence of seemingly suitable habitat throughout most of the Gila National Forest.

*Crotalus cerberus* is known to occur in Arizona from the Hualapai Mountains across the Mogollon Rim at elevations of 900–3000 m (Brennan and Holycross 2006, Schuett et al. 2016) to west central New Mexico in Catron and Grant counties at elevations of 1860–2507 m (Klauber 1972, Mellow 1978, Degenhardt et al 1996, Klauber 1997, Christman et al. 2000, Rubio 2010, Christman et al. 2019) within the Arizona/New Mexico Mountains ecoregion. *Crotalus cerberus* occurs in Interior Chaparral, Great Basin Conifer Woodland, Madrean Evergreen Woodland, and Petran Montane Conifer Forest (Brown 1994, Brennan and Holycross 2006, Schuett et al. 2016). In Arizona, where *C. cerberus* occurs at lower elevations into upper portions of Arizona Upland Desert-scrub, snakes are often encountered in riparian habitats to 900 m. In New Mexico, *C. cerberus* has received little to no study and as a result many observations are anecdotal.

Until recently, this species was considered a subspecies of the Western Rattlesnake complex (*Crotalus viridis*); however, most biologists in both Arizona and New Mexico follow the most recent evidence that points to *C. cerberus* being a distinct species. Although Degenhardt et al. (1996) recognized *C. cerberus* as a subspecies of *C. viridis* and did not recognize differences in biology or distribution within the state, Crother et al. (2012) consider the species as distinct and summarized taxonomic changes proposed in the *C. viridis* group by Pook et al. (2000), Ashton and de Queiroz (2001), and Douglas et al. (2002); who all agree on *C. cerberus* being a distinct species. *Crotalus viridis* currently represents two subspecies (the Prairie Rattlesnake [*C. v. viridis*] and the Hopi Rattlesnake [*C. v. nuntius*]). The remainder of the former *C. viridis* complex are currently assigned to *C. oreganus* (Crother et al. 2012). The Arizona Game and Fish Department recognizes *C. cerberus* as distinct from the *C. viridis* complex and regulates it as a game species with limited take of four per year. New Mexico Department of Game and Fish allows take of five per year for commercial collection (2016) and recently listed *C. cerberus* as a Species of Greatest Conservation Need (SGCN) in the State Wildlife Action Plan for New Mexico (NMDGF 2016).

The earliest record of *C. cerberus* in New Mexico is one specimen from 31 July 1966, 2 miles west of Luna in Catron County. Then five more specimens were collected in the 1970's, two in the 1980's, two in 1995, 10 in the 2000's, and 28 (specimens, captures, and observations) from 2010 to present. The record from near Steeple Rock in Grant county (USNM 52273), currently listed as *C. viridis*, was first cataloged as *C. pricei* and identified by Klauber (1934) as *C. confluentus oreganus*. This record may in fact be the earliest record for *C. cerberus* in the state (cataloged 8 Apr 1915). We were unable to examine photos of this specimen to confirm identity prior to the completion of this report. However, we have the following description from Klauber: "from the nature of the markings, particularly the postocular stripe, character of the blotch-edges, tail rings and heavy ventral mottling, I have no hesitancy in classifying it as *Crotalus confluentus oreganus." Crotalus confluentus* is an earlier name used to identify the Western Rattlesnake, which then became *C. viridis* (Klauber 1972, Degenhardt et al. 1996, Crother et al. 2012, Holycross and Mitchel 2020). Klauber's description includes "heavy ventral mottling", which is a character consistent with *C. cerberus.*

Without detailed information on general status and distribution, land and resource managers cannot adequately address specific management concerns for any given species. Knowledge of SGCN abundance and distribution and the connectivity and condition of key habitats is of particular interest, as are studies that monitor the status of SGCN and identify and quantify factors limiting their populations. In the Share with Wildlife Call for Project Information (2018), *C. cerberus* was specifically listed as a species in need of review. The goals of this project were to provide locality data and define a baseline distribution and prey availability for, and habitat associations of, *C. cerberus* in New Mexico. These data may help inform Agency management programs, determine population status or factors limiting populations, and determine whether *C. cerberus* is in need of additional conservation efforts.

## Methods

### *Historical Data and Visual Encounter Surveys*

Historic data on *C. cerberus* were gathered using existing museum records and questioning state and federal wildlife biologists.

Survey methods included visual encounter surveys (VES), which involve walking through steep, rocky habitats and poking under rocks and ledges, all while looking and listening for snakes. They also involve driving roads at night (during warm weather) that cross suitable habitat. Areas targeted for searches were rock outcrops with south, east, or west aspects with vegetation dominated by grasses, including bear grass; yucca; and cacti indicating warmer, drier slopes that would be expected to have a greater number of snow-free days during winter months when snakes would be denning. Search areas included the following areas in Catron and Grant County: 1) Catron County: Canovas Creek, Chimney Rock Canyon, Citizen Canyon, Cottonwood Canyon West of Campground, Dillon Mountain, Dry Blue Creek, FS Rd 141West of Sheep Basin Divide, JTS Park, SA Creek, San Francisco Mountains (Scenic overlook, Trail Canyon, San Francisco River West of Luna), San Francisco River North of Reserve, Silver Peak East of Alma, Spring Mountain West of Mogollon, South Fork Negrito Creek, Trout Creek, West Fork Gila River, Willow Springs Canyon, and White Rocks Mountain.; 2) Grant County: Brushy Mountain South of Mule Creek; Jack's Peak, Big Burro Mountains; Mogollon Creek; and Steeple Rock.

Snake observations, including *C. cerberus*, were recorded with GPS points. Distribution data were also collected for other rattlesnake species: Prairie Rattlesnake (*C. viridis*), Rock Rattlesnake (*C. lepidus*), and Northern Black-tailed Rattlesnake (*C. molossus*) that may have overlapping or contiguous distributions. Search effort (time-spent and distance moved) was recorded via the tracking function of a GPS. All snakes captured were measured, weighed, their sex recorded, age evaluated based on size, and a PIT tag inserted for future identification. Genetic samples, in the form of blood drawn from the caudal vein, were collected from most *C. cerberus* captured. Genetic samples have been deposited at the Museum of Southwestern Biology (MSB) in anticipation of future collaborative genetic research. During handling, venomous snake species were restrained using either snake tubes or a squeeze box for safety of both snake and researcher. Photos were taken of all snakes and habitats where snakes were encountered.

*Habitat Associations*

For all surveys, basic abiotic data were collected including: weather, temperature, search effort, aspect, and locality. The last variable was collected with a Global Positioning System (GPS) using North American Datum 1983 in Universal Transverse Mercator. Additional relevant habitat data were collected (e.g., presence of rock piles, talus/scree slopes, and drainages; distance to available water; and main vegetation types (e.g., Ponderosa, Piñon-Juniper, Madrean Evergreen Oak).

*Prey Availability*

All other amphibian and reptile species and potential prey species encountered during VES were recorded. As part of evaluating available prey species, small mammal trapping was conducted at select locations representative of surveyed habitats.. All small mammals were identified and released at the point of capture. Other potential prey (lizards and birds) were identified via opportunistic observations.

*Snake Fungal Disease*

We also collected swabs for Snake Fungal Disease (SFD) testing. Swabbing snakes involves rubbing a snake, with a polyester swab, along the length of the body and the head and face following Allender et al. (2015). To swab a rattlesnake safely, we first tubed the snake to restrain it. We then gripped with the swab with large forceps and rubbed around the snake's head and face inside the tube, then rubbed the body outside of the tube.

*Genetic Analysis*

Genetic analysis could not be performed in 2020 due to COVID-19 related logistical issues and lab access restrictions at the University of New Mexico.

*Distribution Modeling*

We modeled the current extent of suitable landscape for Arizona black rattlesnakes in New Mexico using the Maxent algorithm (version 3.4.1, available at http://biodiversityinformatics.amnh.org/open_source/maxent/; Phillips et al. 2006, Phillips and Dudík 2008, Phillips et al. 2019) within the R statistical framework (R Core Team 2020). Maxent uses a maximum entropy probability distribution to contrast occurrence data (presence records) with environmental data in the background (climate, soils, geology, etc.) and estimates a probability distribution that has the maximum entropy (i.e., that is most spread out, or uniform) given certain constraints. The constraints are that the expected values of each feature (for example, a climate variable) must equal the empirical average (i.e., the average value at known occurrence points, or most common value for categorical variables; Phillips et al. 2006). Maxent is one of the best algorithms to calculate the suitability of a landscape for a species when comprehensive presence/absence data are not available (Elith et al. 2006, Elith and Leathwick 2009). This is particularly the case for *C. cerberus* because its presence is difficult to confirm due to low detectability and lack of information about its distribution in New Mexico. Models built with presence-only data do not incorporate information on the frequency of occurrence and therefore cannot accurately predict probability of presence (MacKenzie et al. 2002, Guisan and Thuiller 2005). However, such models can be used to estimate a relative index of the suitability of a landscape for a species (Elith et al. 2006).

Because of the gridded nature of analyses and models, we converted all known occurrences of *C. cerberus* throughout its range into a 1km grid, matching the scale of used variables. We used all occurrences whether they were specimens collected decades ago or recent observations from this project. In cases of multiple records, we only used one set of coordinates to minimize sampling bias, which is especially important for correlative modeling (Phillips et al. 2009). In addition, we spatially thinned these occurrences to 4km.

The variables included in modeling distribution consisted of bioclimatic variables that summarize monthly data from weather stations and that are spatially extrapolated using elevation as a covariate, reflecting various aspects of temperature and precipitation (Hijmans et al. 2005). We used the Wallace platform for modeling (Kass et al. 2018) and fitted models in Maxent by taking advantage of built-in functions for random seeds, selection of background, cross-validation, and model averaging (Phillips and Dudík 2008). Although choice of background data can have important effects on predictions (Van Der Wal et al. 2009), we used a random background set of data from the entire set of possible locations throughout the entire range of *C. cerberus* to serve as pseudo-absences. A large number of locations (1,000) from a broad range of conditions throughout the Mogollon rim was used to ensure good representation of all possible environments, which is important when models are to be projected into different conditions (Elith et al. 2010). We then generated models using two-fold cross-validation to estimate errors around fitted functions and evaluate predictive performance on held-out data (Elith et al. 2010).

This means that the algorithm randomly selected 50% of cells for model testing, while the remaining 50% were used for model training (to formulate the model parameters).

To develop the distribution model, we used the default settings in Maxent but restricted model building to linear, hinged, and quadratic features (in machine learning language, features are transformations of variables into functions). This is because hinge features produce model projections similar to those based on generalized linear models (GLMs) or generalized additive models (GAMs) but allow different fits to different parts of the response (as opposed to GLMs or GAMs, which only describe one response; Phillips and Dudík 2008, Elith et al. 2010). We did not select product features (interactions of variables) because of the complexity in the ecological interpretation of interacting variables, and we did not select threshold features because those tend to be redundant with hinge features (Elith et al. 2010). Prior to inclusion in the models, we examined all continuous variables for correlations between them by calculating the Pearson pairwise correlation coefficient for every pairwise combination of continuous variables using ENM Tools (Warren et al. 2010). However, we did not exclude correlated variables because the strength of correlation varied spatially and because analyses have also shown that Maxent is more stable in the face of correlated variables than stepwise regression (Hastie et al. 2009). We assessed the included predictor variables using the built-in jackknife tests that quantify the contribution of each variable to the model (expressed as percent and based on increase in gain; Phillips et al. 2006) and permutation importance (Phillips and Dudík 2008). We then examined differences in area under the curve (AUC) for both training and test data. We used AUC of the receiver operating characteristic (ROC) as a threshold-independent measure of model performance (Elith et al. 2006). ROC is plotted for all possible thresholds, with sensitivity (true positive rate) on the y-axis and 1-specificity (false positive rate) on the x-axis. The AUC characterizes performance of the model at all possible thresholds and is summarized by a number ranging from 0 to 1, where 1 indicates perfect model performance, 0.5 indicates the equivalent of a random (presence and background not different), and less than 0.5 indicates performance worse than random (Phillips et al. 2006).

## Results

*Historical Data and Visual Encounter Surveys*

We gathered historic data by checking *C. viridis* data used in "Amphibians and Reptiles of New Mexico" (Degenhardt et al. 1996), which produced six records (1966–1988); searching museum records (MSB, Western New Mexico University, New Mexico State University, San Diego Natural History Museum, Arctos, and Vert Net), which produced 12 records, (1977–2016); and having conversations with New Mexico Department of Game and Fish (NMDGF) biologists, which produced another record from 2016. Additional observations were gathered from U.S. Forest Service (USFS) biologists.

Records of *C. cerberus* in New Mexico to date total 59; including 26 museum specimens, 27 captured and released snakes, and 6 observations. These records are from 20 geographic locations (Table 1, Figure 2).

Collection/observation dates for *C. cerberus* in NM are from 18 April to 1 October with seasonal activity possible a week or two earlier and a month later.

**Table 1.** Arizona Black Rattlesnake (*Crotalus cerberus*) localities for NM, 1915 and 1966–2020, with year(s) of collection, observation, or capture. Records that were confirmed or first observed during this project are shown in bold.

1. West of Luna, San Francisco River Canyon, Catron County (1966, 1977, 1983. 1988, 2000, 2002, 2009, 2016, 2018).
2. **Dry Blue Creek, Catron County** (1995, 2000, **2019, 2020**).
3. Mogollon Creek, Gila Wilderness, Grant County (1972, 1974).
4. Mineral Creek, East of Mogollon, Catron County (1974).
5. FS Rd 35 near US 180, San Francisco Mountains, Catron County (1974).
6. FS Rd 35, East of US 180, Catron County (1973).
7. San Francisco River at New Mexico/Arizona border, Catron County (2018).
8. **Mother Hubbard Canyon, Catron County** (2006, **2020**).
9. **Trail Canyon, San Francisco Mountains, Catron County** (2011, 2016, **2019**).
10. **Head of SU Canyon, San Francisco Mountains, Catron County** (2016, **2019**).
11. Devil's Park /Apache Peak Area, Catron County (2012).
12. Willow Springs Canyon, Catron County (2002).
13. **FS Rd 141, Catron County** (2016, **2019, 2020**).
14. Chimney Rock Canyon, Catron County (2012, 2014).
15. **SA Creek, Catron County** (**2019, 2020**).
16. **Brushy Mountain, Grant County (2019).**

17. Apache Box, Grant County (2000).
18. **Hell Roaring Mesa, Catron County** (**2020**).
19. **Strawberry Canyon, Catron County** (**2020**).
20. **Steeple Rock, Grant County (1915)**.

Surveys were conducted in spring and fall 2020 at 38 sites over 35 days totaling 555 person hours of search effort from 18 April to 1 October (Figure 3). Surveys resulted in detections of 12 *C. cerberus* (Figure 2), 15 *C. molossus*, 6 *C. lepidus*, 11 Gophersnake (*Pituophis catenifer*), 59 Wandering Gartersnake (*Thamnophis elegans*), 7 Black-necked Gartersnake (*T. cyrtopsis*), 5 Sonoran Mountain Kingsnake (*Lampropeltis pyromelana*), 1 Ring-necked Snake (*Diadophis punctatus*), 2 Chihuahuan Nightsnake (*Hypsiglena jani*), 2 Mountain Patch-nosed Snake (*Salvadora grahamiae*), and 2 Striped Whipsnake (*Masticophis taeniatus*; Table 2). Some sites were visited more than once during spring and fall surveys.

<u>Spring Surveys</u>

In spring of 2020, surveys were conducted at 30 sites over 22 days totaling 315 person hours of search effort from 18 April to 11 June 2020. Surveys were conducted on 18 April, 27 April to 7 May, 29 - 30 May, 1, 3, 11, 16, 17, 23 and 25 June. Surveys resulted in detections of 9 *C. cerberus*, 12 *C. molossus*, 3 *C. lepidus*, 11 *P. catenifer*, 54 *T. elegans*, 5 *T. cyrtopsis*, 4 *L. pyromelana*, 1 *D. punctatus*, 1 *H. jani*, 1 *S. grahamiae*, and 2 *M. taeniatus* (Table 2).

We surveyed a site four miles east of Mogollon based on a vouchered specimen (UMC 5171), which we determined to be in the Spring Creek drainage, to verify continued species persistence. While habitat seemed appropriate, survey results were negative. After receiving photographs of the specimen, we determined that the species identification was correct but we learned from the field tag that it was collected in Mineral Creek (the next drainage to the north). Follow-up surveys were not conducted in 2020.

Weather conditions during late April and early May were warmer than expected (clear and sunny with temperatures in the low to high 80’s F), with observed snakes away from presumed denning areas.

While conducting surveys for Narrow-headed Gartersnake (*T. rufipunctatus*), which were not funded under this project, we also collected incidental data for other snakes including *C.*

*cerberus.* These surveys were conducted 25–29 May (Saliz Creek), 1–5 June (Turkey Creek), 8–12 June (San Francisco River East of Luna). Further surveys were conducted on 30–31 May (Pueblo Park Rd., NM 159 to Mogollon, and JTS Park). (Table 2).

Fall Surveys

In the fall of 2020, surveys were conducted at 24 sites over 19 days totaling 240 person hours of search effort from 1 July to 1 October 2020. Surveys were conducted on 1 July, 8–12 August, 9–13, 15–17, 27–30 September, and 1 October. Surveys resulted in detections of 3 *C. cerberus,* 3 *C. molossus,* 3 *C. lepidus,* 5 *T. elegans*, 2 *T. cyrtopsis*, 1 *L. pyromelana*, 1 *H. jani,* and 1 *S. grahamiae* (Table 2).

**Table 2.** Arizona Black Rattlesnake *(Crotalus cerberus)* survey locations 2020, with additional snake species detections. These species include: Northern Black-tailed Rattlesnake (*C. molossus*), Rock Rattlesnake (*C. Lepidus*), Gophersnake (*Pituophis catenifer*), Wandering Gartersnake (*Thamnophis elegans*), Black-necked Gartersnake (*T. cyrtopsis*), Sonoran Mountain Kingsnake (*Lampropeltis pyromelana*), Ring-necked Snake (*Diadophis punctatus*), Chihuahuan Nightsnake (*Hypsiglena jani*), Mountain Patch-nosed Snake (*Salvadora grahamiae*), and Striped Whipsnake (*Masticophis taeniatus*;

1. Dry Blue Creek, Catron County — 3 *C. cerberus*
2. Mother Hubbard Canyon, Catron County — 1 *C. cerberus*
3. “The Box” San Francisco River, Catron County — 1 *L. pyromelana*
4. Hell Roaring Mesa, Catron County — 3 *C. cerberus*
5. Trail Canyon, San Francisco Mountains, Catron County — 0 detections
6. West of Prairie Point, San Francisco Mountains, Catron County — 0 detections
7. Chimney Rock Canyon, Catron County — 0 detections
8. Willow Springs Canyon, Catron County — 0 detections
9. Trout Creek below Hell Roaring Mesa, Catron County — 1 *T. elegans*
10. Saliz Creek, Catron County — 3 *C. molossus,* 7 *T. elegans*, 1 *S. grahamiae*
11. Black Peak, Catron County — 0 detections
12. Basalt Ridge North of Black Peak, Catron County — 0 detections
13. Head of SU Canyon, scenic overlook, Catron County — 0 detections
14. Apache Peak, Sheep Basin Divide, Catron County — 0 detections
15. East side Hell Roaring Mesa, Catron County — 0 detections
16. San Francisco Mountains rim at powerline, Catron County — 1 *C. molossus*
17. Dillon Mountain, Catron County — 1 *C. molossus*
18. Wet Leggett Canyon, Catron County — 0 detections
19. Strawberry Canyon, Catron County — 2 *C. cerberus*
20. Freeman Mountain, Catron County — 0 detections
21. Largo Canyon, site 1, Catron County — 0 detections

22. Largo Canyon, site 2, Catron County — 0 detections
23. Pueblo Park Road, Catron County — 1 *M. taeniatus*,1 *H. jani*
24. JTS Park, Catron County — 1 *C. molossus*
25. NM Hwy 159 to Mogollon, Catron County — 1 *H. jani*
26. Turkey Creek, Grant County — 4 *C. molossus,* 1 *P. catenifer,* 2 *T. cyrtopsis,* 1 *T. elegans*
27. San Francisco River, East of Luna, Catron County — 5 *T. elegans*, 1 *T. cyrtopsis*
28. Sign Camp Canyon, Southeast of Reserve, Catron County — 0 detections
29. Pine Canyon, West of Glenwood, Catron County — 1 *T. elegans*
30. Sacaton Creek, Catron County — 0 detections
31. Burn’s Spring, East of Glenwood, Catron County — 0 detections
32. Talus, Little Whitewater Creek, Catron County — 0 detections
33. Mogollon Creek and side canyons, Grant County — 2 *C. molossus,* 3 *C. lepidus*, 1 *S. grahamiae*, 2 *T. cyrtopsis*, 3 *T. elegans*
34. Trout Creek, South end of Hell Roaring Mesa, Catron County 1 *C. cerberus*
35. SA Creek, Catron County — 1 *C. cerberus*, 1 *C. molossus,* 1 *T. elegans*
36. FS Rd 141, West of Sheep Basin Divide, Catron County — 1 *C. cerberus*, 1 *L. pyromelana*
37. Black Creek, Grant County — 2 *C. lepidus*, 4 *P. catenifer,* 20 *T. elegans*, 1 *L. pyromelana*
38. Diamond Creek, Catron County — 1 *C. lepidus*, 2 *C. molossus*, 6 *P. catenifer,* 20 *T. elegans,* 2 *T. cyrtopsis,* 2 *L. pyromelana*, 1 *D. punctatus*, 1 *M. taeniatus*

The presence of young snakes born last year from one location indicates a likely denning area nearby, however no concentrations of snakes were observed. The 5 snakes found at 2 locations (Hell Roaring Mesa and Strawberry Canyon) represent new localities (from 2020) within the expected range for this species in New Mexico.

An effort was made to verify the continued persistence of *C. cerberus* in Mogollon Creek in September 2020 based on a literature record (Mellow 1974) and a museum specimen (NMSU 3687) from 1972; we documented 3 *C. lepidus* and 2 *C. molossus* during 110 person hours of search effort (Table 2, Figure 3).

Despite the relative abundance of *C. cerberus* specimens from the San Francisco River canyon two miles west of Luna (Table 1) to the Arizona state line, surveys in both 2019 and 2020 failed to turn up a single snake of any species. We expect that *C. cerberus* is still extant within this locality and this population is likely stable due to the extensive suitable habitat available. Data from within this locality span dates from 1966–2018.

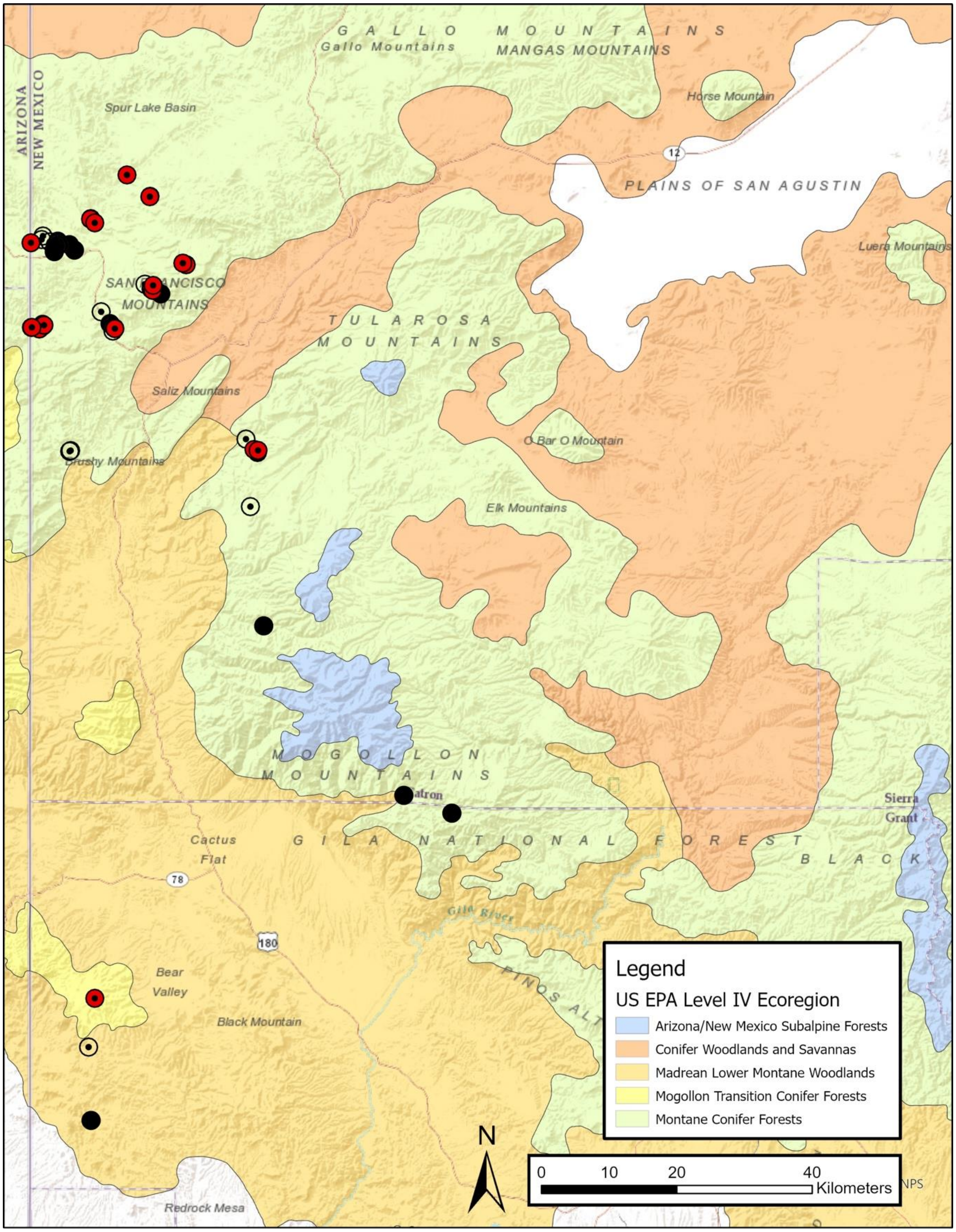


**Figure 2.** Known localities of Arizona Black Rattlesnake (*Crotalus cerberus*) in southwestern New Mexico based on literature, museum specimens, and observations. 1915, 1966–1999 (black dots), 2000–2017 (open circles), and 2018–2020 (red dots).

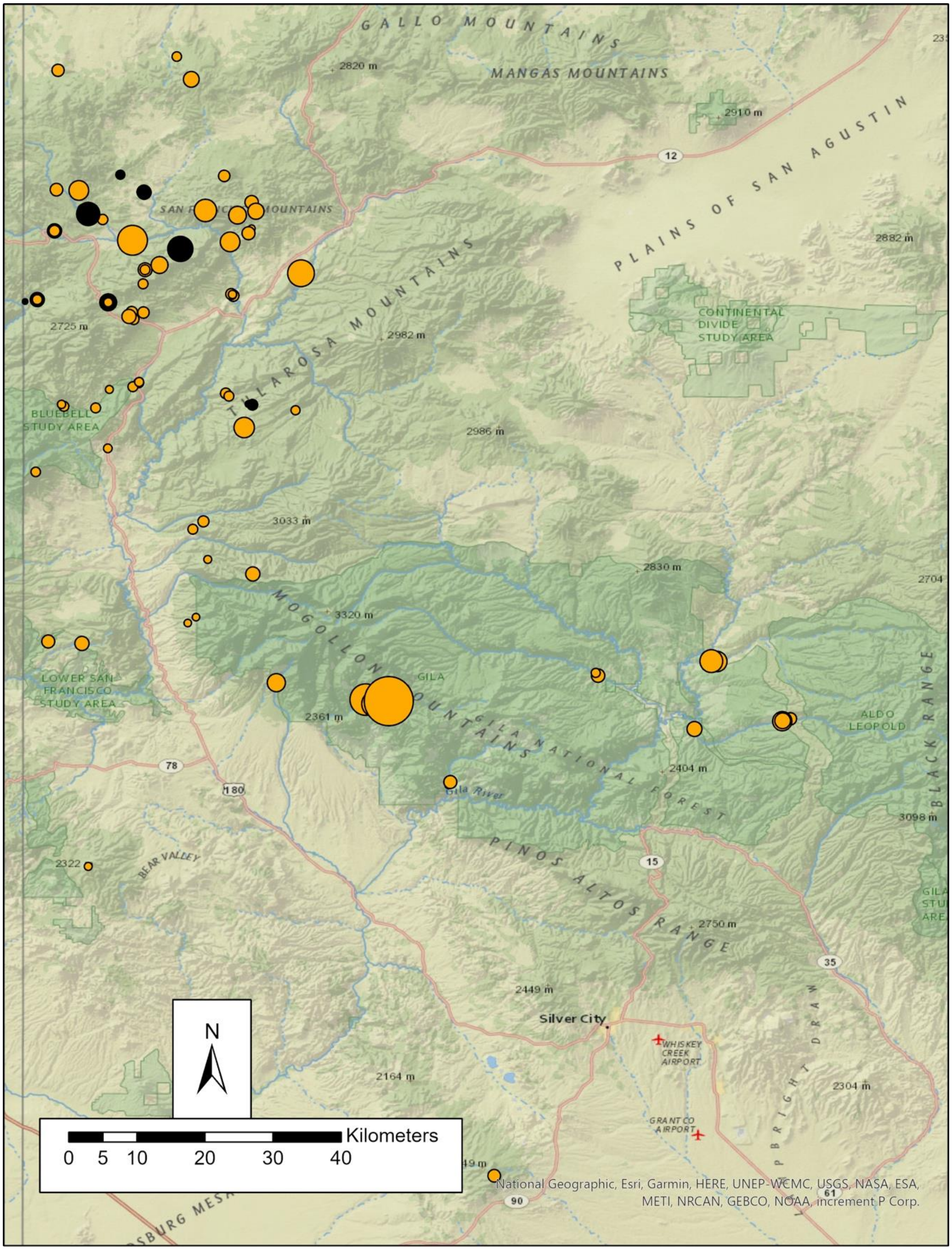


**Figure 3.** Search effort across the expected range of Arizona Black Rattlesnake (*Crotalus cerberus*), positive (black circles) and negative (orange circles) detections during 2020 surveys; circle size represents 0.5 – 48 hours of search effort.

*Color variation*

Despite its common name of Arizona Black Rattlesnake, *C. cerberus* is highly variable in color and has the ability to alter its color over a short period of time (Schuett et al. 2016 and references therein). There is an ontogenetic shift in coloration (silver gray and brown as young of year) with a general darkening as snakes age (light brown and dark brown to nearly black as adults), but adult snakes in New Mexico may not regularly express the black coloration observed in snakes found further west in Arizona. A female *C. cerberus* from near the border with Arizona that has been in captivity for 14 years and is believed to be at least 16 years of age has not shown any shift towards black coloration. Figure 4 shows variation in adult coloration.

**Figure 4**. Color variation in male Arizona Black Rattlesnakes (*Crotalus Cerberus*) from Chimney Rock (top left), Dry Blue Creek (top right), and SA Creek (bottom).

*Size*

The size of *C. cerberus* varies throughout its range, with larger snakes found in central Arizona in the Catalina and nearby mountain ranges (slightly exceeding 1000 mm SVL). Snakes from northern portions of its range rarely exceed 800 mm. *Crotalus cerberus* exhibits sexual dimorphism typical of rattlesnakes with males a bit larger than females. Our data show adult males averaged 656 mm SVL (520–685; n=9) and adult females averaged 508 mm SVL (452–573; n=10; Figure 5). Sexual maturity in males is likely attained around 560 mm SVL (Goldberg 2002) and for females around 460 mm SVL (Bruce Christman, personal observation). Snakes under 500 mm (males) and 450 mm (females) are considered juveniles.

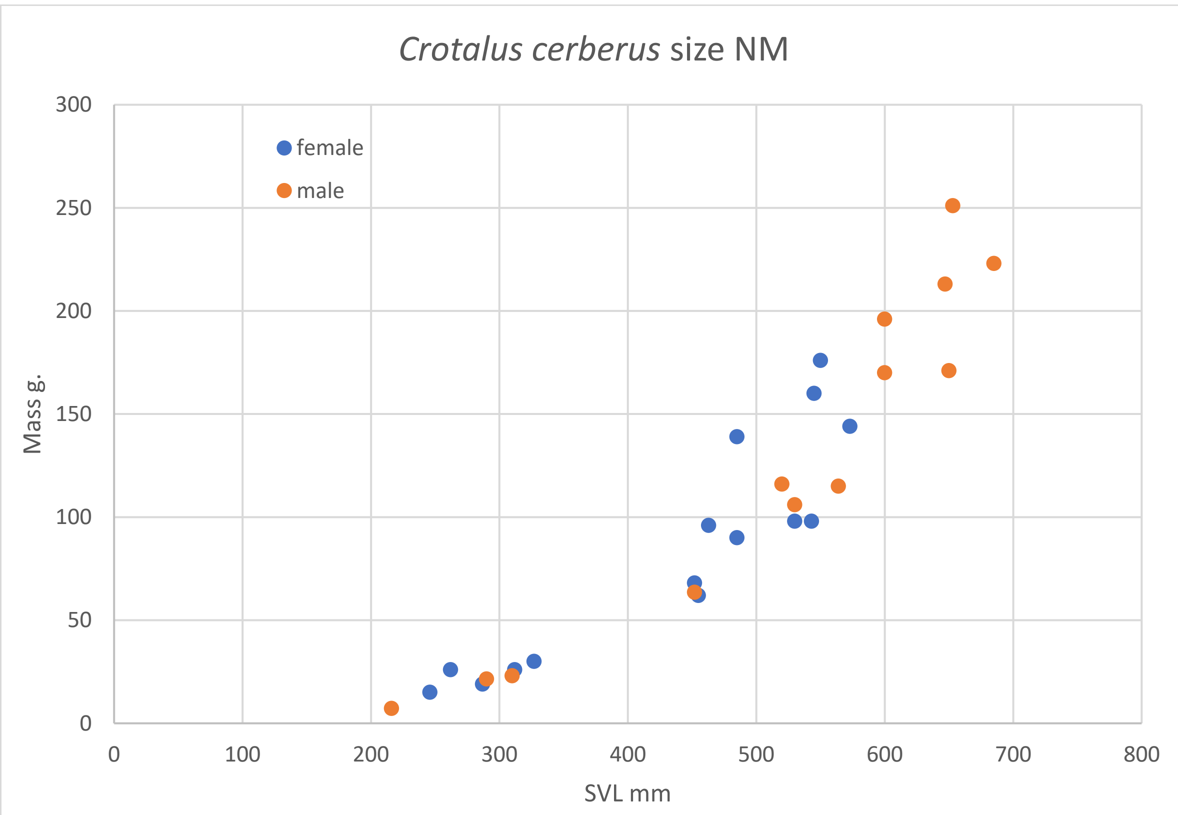


**Figure 5**. Size distribution of Arizona black rattlesnake (*Crotalus cerberus*) in New Mexico n=28 (males n=13, females n=15).

*Identification*

*Crotalus cerberus* is most similar to *C. viridis*, which is variable in color across its range in New Mexico and is sometimes shades of reddish brown and tan. These two species can be easily separated by ventral coloration, with *C. cerberus* having a mottled venter and *C. viridis* having an un-mottled or immaculate venter (Figure 6).

*Crotalus cerberus* is further identified by scale arrangement on the head. There are usually two loreal scales on each side (Klauber 1997, Stebbins 2003, Schuett et al. 2016), four or more internasals contact the rostral (Brennan and Holycross 2006) and intervening scale between the prenasal and first supralabial (Klauber 1997, Schuett et al. 2016)

**Figure 6**. Ventral and dorsal coloration of Arizona Black Rattlesnake (*Crotalus cerberus;* top), and Prairie Rattlesnake (*Crotalus viridis;* bottom).

*Distribution of C. cerberus in New Mexico*

The distribution of *C. cerberus* and other, rattlesnake species found in the greater Gila region (*C. viridis, C. lepidus,* and *C. molossus*) is shown in Figure 7. The classification of vegetation types within the Arizona/New Mexico Mountains Ecoregion (level III ecoregion; Figure 7) is based on level IV ecoregions. Both level III and level IV ecoregions are from the U.S. Environmental Protection Agency's national classification system (Omernik and Griffith 2014).

The Eastern Black-tailed Rattlesnake (*C. ornatus*) has been represented here as *C. molossus* due to their taxonomic history and unresolved contact points . *Crotalus ornatus* is known from the eastern portions of the Gila in the Black Range. *Crotalus cerberus* is primarily been found in Montane Conifer Forest and Mogollon Transition Conifer Forest with only a few records in Madrean Lower Montane Woodlands. The Gila River and its lower elevations may constitute a habitat barrier to *C. cerberus* to the east. *Crotalus molossus* is a generalist found from desert riparian areas to elevations exceeding 2440 m (8000 ft.) in the Gila, but is more of a semi-montane species. *Crotalus cerberus* and *C. molossus* occur in syntopy across much of their common range (Mogollon Highlands) in Arizona and New Mexico. Museum records and observations represented in Figure 7 show that *C. molossus* is found more commonly at lower elevations than *C. cerberus*, within Conifer Woodlands and Savannas and Madrean Lower Montane Woodlands, but has been recorded in Montane Conifer Forest. *Crotalus viridis* is primarily a grassland species showing up along the fringes of the forested portions of the Gila in Conifer Woodlands and Savannas and Madrean Lower Montane Woodlands and has not been found in syntopy with *C. cerberus* in New Mexico (Figure 7). While *C. viridis* has been found in northern Carton County, it has not been documented in southern Catron County. *Crotalus lepidus* is a mountain rock dweller that enters the desert transition zone and appears to have a slight overlap in distribution with *C. cerberus* in the southern slopes of the Mogollon Mountains.

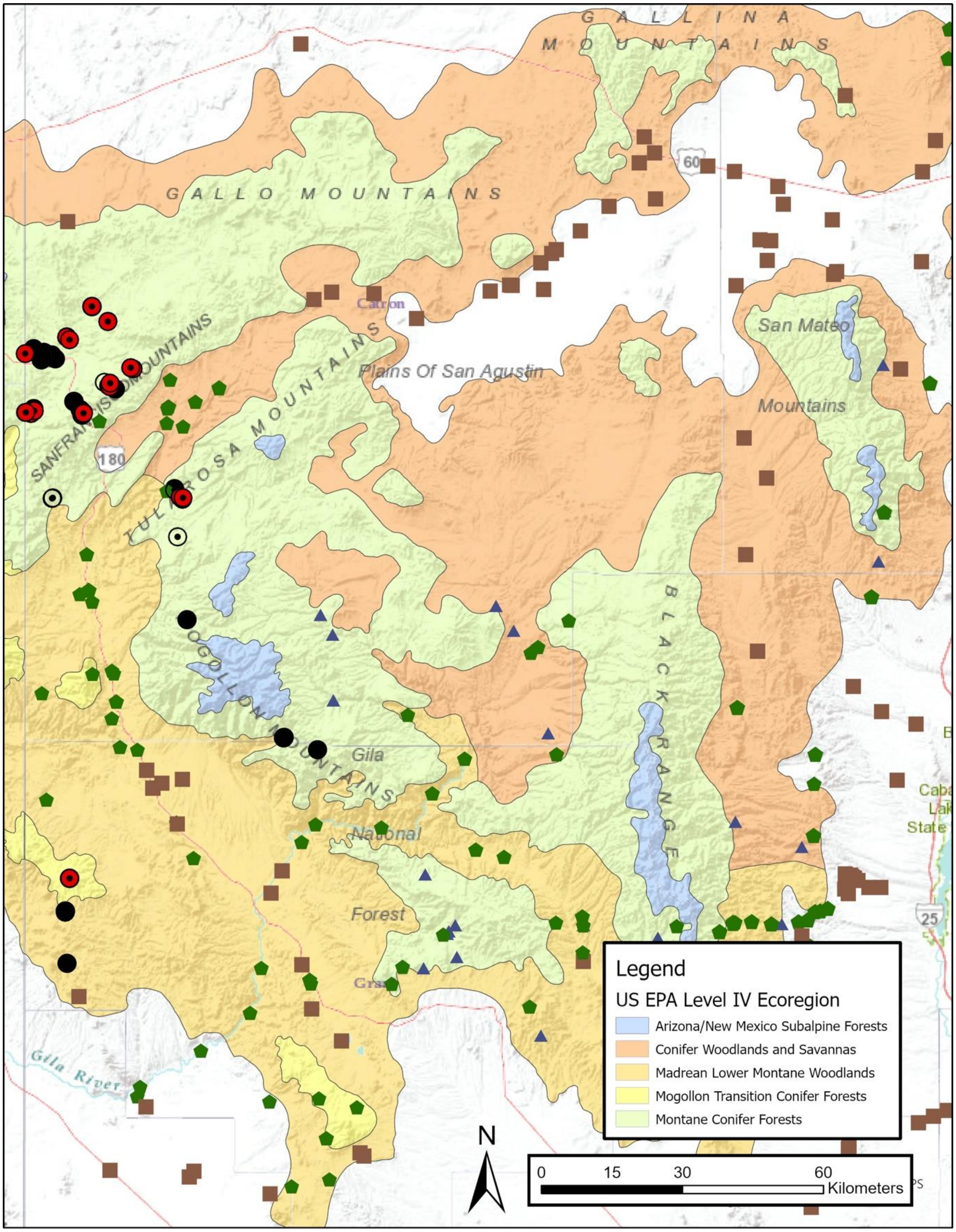


**Figure 7.** Distribution of rattlesnake species within the greater Gila region, New Mexico. Circles (Arizona Black Rattlesnake [*Crotalus cerberus*]), squares (Prairie Rattlesnake [*C. viridis*]), pentagons (Northern Black-tailed Rattlesnake [*C. molossus*]), triangles (Rock Rattlesnake [*C. lepidus*]).

*Habitat Associations*

In the spring, we observed *C. cerberus* in rock out crops or talus habitats with south or southwest aspects. Vegetation associations included: Ponderosa Pine (*Pinus ponderosa*), Alligator Juniper (*Juniperus deppeana*), oaks (Gambel Oak [*Quercus gambeliiI*], Gray Oak [*Q. grisea*], Netleaf Oak [*Q. rugosa*], Silverleaf Oak [*Q. hypoleucoides*], and Sonoran Scrub Oak [*Q. turbinella*],), Piñon Pine (*P. edulis*) and a variety of shrubs (Mountain Mahogany [*Cerocarpus spp*.] and Wolfberry [*Lycium spp*.]), grasses (grama [*Bouteloua* spp.] and muhly [*Muhlenbergia* spp.]), and cacti (cholla [*Cylindropuntia spp*.], hedgehog [*Echinocereus spp*.], and pricklypear [*Opuntia spp*.]),  as well as Banana Yucca (*Yucca bacata*), Beargrass (*Nolina microcarpa*), and Parry Agave (*Agave parryi*). In the summer months, snakes were observed in Piñon-Juniper habitats and canyon bottoms with oaks. In the fall, snakes were encountered in rocky habitats, presumably returning to denning areas.

*Prey Availability*

Potential prey for *C. cerberus* are lizards, small mammals, and birds. Lizards are important prey for young snakes. A diet shift to small mammals and the occasional bird occurs as snakes mature. While prey data are limited, we know that *C. cerberus* preys upon a variety of vertebrate animals. These include 1) lizards: Plateau Lizard (*Sceloporus tristichus*; Schuett et al. 2002), Desert Spiny Lizard (*S. magister*; Loughran et al. 2012), Ornate Tree Lizard (*Urosaurus ornatus*; Bruce Christman, personal observation), Chihuahuan Spotted Whiptail (*Aspedoscelis exsanguis*; Hulse 1973), and Gilbert’s Skink (*Plestiodon gilberti*; Amarello and Smith, personal observation); 2) small mammals: Cactus Mouse (*Peromyscus eremicus*), Harris’ Antelope Squirrel (*Ammospermophilus harrisii*), White-Throated Woodrat (*Neotoma albigula*; Loughran et al. 2012), chipmunks (*Eutamias* [*Tamias*] sp.; A. Holycross and T. Brennan, personal communication), and likely squirrels; and 3) birds: “desert quail” (likely Gambel’s Quail [*Callipepla gambelii*]; Meachum, 1999), Ash-throated Flycatcher (*Myiarchus cinerascens*; Loughran et al. 2012), Pygmy Nuthatch (*Sitta pygmacea*; Schofer 2007), and American Robin (*Turdus americanus*; Vogrinc et al. 2017).

During our investigation, we trapped Brush Mouse (*Peromyscus boylii*), Pinon Mouse (*P. truei*) Northern Rock Mouse (*P. nasutus*), American Deer Mouse (*P. maniculatus*), Stephens’s Woodrat (*N. stephensi*), Mexican Woodrat (*N. mexicana*), and Mogollon Vole (*Microtus* *mogollonensis*). We observed Abert's Squirrel (*Sciurus abertii*), Red Squirrel (*Tamiasciurus hudsonicus*), Cliff Chipmunk (*Tamias dorsalis*), Golden-mantled Ground Squirrel (*Spermophilus lateralis*), and Rock Squirrel (*Spermophilus variegatus*) in the San Francisco Mountains (Catron County). Data shared with us (S. Liphart, MSB, personal communication) from a small mammal survey at Brushy Mountain (South of Mule Creek, Grant County) revealed *P. boylii*, *P. truei*, *P. nasutus*, *N. albigula*, and Silky Pocket Mouse (*Perognathus flavus*).

During snake surveys, we observed *S. tristichus* and *U. ornatus* to be common at most sites. Less commonly observed were Many-lined Skink (*Plestiodon multivirgatus*), Clark's Spiny Lizard (*S. clarki*), and Mountain Short-horned Lizard (*Phrynosoma hernandesi*). We also observed droppings of *Neotoma* spp. at most sites. Birds were commonly observed and species diversity varied.

One *C. cerberus,* captured on 5 May 2020, regurgitated a *Peromyscus* spp., which was identified to be either *P. boylii* or *P. maniculatus* (Randy Jennings, personal observation).

*Snake Fungal Disease*

We collected swabs for SFD from 27 snakes (15 *C. cerberus*, 8 *C. molossus*, 1 *C. lepidus*, and 3 *L. pyromelana*) from 18 sites, 10 of which were occupied by *C. cerberus* (Table 3). All swabs were sent to and analyzed by the Veterinary Diagnostic Laboratory at University of Illinois; all came back negative for SFD.

**Table 3.** Snake Fungal Disease samples. Arizona black rattlesnake (*Crotalus cerberus*) samples are shown in bold and samples are ordered by date of collection.

1. **Arizona Black Rattlesnake (*Crotalus cerberus*), Brushy Mountain, 26-Apr-19**
2. ***C. cerberus*, Trail Canyon, 2-May-19**
3. ***C. cerberus*, SA Creek, 4-May-19**
4. ***C. cerberus*, SA Canyon, 5-May-19**
5. Northern Black-tailed Rattlesnake (*Crotalus molossus*), West of Prairie Point, 8-May-19
6. ***C. cerberus*, FS Rd. 141, 26-Jun-19**
7. ***C. cerberus*, Mother Hubbard Canyon, 27-Apr-20**
8. ***C. cerberus*, Dry Blue Creek, 27-Apr-20**
9. ***C. cerberus*, Dry Blue Creek, 27-Apr-20**
10. Sonoran Mountain Kingsnake (*Lampropeltis pyromelana*), "The Box" San Francisco River, 28-Apr-20
11. **C. *cerberus*, Hell Roaring Mesa, 29-Apr-20**

**12. *C. cerberus*, Hell Roaring Mesa, 29-Apr-20**
**13. *C. cerberus*, Hell Roaring Mesa, 29-Apr-20**
14. *C. molossus*, San Francisco Mountains, 3-May-20
15. *C. molossus*, Dillon Mountain, 4-May-20
**16. *C. cerberus*, Strawberry Canyon, 5-May-20**
**17. *C. cerberus*, Strawberry Canyon, 5-May-20**
18. *C. molossus*, Saliz Creek, 26-May-20
**19. *C. cerberus*, SA Creek, 30-May-20**
20. *C. molossus*, SA Creek, 30-May-20
21. *C. molossus*, JTS Park, 30-May-20
22. *L. pyromelana*, Diamond Creek, 15-Jun-20
23. *C. molossus*, Diamond Creek, 17-Jun-20
24. Rock Rattlesnake (*Crotalus lepidus*), Black Creek, 25-Jun-20
25. *C. molossus*, Lower Black Creek, 1-Jul-20
26. *L. pyromelana*, FS Rd. 141, 1-Oct-20
**27. *C. cerberus*, FS Rd. 141, 1-Oct-20**

*Distribution Modeling*

The most suitable areas for *C. cerberus* in western New Mexico from the best distribution model are identified in the headwaters of the San Francisco River (San Francisco, Saliz, and Kelly Mountains), the western edge of the Gila Wilderness, as well as the confluence of the West and Middle forks of the Gila River (Figure 8). This modeled distribution relies on a combination of variables that emphasize summer precipitation, the annual range of temperature, topographic complexity, and winter precipitation. The model used 15 parameters, transforming the variables into linear, quadratic, and hinge features, resulting in the highest AUC statistic for training data (0.889; a measure of model departure from random), thus the model is robust. Summer precipitation (July-September) accounted for 25.2% of contribution to the model, whereas annual temperature range, topographic complexity, and winter precipitation accounted for 16.8%, 15.3%, and 9.8% of contribution, respectively.

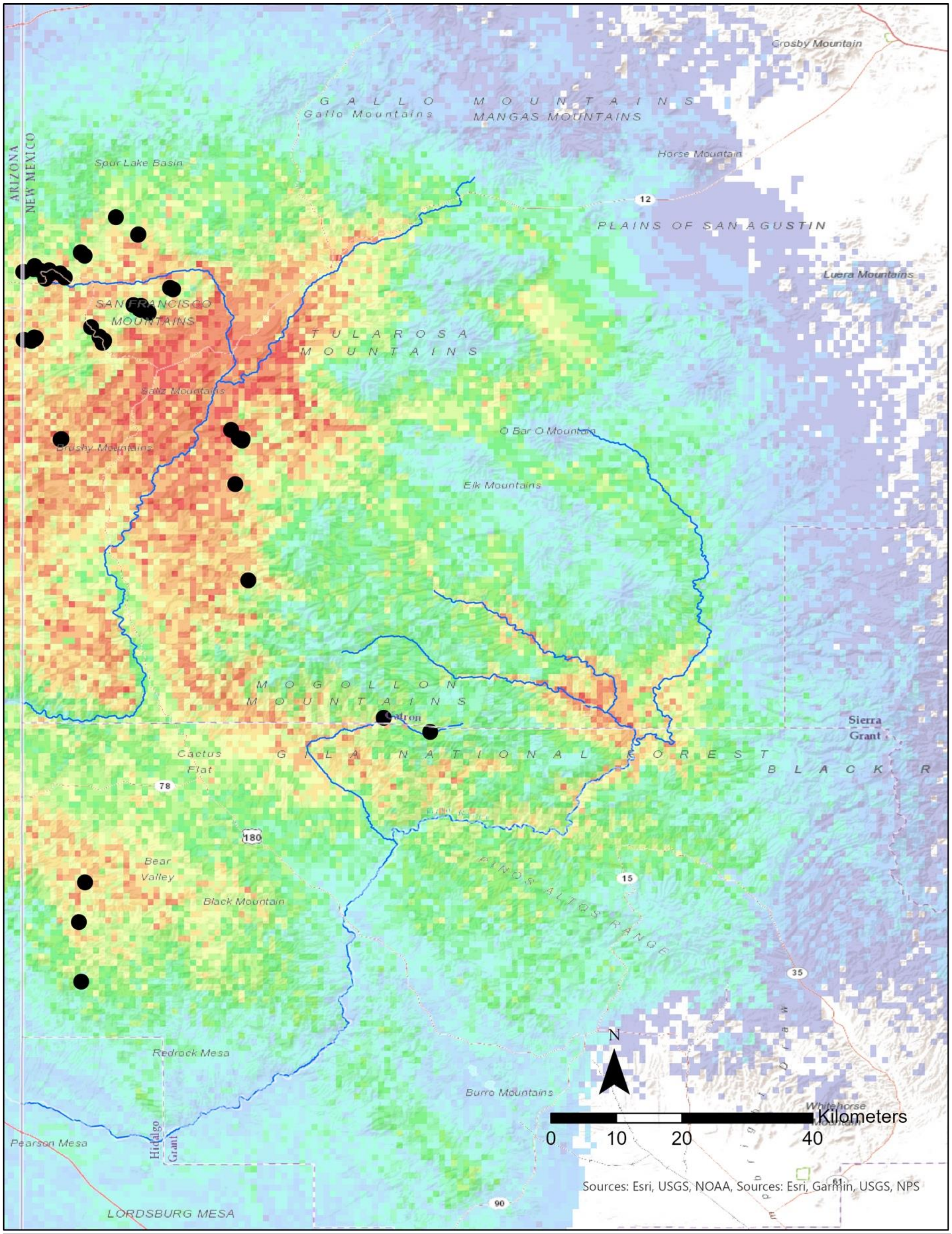


**Figure 8.** Distribution model for Arizona Black Rattlesnake (*Crotalus cerberus*); red represents areas of highest suitability and blue represents areas of lowest suitability.

## Discussion

### *Distribution*

The distribution of *C. cerberus* in New Mexico seems to be associated with the eastern extent of the geology of the Mogollon Rim, which is dominated by igneous rock (basalt and rhyolite), but the presence of similar geology within the greater Gila Region within the Gila National Forest raises the question of why this species does not seem to be distributed more broadly across this habitat. Conversely, the Banded Rock Rattlesnake (*C. lepidus klauberi*) is found in the eastern, but not the western, half of the Gila Region (no records west of Rio San Francisco) or across the Mogollon Rim in Arizona. The third rattlesnake species commonly encountered during our surveys, *C. molossus*, is distributed across the range of both the afore mentioned species.

During the course of this investigation (2019-2020), we surveyed several localities believed to be on the limits of the range of *C. cerberus*: Steeple Rock and Big Burro Mountains to the south, Mogollon Creek to the east and four miles east of historic Mogollon. We were unable to verify the persistence of *C. cerberus* at any of these localities. These localities are on the fringes of the most suitable habitat (Figure 8). However, searching to the north, we verified two localities (i.e., Hell Roaring Mesa and SA Creek) that extend the known range approximately 4.8 and 9.6 kilometers to the northeast of previously known records 3–5 km west of Luna. Surveys further north and east at Black Peak, Dillon Mountain, and JTS Park did not detect *C. cerberus* despite seemingly suitable habitat (Table 2 and Figure 3).

### *Habitat Associations*

Based on our observations, *C. cerberus* in New Mexico occurs primarily in *P. ponderosa-Q. gambelii* woodlands at higher elevations (2200–2500 m), down into Piñon-Juniper / Madrean Oak woodland habitats (1800–2200 m). In both of these habitat associations, the presence of volcanic rock outcrops or deep fractured rock, which provide suitable over-wintering sites, is an essential habitat component. Additionally, the presence of water in the form of a stream or spring also seems to be an important habitat characteristic.

In an assessment of the effects of climate change on southwestern species by van Riper et al. (2014), the most important variables in the model best predicting current distribution for *C. cerberus* were: minimum winter temperature, terrain ruggedness, total summer precipitation, rock type, insolation, lithology, and the distribution of *Q. gambelii* and other oak species. Based on observations of telemetered individuals, Schofer (2007) suggests that downed woody debris (pine or oak logs) may be a more important characteristic than tree species when understory vegetation is limited.

*Potential Threats*

Climate change is considered the greatest threat to continued persistence of *C. cerberus* (NMDGF 2016). Climate change may have significant impacts on local habitats, which may in turn have adverse effects on *C. cerberus* populations through time. Douglas et al. (2016) note that climate change, in synergy with catastrophic wildfire, can be an ecosystem converter. Catastrophic wildfire also is likely to adversely affect small mammal populations, which provide significant prey for adult *C. cerberus* (Douglas et al. 2016 and references therein). As changes occur, *C. cerberus* will only be able to move up in elevation rather than latitudinally (van Riper et al. 2014, Douglas et al. 2016). Projected range reductions with climate change range from 32 to 46% by 2099 (van Riper et al. 2014). Douglas et al. (2016), evaluated the genetics of *C. cerberus* identifying four clades across its range with limited genetic interchange, suggesting further vulnerabilities to climate change.

Road mortality for *C. cerberus* in New Mexico is believed to be limited due to the rugged habitats where they are most likely encountered. There are only two paved roads that cross currently occupied habitat and have resulted in the collection of dead on road (DOR) specimens (US Hwy 180, west of junction with NM Hwy 12 and FS Rd 141, west of Sheep Basin Divide).

There is always the potential for incidental killings of rattlesnakes when human contact occurs. Such mortality is generally assumed to be limited due to the rugged habitats *C. cerberus* occupies. However, there is a greater potential for human-snake interactions during wildfire suppression activities.

Disease in the form of SFD (*Ophidiomyces ohpiodiicola*) represents a potential threat to snakes in the west, but has not yet been detected in New Mexico. Snake Fungal Disease has been detected in Arizona (Northern Arizona University [NAU] News press release 2019) and California (California Department of Fish and Wildlife [CDFW] press release 2019) and in Texas (Barber et al. 2016). In New Mexico, samples for SFD have been tested from sites along the Gila and San Francisco rivers (Allender et al. 2017) and White Sands Missile Range (Allender et al. 2020), with all results coming back negative for SFD.

*Recommendations*

As humans work to restore forests to natural fire regimes, there are some activities that can be modified to limit the effects to *C. cerberus*. These include lighting burn piles from only one side to allow snakes and other animals to escape and educating fire personnel that rattlesnakes are a natural part of the landscape and should be left unmolested.

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