

Rattlesnake Relocation at Montezuma Castle National Monument

Final Report to Southwest Parks and Monuments Association

Principal Investigator: Dr. Charles van Riper III

Research: Erika M. Nowak

Colorado Plateau Research Station at Northern Arizona University
National Biological Service
Flagstaff, Arizona

Rattlesnake Relocation at Montezuma Castle National Monument

Final Report to Southwest Parks and Monuments Association

INTRODUCTION

Venomous snakes in human access areas have long presented a management problem for southwestern national parks. The National Park Service's 1991 Natural Resources Management Guidelines (NPS-77) addresses this issue by stipulating that "when control or removal of individual animals that are considered 'hazardous' is necessary, integrated pest management (IPM) techniques involving scientific research should be used to design an action plan ...that protects the resources within parks in an effective and ecologically sound manner". In spite of these guidelines, only a few Southwestern parks have conducted scientific studies of rattlesnake natural history and/or movement patterns within their parks, and only Chiricahua and Natural Bridges National Monuments have used this research to develop rattlesnake management plans. Rattlesnake management policies vary widely among parks both in the number of snakes relocated per year and the distances they are moved.

A few studies have looked at rattlesnake management and interaction with humans. At the Arizona-Sonoran Desert Museum in Tucson, 50% of the rattlesnakes released immediately adjacent to the museum have returned, 15-20% released at 1.5 km, and one released 4 km may have returned (Perry-Richardson and Ivanyi, 1992). The Desert Museum study and a similar project at Natural Bridges National Monument, examined the reasons for rattlesnake presence in human use areas (Graham, 1991 and 1994 unpubl.). Both studies found that the major factors are

the presence of high concentrations of rodents and rabbits associated with garbage and watering of forage-producing vegetation, and the proximity to seasonal migratory paths.

Other studies have looked at the effects of relocation on rattlesnakes, and have found aberrant social behavior or unusual, long-distance movements by the snakes (Fitch and Shirer, 1971; Landreth, 1973; and Galligan and Dunson, 1979). Studies conducted with timber rattlesnakes (*Crotalus horridus*) in Pennsylvania, with eastern massauguas (*Sistrurus catenatus*) in Canada, and with several desert species in Tucson urban areas, all showed that relocated rattlesnakes had much larger home ranges than their non-relocated counterparts, and mortality rates three times or more that of non-relocated rattlesnakes (H. Reinert, 1995; J. McNally, 1995; and C. Parent, pers. comm.). Causes of mortality included predation, starvation, and freezing, apparently due to being in an unfamiliar area or to selecting an inappropriate hibernation site.

We conducted a radio telemetry study of rattlesnakes at Montezuma Castle National Monument (MOCA) in 1994 and 1995. MOCA is home to three rattlesnake species (of which there are about 12 sightings a year), and receives approximately 790,000 visitors per year at the Castle unit alone (S. Sandell, pers. comm.). Prior to 1994, at least 75% of rattlesnakes sighted at the Castle unit were relocated off the Monument to adjacent National Forest land. We addressed the reasons for rattlesnake presence in human use areas, the efficacy of relocation, and the effect of these practices on the survivorship, fitness, and movements of rattlesnakes. Based on the natural history and movement patterns of MOCA rattlesnakes, we suggest some strategies for managing venomous snakes that may also be applicable to other parks and public land areas in the

southwestern U.S..

METHODS

I. Study Site

The Castle Unit of Montezuma Castle National Monument is located in the Verde Valley of central Arizona, at an elevation of 970 m (3200'). The unit has an area of 235 ha (580 acres), and is bordered on the north, south and east by U.S. Forest Service and on the west by Interstate I-17. It is located along Wet Beaver Creek, a tributary of the Verde River. Vegetation in the area is creosotebush-crucifixionthorn (Sonoran Desertscrub vegetation association) and Interior Riparian deciduous forest (Turner and Brown, and Minckley and Brown, 1994). The region also contains many limestone rock outcrops and cliffs with crevices and caves that are potential rattlesnake hibernacula.

II. Capture

Although we proposed to study three rattlesnake species at MOCA, to facilitate statistical sample analysis, we used only adult western diamondback rattlesnakes (*Crotalus atrox*). Most rattlesnakes were captured in visitor use areas, staff housing, and daily maintenance areas, and a few were captured while previously tagged individuals were being tracked. Rattlesnakes were restrained using corked plastic tubes, and then sexed, weighed, measured, and individually marked on the basal rattle segment with model airplane paint. We palpated all females captured to determine reproductive condition, and did not implant obviously pregnant females or juveniles.

Male and non-pregnant females large enough to be implanted with a transmitter less than or equal to 5% of their body weight (Reinert, 1992) were then held at MOCA in a locking cage, usually not more than 24 hours, until implantation surgery.

III. Surgery and Transmitter Implantation

All rattlesnakes were driven to the Verde Veterinary Hospital in Cottonwood, AZ, where Dr. Bruce Weber or Dr. Michael Walker performed the implantation surgeries. Snakes were placed into an aquarium and administered gaseous isoflurane through an anesthesia machine to render them unconscious prior to surgery. During surgery, anesthesia was administered by tracheal intubation to maintain unconsciousness, and the lungs were artificially "bagged" (inflated) to ensure both adequate anesthesia delivery during surgery and oxygen delivery after surgery. The snake was judged ready for surgery when it no longer responded to pinches and did not try to right itself, and then the area of surgery was scrubbed with an antiseptic.

New transmitter packages consisted of a pre-potted 150-151 MHZ frequency implantable transmitter and a 1.5-volt battery in a polymer mixture, attached to a thin, flexible 30-40 cm whip antenna ¹ (Reinert, 1992). The whole package weighed 11-13 grams, and its life was 1 to 2 years, depending on the pulse rate as detected by an added ambient temperature-sensing device. A Telonics "TR-4" receiver and an "H"-style directional antenna were used to track the tagged snakes.

¹ By Telonics Telemetry-Electronics Consultants, Mesa, AZ, or Holohil Systems Ltd., Ontario, Canada.

Surgical methods generally follow those of Greene and Hardy (1992 unpubl.). Transmitters were surgically implanted in the body cavity (intracoelmically) about 3/4 of the snout-vent length behind the head, and the antenna was run just under the skin toward the head. To speed recovery and prevent dehydration, we gave each snake an injection of saline equal to 5% of its body weight, and we gave a weight-specific injection of short-term antibiotic if the snake had obvious wounds (D. Duvall and D. Hardy, pers. comm.).

After surgery, the snakes were returned to Montezuma Castle and held for 24 hours to ensure adequate recovery from anesthesia. During this post-operative period, the snakes were given water ad libitum and held in a locking wooden box with a screen top, in a warm, quiet room.

IV. Tracking

After recovery, all snakes were returned to their original capture area and released. In 1994, we used radio-telemetry to determine the position of each snake once a day during the active period and once a week during the hibernation period. In 1995, rattlesnake portions were recorded about every other day during the active season and weekly during the hibernation period. When we located a snake, we would record the date, time, weather conditions, ambient temperature, substrate temperature, microhabitat, and the snake's body temperature, activity, and behavior. The position was precisely recorded using a Trimble Geo-explorer global positioning system (GPS) unit.

We recaptured rattlesnakes just prior to their entering hibernation in the fall and just after they

emerged in the spring, to record changes in their condition. At this time, we weighed the snakes and noted the number of new rattle segments. Measurements of length were also taken at these times when possible. Four rattlesnakes were recaptured during the summer of 1995 for replacement of their transmitters.

V. Relocation

We used one relocation distance (again different from our proposal due to the small sample of snakes): in cliffs about 1 km east of the monument's east and south boundary fences (Figure 1). On August 20 - 22 1995, after all rattlesnakes had been tracked for at least four weeks, a relocation experiment was conducted with eight adult rattlesnakes. On August 20, one female and three males were randomly selected, captured, and held in a snake handling bucket until August 21. Two of these, the "handling controls", were then randomly selected, carried a distance equivalent to 2 km, then released back at their August 20 capture point, and observed for three hours. The other two rattlesnakes were randomly assigned to two of four sites previously selected two km east of the concentration of 1994 hibernation sites. The snakes were carried to these sites, released, and observed for three hours. The remaining female and three males were captured on August 21 and treated as described above on August 22. All rattlesnake positions were recorded daily for the next week, then about every other day until the onset of hibernation in mid-October.

VI. Data Analysis

Radio-telemetry locations for each snake were used to evaluate movements and activity ranges of the snakes. We used Trimble Pathfinder (global positioning system interpretative software) and

the Colorado Plateau Research Station's base station to differentially correct and plot rattlesnake locations, then converted these into mapped positions using Arc-Info and Arc-Plot software. Home ranges were calculated as minimum convex polygons (in hectares) from UTM coordinates using the software program Telem. The means for activity ranges of different groups of snakes (ie, males vs female; relocated vs non-relocated) were calculated by hand and the standard deviations by using the statistical computer program SPSS (Seigel and Castellan, 1988).

We used growth rate and weight change as an indication of the health and general condition of the rattlesnakes. An index of condition was calculated from a ratio of the change in rattle string length (an approximation of change in length) divided by the change in weight. The condition of relocated snakes versus that of non-relocated snakes was compared using the Kruskal-Wallis one-way ANOVA (Seigel and Castellan, 1988).

VII. Education and Outreach

On April 10 and 12, 1995, slide show updates on the project were presented to all MOCA staff, and there was a discussion of the identification and handling of rattlesnakes and of the project results. A final report to interpretative staff and management will be presented in mid- December 1995. On May 16, 1995, the first public outreach effort was conducted when the project and basic life history of rattlesnakes were explained to third-graders at a local school. Outreach continued with a poster display at the Verde River Days festival on September 30 and then with a presentation to the residents of a local planned retirement community on November 14. A brochure describing the project's objectives and results will be developed for MOCA visitors. The

brochure will also discuss facts and myths about rattlesnakes.

RESULTS

I. Resident Rattlesnake Home Ranges

Fifteen western diamondback rattlesnakes were implanted with radio transmitters; most of these were captured in the fall of 1994 and the spring and summer of 1995. One male died before release, probably due to a combination of an overdose of anesthesia and a low post-operative body temperature. No mortality was observed during the study for the remaining fourteen rattlesnakes. Thirteen of these animals were sexually mature adults (five females and eight males) and one was a subadult female. Three rattlesnakes were lost when their radio transmitters failed, and one rattlesnake was lost through unknown causes. The remaining ten rattlesnakes are currently hibernating, and will be tracked until the spring of 1997 to determine the long-term effects and effectiveness of relocation.

From August 3, 1994 to August 20, 1995, we located the positions of twelve rattlesnakes a total of 473 times (average number of locations per rattlesnake was 40, with a minimum of 5 and a maximum of 86 locations per rattlesnake). From August 21 to November 19, 1995, 9 rattlesnakes (including 7 rattlesnakes from the previous period) were located a total of 93 times (average number of locations per rattlesnake was 10, with a minimum of 8 and a maximum of 14 locations per rattlesnake). The actual number of locations per snake was slightly higher in both groups (particularly in the second group), but some positions collected with the global positioning system could not be corrected and so were not used in this analysis. All corrected positions on or near the

monument are shown in Figure 2.

The average resident home range size for the 14 western diamondbacks at MOCA is 12.44 hectares (ha), with a minimum of 0.55 ha (a male, 17 positions) and a maximum of 49.24 ha (a male, 58 positions). The home range of the subadult was 5.84 ha (86 positions), about half that of the average home range size at MOCA. There was no difference between female and male home range size (male mean = 13.92, sd = 15.66; female range = 10.12, sd = 11.79), although at least four animals had very large or very small ranges. When these outliers were removed, males had an average home range that was nearly twice that of females: 9.47 ha (sd = 5.81) versus 5.69 ha (sd = 1.22). A representative male's home range (snake X-OR-BLK) is shown in Figure 3 and a representative female's home range (snake W-R-Y) is shown in Figure 4. Home ranges were slightly larger in the fall (11.56 ha, sd = 7.08) than they were in the spring and summer (7.08 ha, sd = 7.29).

II. Den Sites and Hibernation

Eight of the 14 rattlesnakes had hibernation sites in the cliffs directly behind and southwest of the visitor center (Figure 5). Typical den sites were large, deep caves with an overhung flat basking area at the front, and containing an active or inactive woodrat nest. Two non-relocated rattlesnakes were tracked in 1994 and again in 1995, and were found to use the same hibernation sites both years. At least one den in this area has contained four rattlesnakes during hibernation, although most other dens at MOCA appear to hold single rattlesnakes.

In 1994, all (6) rattlesnakes entered hibernation between October 12 and October 14, corresponding to the onset of the first cold winter storm system. From mid-October until mid-November, three of these snakes were observed basking at the entrance of their dens on warm days. One female (W-R-Y) emerged from hibernation on February 3, 1995, most of others emerged in early March, and the last rattlesnake (X-GR-BLK, the subadult) emerged from hibernation on May 15. X-GR-BLK's hibernation site differed from the others in its location (in a 1.5-meter-high roadcut) and in having almost no area at the front for basking.

In 1995, entrance into hibernation was more variable, with the first of ten rattlesnakes entering hibernation on October 5 or 6, many entering about October 17, and the last rattlesnake entering on October 22 or 23. Only one rattlesnake was observed basking at the entrance of its den between mid-October and November 19.

III. Foraging in Visitor and Housing Areas

Nine of the fourteen snakes in this study spent one week or more foraging in the visitor access or housing areas. At least one snake (GO-SI-GO, a male) found foraging in these areas did not also hibernate here, but across Wet Beaver Creek. His home range is shown in Figure 6.

One prey item, a mockingbird, was seen being consumed near the housing area. Other prey items identified only by the size of bulges in rattlesnakes' bodies included 2 rabbits (both taken in the visitor access area), woodrats, and/or ground squirrels.

In spite of all of the locations of rattlesnakes in visitor access and housing areas, only one implanted female (W-R-Y, whose range is shown by Figure 4) was seen again (twice) by visitors and staff after her initial capture in these areas. On several occasions, visitors walked within a meter of a rattlesnake hidden near a trail without seeing it, and on several occasions we approached rattlesnakes to within a half-meter while tracking them. Although we have not analyzed behavioral data specifically yet, in over 566 field locations of rattlesnakes, striking behavior occurred only when rattlesnakes were being handled, and rattling (or other defensive behavior such as moving into a head-cocked position) was observed approximately 15 times.

IV. Relocation

The relocation experiment results should be interpreted with the low sample size for relocated snakes in mind. However, at least in the three months after relocation, no relocated rattlesnakes returned to their original home range, although one did return to the edge of the monument. No differences were seen in behavior in the first three hours after relocation: seven of the eight rattlesnakes went under the nearest shrub and stayed there for the remainder of the observation period, and the eighth, a relocated snake, took off immediately, traveling a distance of about 50 meters, before stopping and remaining under a shrub for the duration. It is likely that the shrubby terrain made it impossible to observe the rattlesnakes, even with binoculars, without affecting their behavior.

Two days after her relocation, the female disappeared. It is unclear whether this was a predation event, a transmitter failure, or simply a moving out of range of the receiver, but since Arizona

Game and Fish researchers searching the area by plane were unable to locate her, the first two options are more likely. The remaining three males were observed to make longer and more frequent movements than either before they were relocated and also when compared to non-relocated snakes during the same time period after relocation, although we did not quantify these observations. All three rattlesnakes exhibited some degree of "circling" (coming back a few times to the same point) after relocation.

The average range for relocated snakes (defined as the "activity range", as the snakes did not appear to settle into a familiar pattern of movements) between August 21 and November 19 was 35.43 ha (sd = 16.39) versus 15.96 ha (sd = 14.25) for the non-relocated snakes. The average range for relocated snakes was 18.10 ha (sd = 27.04) before relocation and 35.43 ha (sd = 16.39) after relocation. The home range size for non-relocated snakes did not differ before (10.51 ha, sd = 6.63) and after their handling control (18.10 ha, sd = 27.04). In addition, the average home range size for relocated and non-relocated snakes prior to the relocation experiment was not different (15.96 ha versus 10.51 ha).

A few differences were seen in the health condition of relocated and non-relocated rattlesnakes. When the percent weight change was compared between relocated and non-relocated rattlesnakes, there was a significant difference ($p = .0253$, $df = 1$, $\alpha = 0.05$), as all of the relocated snakes gained considerable weight (average = 287 g, sd = 260.61). However, four of the six non-relocated snakes also gained some weight (average = 6.47 g, sd = 60.41). Changes in rattle string length were used as a gross approximation to increase in body length, and there was a slightly

higher average number of rattles added in non-relocated snakes (0.60 rattles, $sd = 0.55$) than in relocated snakes (0.33 rattles, $sd = 0.58$) ($p = .4945$, $df = 1$, $\alpha = 0.05$). An index of overall condition determined by dividing the change in rattle string length by the weight change was not significant ($p = .4271$, $df = 1$, $\alpha = 0.05$).

All three relocated rattlesnakes switched hibernation sites about two weeks after entering hibernation (although one rattlesnake then returned to his initial location). Two of the rattlesnakes traveled over 50 m to larger outcrops. This occurred in 1994 and in 1995, and the frequency of hibernation site switching was higher for relocated snakes (.67) than for non-relocated snakes (.33).

DISCUSSION

Why are rattlesnakes in visitor access and housing areas?

I. Hibernation

A primary reason for rattlesnake presence in visitor access areas at MOCA is well illustrated by Figure 5. The cliff areas behind and to the southwest of the visitor center appear to provide preferred hibernation sites for rattlesnakes at MOCA, probably due to their southerly exposure and to the presence of deep caves (presumably well-insulated and humid) with basking areas at their entrance. At least two pairs of rattlesnakes were seen courting within 50 m of these cliffs (one pair in the spring and one in the fall), so the concentration of snakes hibernating in these cliffs may also serve a social function in making mates easier to find. The appearance of higher

numbers of rattlesnakes in the visitor access area in March and again in October is explained by seasonal migrations to and from these den sites, and does not indicate a high number of resident rattlesnakes in this area. Given that most rattlesnakes show a pronounced tendency to return to the same hibernation area (if not the same site) year after year, continuous removal outside their normal home range could have a negative impact on the social and genetic structure of this population.

II. Foraging

The second reason for rattlesnake presence in the visitor access and housing areas is illustrated by the foraging migrations of GO-SI-GO in Figure 6. This male was captured in the picnic area on July 26, spent a few days in the area after implantation, and by August 20, had moved into the cliff area east of Wet Beaver Creek, a distance of nearly one kilometer. He spent a few weeks foraging in this area, and by September 9, he was back near the picnic area. After about one week of foraging here, he returned to the east cliffs, where he eventually hibernated. While we are fairly certain that this snake was foraging during his return trip to the visitor access area, another possible explanation for the seasonal presence of male snakes in this area could be the presence of sexually receptive resident females (Graham, 1994). We know that at least one female snake, W-R-Y, is a resident in the visitor access area, and that eight other snakes have spent some time foraging here and/or in the housing area.

At least four other studies looking at the reasons for rattlesnake presence in concentrated human-use areas across the U.S. and Canada found that the presence of artificially high prey

concentrations in these areas was the primary factor (Perry-Richardson, 1992; Graham, 1994; and J. Scaly and C. Parent, pers. comm). While we have not yet tested this hypothesis yet at MOCA, we also assume that the concentration of rodents and rabbits in the visitor access and housing areas is due to a high concentration of potential nesting sites, garbage, irrigated lawns, and perhaps to the relative protection of these areas from predators such as coyotes (C. Drost, pers. comm). Rattlesnakes repeatedly visit particularly rodent-rich sites in these areas (ie, behind the housing area where bird seed is put out and under the storage building), adding support to the hypothesis.

III. Behavior in visitor access areas

Although rattlesnakes are theoretically likely to be sighted in visitor access and housing areas frequently throughout the spring, summer, and fall, in practice they are rarely seen by visitors and/or park staff. One reason is that they usually prefer to forage by coiling in fairly dense cover away from the trails and waiting for prey to run by. Rattlesnakes also rely primarily on their cryptic coloration for protection from predators, and, at least in this population, have a pronounced tendency not to rattle unless approached closely in a threatening manner. (We noted that rattling tended to occur most frequently at night, when a rattlesnake in sparse cover was approached quickly, or when a nervous (and therefore, quick-moving) person unfamiliar to the snakes accompanied the researcher). While this observation may seem alarming to management personnel, this population is not usually aggressive, unless directly threatened (ie, teased or cornered) or handled. This observation is supported by many other rattlesnake researchers working across the U.S. (D. Duvall, H. Greene, M. Martin, C. Parent, H. Reinert, B. Savitzky,

and W. Timmerman, pers. comm.). As such, the presence of rattlesnakes in the visitor access areas per se is not a threat to humans, but education of visitors to be aware and to avoid closely approaching rattlesnakes is needed to help prevent unwanted interactions.

What happens to relocated rattlesnakes?

The results of the relocation study are limited by the small number of rattlesnakes relocated, and by the amount of time they were studied after relocation- whether or not the relocated snakes will survive the hibernation period is unknown, and so are the long-term effects of relocation on both relocated and resident snakes. To begin to address these issues, we will continue the study for another year with funding from another (as yet unknown) source.

I. Effectiveness of relocation

Four relocated rattlesnakes did not return to their original home range in the initial three months after their relocation, and so from this standpoint, relocation of MOCA rattlesnakes to a distance of two kilometers could be considered "effective". However, we can also conclude that relocation to a distance outside their normal home range is disruptive to rattlesnake behavior and biology. Disruption manifested itself in the relocated rattlesnakes through abnormally large ranges, their patterns of frequent and long straight-line movements, and circling (as if to establish a reference position from which to explore their unfamiliar surrounding). Another unusual behavior observed in a relocated snake was tree climbing: during the initial observation period after relocation, X-OR-BLK climbed approximately one meter into a crucifixion-thorn and remained there for 3 hours.

II. Change in condition

It is likely that the time spent adjusting to their new range or in trying to home to their former range would preclude appropriate levels of foraging and mating behavior, and would increase the risk of injury or predation. We did not see an obvious reduction in condition of the relocated rattlesnakes in the initial three months after relocation, however, we were not able to obtain length and weight measurements on all the animals. Although on average they did not add as many rattle segments as the non-relocated rattlesnakes, given the large weight increase in the relocated snakes ², we do not think this indicates reduced condition. Realistically, a larger sample size would also help detect subtle differences in the health of relocated and non-relocated rattlesnakes, and these effects may take some time to show up. The crucial period for detecting differences in condition may be next spring, when and if the rattlesnakes emerge from hibernation, having not eaten for five to six months. Starvation during hibernation has been the cause of mortality for several relocated rattlesnakes (H. Reinert, pers. comm), but southwestern relocated rattlesnakes may have some initial survival advantage over rattlesnakes in higher latitudes, as the potential foraging season is longer.

III. Hibernation

Hibernation temperatures are also a factor in rattlesnake overwinter survival. The apparently higher incidence of hibernation site switching in the MOCA relocated rattlesnakes suggests that the initial sites selected were inadequately insulated or insufficiently humid to sustain the snakes

² The large weight gain in the three relocated snakes may be partially explained by their relatively larger size as compared to the non-relocated group.

over the winter. Here in particular southwestern rattlesnakes have a clear advantage over their higher latitude counterparts- any switching (if attempted) would result in sure death by freezing for those rattlesnakes. Indeed, a major cause of mortality in at least two other relocation studies has been overwinter mortality, primarily by freezing (C. Parent and H. Reinert, pers. comm.). We will continue this study through the next hibernation period to determine the long-term effects of relocation on rattlesnakes at MOCA.

IV. Population effects

There may also be long-term negative impacts such as increased competition for food or mates, on resident populations in areas where rattlesnakes are relocated, especially as parks tend to remove "nuisance" snakes to the same areas over long periods of time. Many researchers suggest that animals introduced into areas outside of their normal home range, especially if many are introduced over long periods of time into the same area, may serve as vectors for the spread of disease (McNally, 1995; Burke, 1991; Dodd and Seigel, 1991; and Reinert, 1991). McNally suggests that the Viperid Paromyxovirus may be one such disease that could be spread by relocation of rattlesnakes (McNally, 1995).

There is limited evidence that neonate rattlesnakes adapt to relocation more readily than adults (J. Monahan, pers. comm.), but in general these small snakes are rarely seen and thus not considered nuisance snakes in parks.

What are the options for managing MOCA snakes?

Based on the natural history of rattlesnakes at MOCA and on the results of the relocation experiment, we have made some management recommendations for rattlesnakes at the park.

I. Re-route rattlesnakes

One option to manage rattlesnakes in visitor access areas would be to re-route them from these areas. This could involve installing a drift fence to route rattlesnakes entering or emerging from hibernation sites around the visitor access area (completely encircling the visitor access area). This might be feasible if it were not for the seasonal flooding of Wet Beaver Creek, which would bring down the fence on the creek side and create a situation where migrating or foraging rattlesnakes returning to the cliffs would become trapped on the visitor side of the fence.

Another option would be to seal off potential den openings and rodent burrows to prevent snakes from using them. This is also probably not a feasible option, as it would be almost impossible to locate and close off all potential openings in the area and would require constant maintenance. This action would also negatively impact other animals, for which the cliffs provide important habitat. Finally, in an area such as MOCA, such action would be unacceptable because of the damage and disturbance to archaeological sites in the cliff areas.

II. Decrease rattlesnake prey concentrations

A more feasible option to discourage rattlesnakes from foraging in visitor access and housing areas would be to discourage their main prey, rodents and rabbits, from heavy use of these areas.

This could include regular garbage control, especially before nightfall when rodents are most active, containing garbage materials in rodent-proof containers, regular cleaning of all buildings to discourage rodent nesting³, and removal of non-native vegetation that requires regular watering (such as lawn grasses) and replacement with native vegetation. Working on this same issue at Natural Bridges National Monument in the early 1990's, Tim Graham suggested that the number of resident snakes in visitor access areas could be decreased by controlling rodent populations through trapping, cleanliness, and replacing ornamental vegetation and lawns with native vegetation to decrease habitat for rattlesnake prey. We feel that rodent and rabbit control, while difficult, could help reduce the number of resident rattlesnakes in the visitor access and housing areas over time.

Rattlesnakes do not spend much time away from cover, and so the current practice of cutting vegetation back from the edges of trails likely discourages rattlesnakes from close proximity to trails. However, the continuous clipping of this vegetation encourages tender new growth which likely draws rodents and rabbits in for foraging when visitors are not present, perhaps attracting even more rattlesnakes than if the vegetation were not cut. One option for resolving this dilemma might be to plant native forbs or grasses that have spindly growth forms (such as penstemons or bunchgrasses) that would not provide cover for adult rattlesnakes, would not require cutting, and could also decrease the incidence of trespass if planted close to the trails.

³ Any cleaning in areas already having rodents should follow precautions to avoid exposure to rodent-borne hantavirus (Center for Disease Control, 1993).

III. Relocation

We recommend that rattlesnakes be relocated only if they are encountered on or in clear view of a trail when visitors are present, if they are on a road, or if they are trapped in a sewage lagoon.

Rattlesnakes seen away from the trails or in low-human-use areas around MOCA do not pose a direct threat to the public and it may be safer to leave them alone. We strongly encourage the park to design a standardized relocation plan, included in its Natural Resources Management Plan, that all park personnel will be familiar with and will be expected to follow. Due to the potential for injury to themselves and to the rattlesnakes, under no circumstances should personnel who are strongly apprehensive about handling rattlesnakes relocate them.

When relocation of specific rattlesnakes is deemed necessary because they are posing a potential threat to, or are threatened by, visitors, we do not advocate relocating rattlesnakes outside of their normal home range due to a range of potential negative impacts. Given the tremendous human use potential in areas around the monument and the suspected loss of at least one rattlesnake to human predation, we also recommend that rattlesnakes be relocated on monument property, and away from roads and highways bordering the monument. At MOCA, no rattlesnake should be moved more than 12.44 ha (about ½ mile linear distance) from its capture point, and preferably, should only be removed a few meters from a trail (at least 25 meters from a road or the sewage lagoons).

The time of year is important in determining where to relocate nuisance rattlesnakes. In the spring, when emergence from dens is occurring, rattlesnakes should be relocated in the direction

away from cliff areas. In fall, when they are returning to hibernate, they should be relocated toward cliff areas.

We request that no rattlesnakes be relocated until the conclusion of the ongoing study in the spring of 1997.

IV. Education

The 1980's envenomation of a child at MOCA who innocently stepped on a rattlesnake, and the occasional appearance of a rattlesnake on a trail both point out the need for the public education before such events occur. The primary and most long-term way to decrease the number of human-rattlesnake interactions will be to educate the staff and visitors:

1. First, that visitors should be aware that they are visiting a natural environment containing resident rattlesnakes;
2. Second, that rattlesnakes prefer denser cover to trails, so visitors should not trespass off the trails;
3. Third, that these rattlesnakes are not usually aggressive but should never be approached closely (stay at least 6 feet back from a snake on the trail) or teased; and
4. Fourth, that only trained staff members should closely approach and handle any rattlesnake. We suggest that all personnel who feel comfortable handling rattlesnakes receive personal training from a professional herpetologist, perhaps at annual or as-needed training sessions.

We recommend that a pictorial wall or portable trail display and a brochure with information

about rattlesnakes in several languages be made available for visitor information. As outlined above, these educational aids should contain tips for avoiding encounters with rattlesnakes, discussion of certain myths about rattlesnakes (ie., all rattlesnakes are aggressive), and also discussion of the objectives and results of the relocation study at MOCA. We will develop the brochure as part of this project, and will assist the interpretative staff in developing the interpretative display.

Rattlesnake species are in decline or are extirpated in many parts of their range across the U.S., primarily due to over collecting and to habitat destruction, but also to fear caused by misunderstanding of their habits and ignorance of their importance in the ecosystem. MOCA is in an excellent position to provide both a long-term refuge for rattlesnakes and to educate large numbers of people about the habits, myths, and importance of rattlesnakes. We encourage the park to aggressively pursue both of these methods of natural resource conservation.

ACKNOWLEDGMENTS

Funding was provided by the Southwest Parks and Monuments Association. This project would not have been possible without permission and support from Montezuma Castle National Monument, the U.S. Forest Service, and the Arizona Game and Fish Department. Kathy Davis of the Southern Arizona Group office of the National Park Service provided additional funding and project support. Dr. Bruce Weber and his staff at the Verde Valley veterinary Hospital have graciously provided space, materials, and assistance for transmitter implantations. John Goodwin and Tom Britt of the Arizona Game and Fish Department donated important aerial tracking time to search for missing rattlesnakes.

Each person with the interpretive and maintenance staff at the monument was crucial for their efforts in capturing rattlesnakes. Manuel Santana-Bendix was invaluable for his time spent tracking and capturing rattlesnakes and for his technical advice. Jeff Larson, Valerie Coombs, and Paul Deshler assisted with the GIS data development. Lee Benson of the Southern Arizona Group office of the National Park Service, Michael Marshall, Bill Freeman, Mark Smedick, John Grahame, and Betty Sutton assisted with the relocation experiment. Much needed advice and/or personal field observations during project development and implementation were provided by: Dr. Charles van Riper III, Dr. Kiisa Nishikawa, Dr. Dave Duvall, Charles Drost, Dr. Howard Reinert, Dr. Harry Greene, Dr. David Hardy, Dr. Steve Beaupre, Joleen Berry, Carol Kruse, Shane deSolla, Matt Goode, Dr. Tim Graham, Trevor Hare, Andy Holycross, Marty Martin, Jude McNally, Joe Monahan, Jack O'leile, Chris Parent, Jan Perry-Richardson, Bob Reed, Phil Rosen, Dr. Matt Rowe, Dr. Barbara Savitzky, Mike Sredl, Dr. Cecil Schwalbe, J. Scaly, Dr. Walter Timmerman, and David Willey.

LITERATURE CITED

- Burke, Russell L. 1991. Relocations, repatriations, and translocations of amphibians and reptiles: Taking a broader view. *Herpetologica*, 47(3): 350-357.
- Center for Disease Control. 1993. Hantavirus Infection- Southwestern United States: Interim recommendations for risk reduction. Adapted from *Morbidity and Mortality Weekly Report*, July 30, 1993, Vol. 42, Number RR-11: pp 1-13.
- Dodd, C. Kenneth Jr., and Richard A. Seigel. 1991. Relocation, repatriation, and translocation of amphibians and reptiles: Are they conservation strategies that work? *Herpetologica*, 47(3), 1991, 336-350.
- Fitch, H., and W. Shirer. 1971. A radiotelemetric study of spatial relationships in some common snakes. *Copeia* 1971: 118-128.
- Galligan, J.H., and W.A. Dunson. 1979. Biology and status of timber rattlesnake (*Crotalus horridus*) populations in Pennsylvania. *Biological Conservation* 15: 13-58.
- Graham, Timothy. 1991. Western Rattlesnake ecology at Natural Bridges NM, Utah. *Park Science* 11(4). Fall 1991.

- . 1994 unpublished. Ecology of a population of *Crotalus viridis* at Natural Bridges National Monument: management of people and rattlesnakes. Report to Natural Bridges National Monument.
- Greene, H. W., and D. L. Hardy. 1992 unpublished. Protocol for surgical transmitter implantation on snakes in the field.
- Kruse, Carol. 1993. CHIR/FOBO Office Orders #33: Snake Relocations. United States Department of the Interior, National Park Service, Chiricahua National Monument, Wilcox, Arizona: 3 pp.
- Landreth, H.F. 1997. Orientation and behavior of the rattlesnake, *Crotalus atrox*. *Copeia* 1973: 26-31.
- McNally, Jude T. 1995. Evaluation of a rattlesnake relocation program (U93009). Final report submitted to the Arizona Game and Fish Heritage Fund.
- Minckley, W.E., and D. E. Brown. Wetlands. Chapter 6 *In* David E. Brown (ed.). Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City, UT: 342 pp.
- National Park Service. 1991. NPS-77: Natural Resources Management Guidelines.
- . 1988. Natural Resource Management. *In* Management Policies, Chapter 5.
- Perry-Richardson, Janice, and Craig Ivanyi. 1992. Preliminary analysis of a study on the free-ranging rattlesnakes on Arizona-Sonora Desert Museum grounds. AAZPA 1992 Regional Proceedings.
- Reed, Robert. 1993 unpublished. Master's thesis: the Grand Canyon rattlesnake (*Crotalus viridis abyssus*): Status and ecology in the Little Colorado River Gorge.
- Reinert, Howard K. 1995. Abstract: The impact of translocation on the behavior and survival of timber rattlesnakes, *Crotalus horridus*. 1995 Society for the Study of Amphibians and Reptiles Annual meeting, Boone, N.C.
- . 1992. Radiotelemetric field studies of pitvipers: Data acquisition and analysis. *In* J.A. Campbell and E.D. Brodie (eds.), Biology of the Pitvipers. Selva Press, Tyler, Texas: 467 pp.
- . 1991. Translocations as a conservation strategy for amphibians and reptiles: Some comments, concerns, and observations. *Herpetologica*, 47(3), 1991, 357-363.

Seigel, S. and N.J. Castellan, Jr. 1988. Nonparametric Statistics for the Behavioral Sciences, 2nd ed. McGraw-Hill, Inc., New York.

Turner, R.E., and D.E. Brown. 1994. Tropical-subtropical Desertlands. Chapter 5 *In* David E. Brown (ed.). Biotic Communities: Southwestern United States and Northwestern Mexico. University of Utah Press, Salt Lake City, UT: 342 pp.

Figure 1. August 1995 relocation sites for four adult *Crotalus atrox*, each 2 km from hibernation sites at Montezuma Castle National Monument.

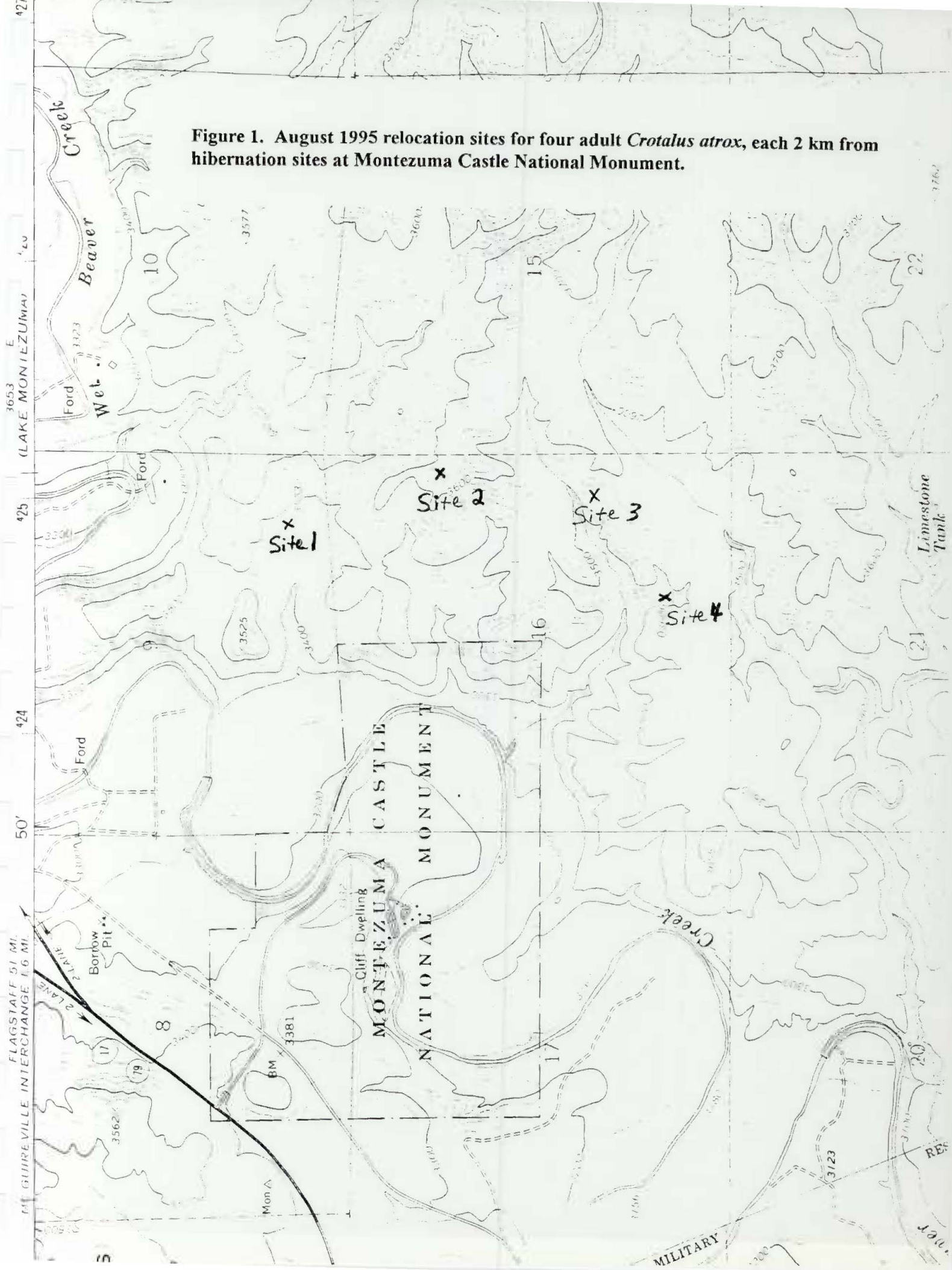




Figure 2. Individual locations of 13 adult and 1 subadult radio-tagged *Crotalus atrox* at Montezuma Castle National Monument, from August 1994 to November 1995.

Data by Erika M. Nowak, 1995
GIS by Valerie Coombs
Colorado Plateau Research Station

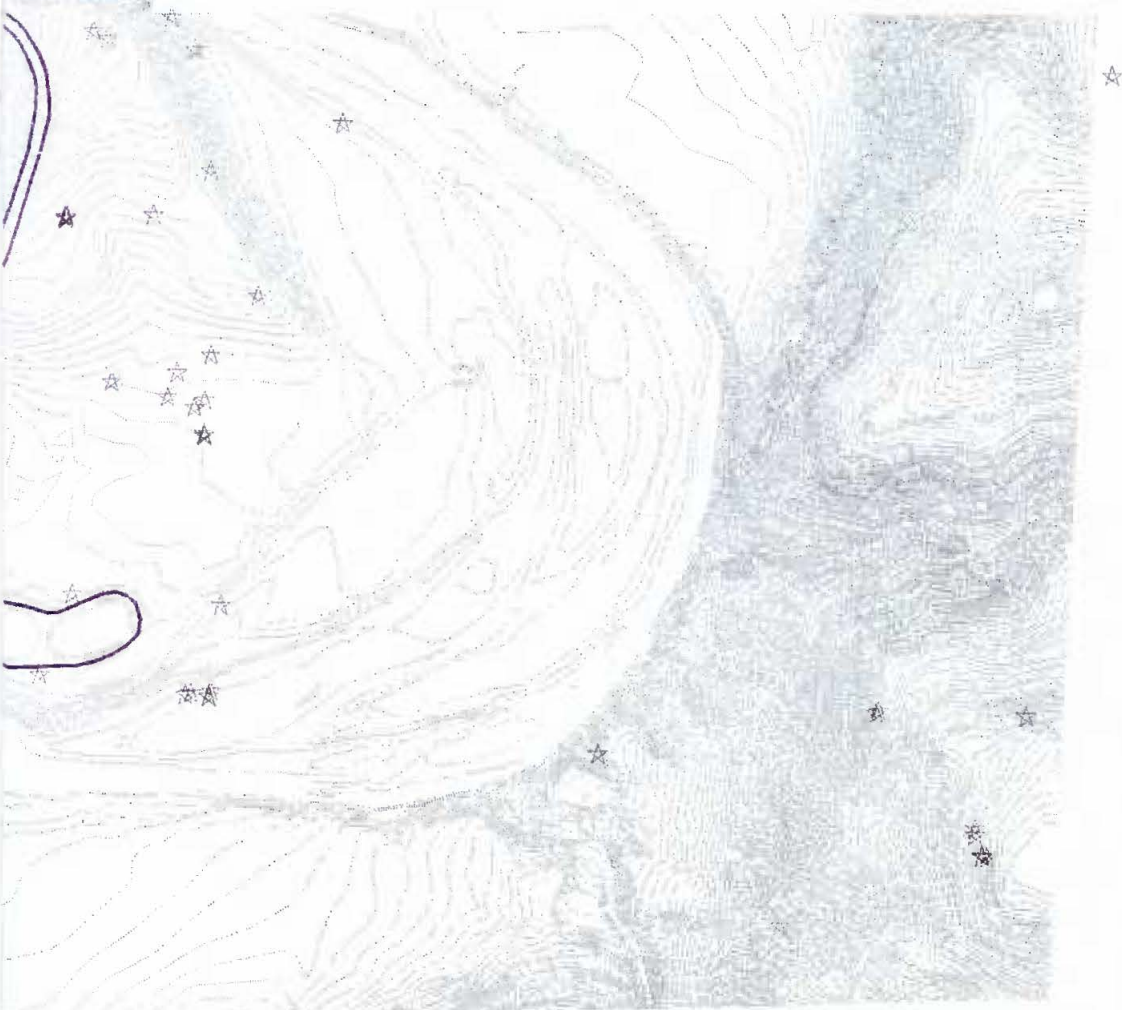
Rattlesnake Locations at Montezuma Castle

August 1994 to November 1995

-  Topography
-  Man-made Structures
-  Roads
-  Rattlesnake Locations



SCALE 1:7000
150 0 150 300
METERS



National Biological Service
Northern Arizona University
Flagstaff, AZ 86011-5614
(520) 556-7466

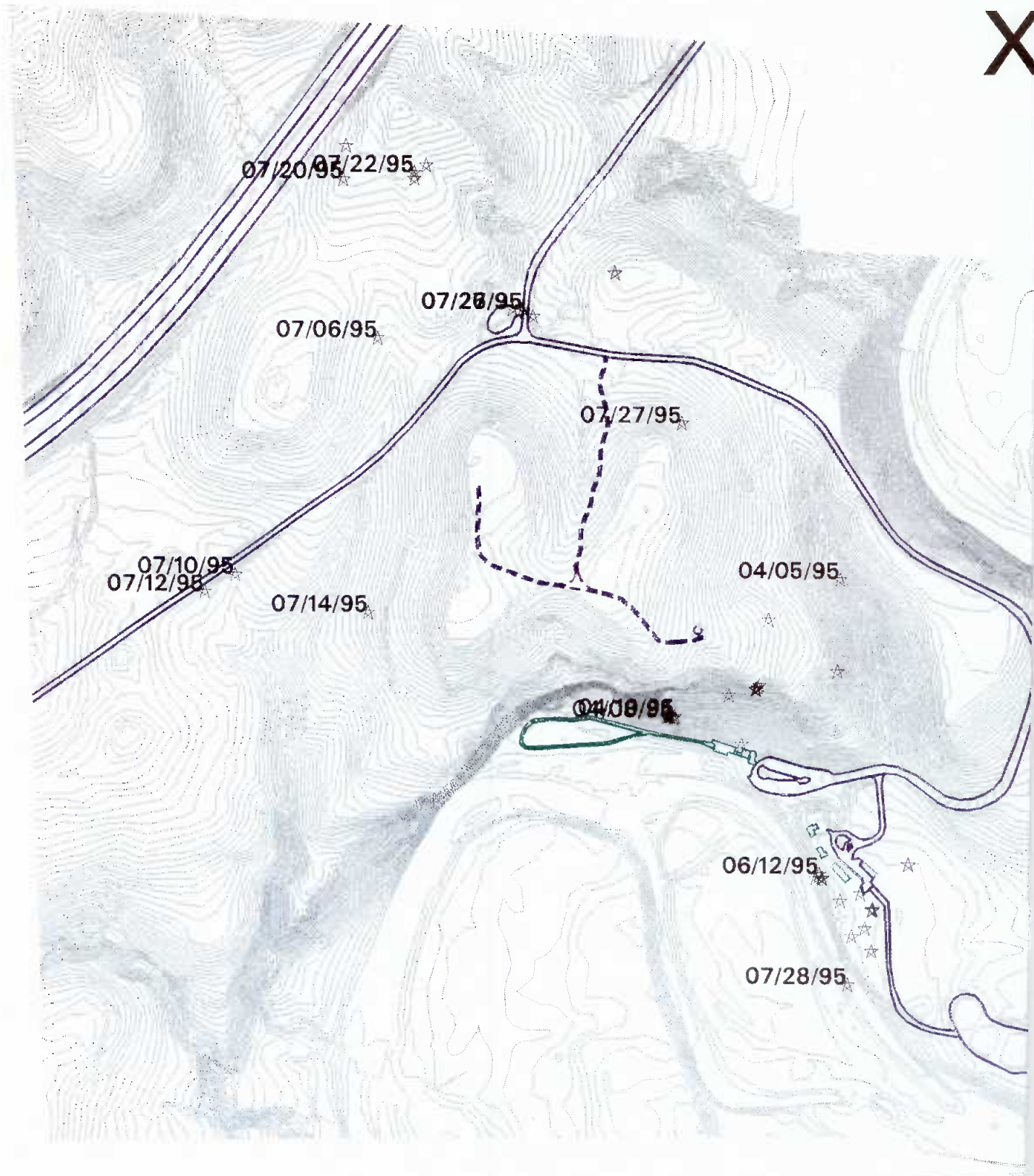


Figure 3. Individual locations of a radio-tagged adult male *Crotalus atrox* (X-OR-BLK) at Montezuma Castle National Monument, from August 1994 to November 1995.

Data by Erika M. Nowak, 1995
GIS by Valerie Coombs
Colorado Plateau Research Station

-OR-BLK Locations at Montezuma Castle

August 1994 to November 1995



Topography



Man-made Structures



Roads



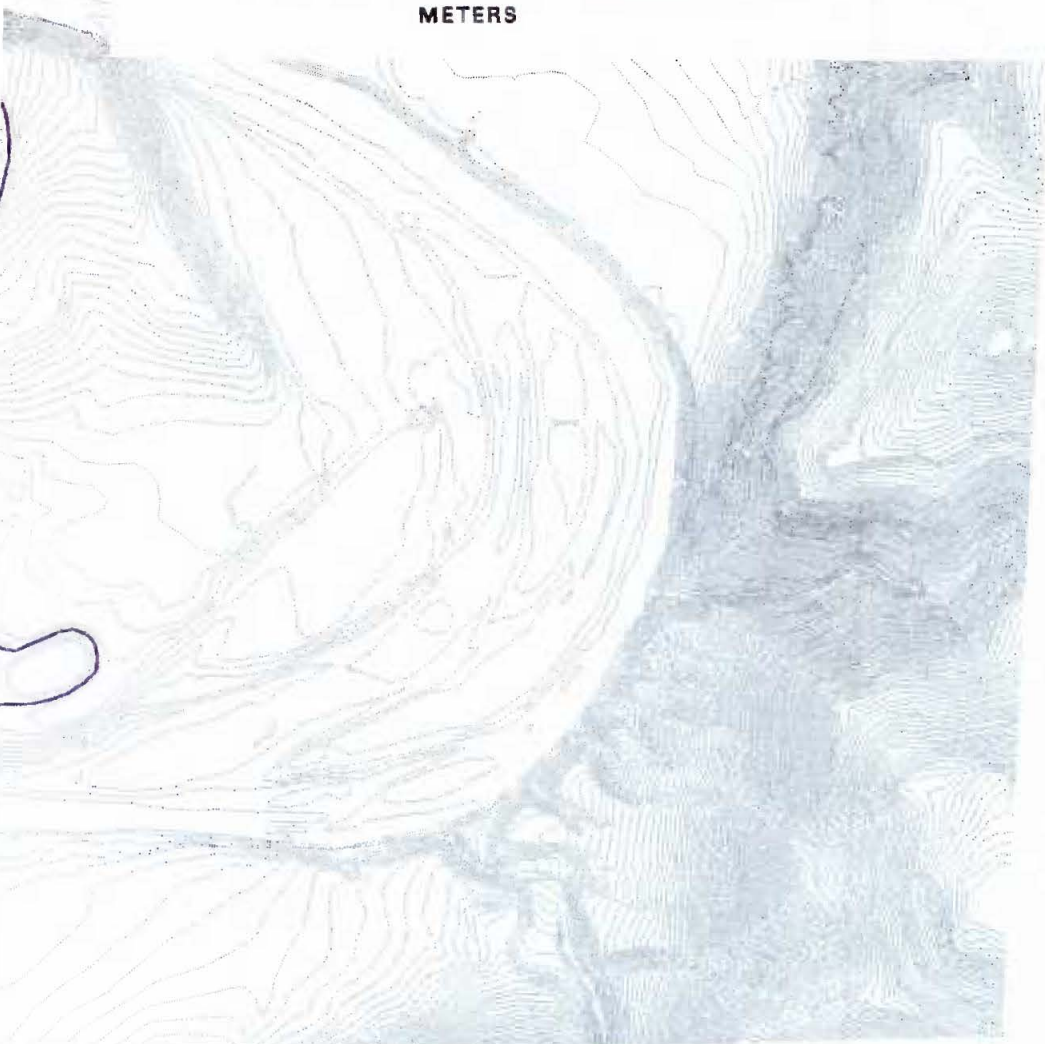
X-OR-BLK Locations



SCALE 1:7000

150 0 150 300

METERS



09/09/95

National Biological Service
Northern Arizona University
Flagstaff, AZ 86011-5814
(520) 556-7466

09/20/95



Figure 4. Individual locations of a radio-tagged adult female *Crotalus atrox* (W-R-Y) at Montezuma Castle National Monument, from August 1994 to June 1995.

Data by Erika M. Nowak, 1995
GIS by Valerie Coombs
Colorado Plateau Research Station

W-R-Y Locations at Montezuma Castle

August 1994 to June 1995



Topography



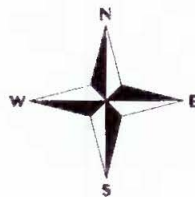
Man-made Structures



Roads



W-R-Y Locations

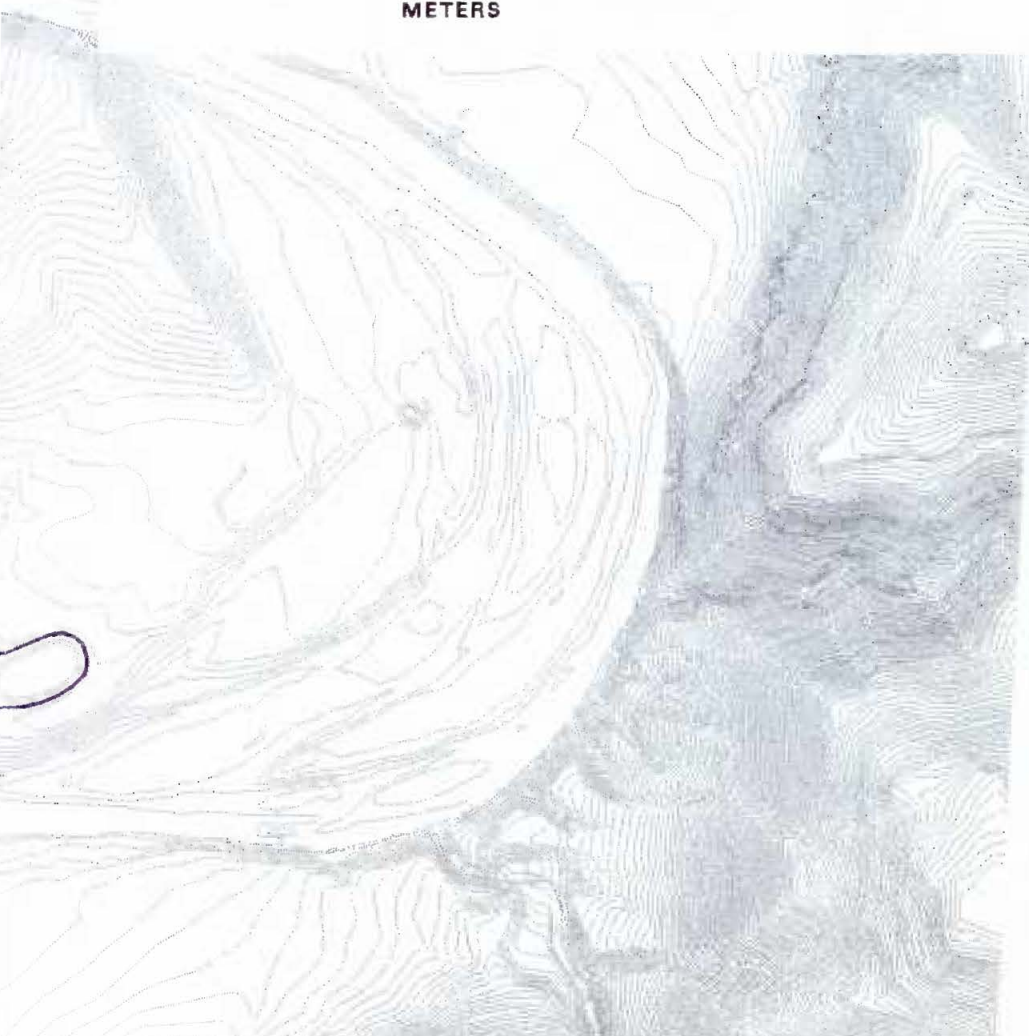


SCALE 1:7000

150 0 150 300



METERS



National Biological Service
Northern Arizona University
Flagstaff, AZ 86011-5614
(520) 556-7468

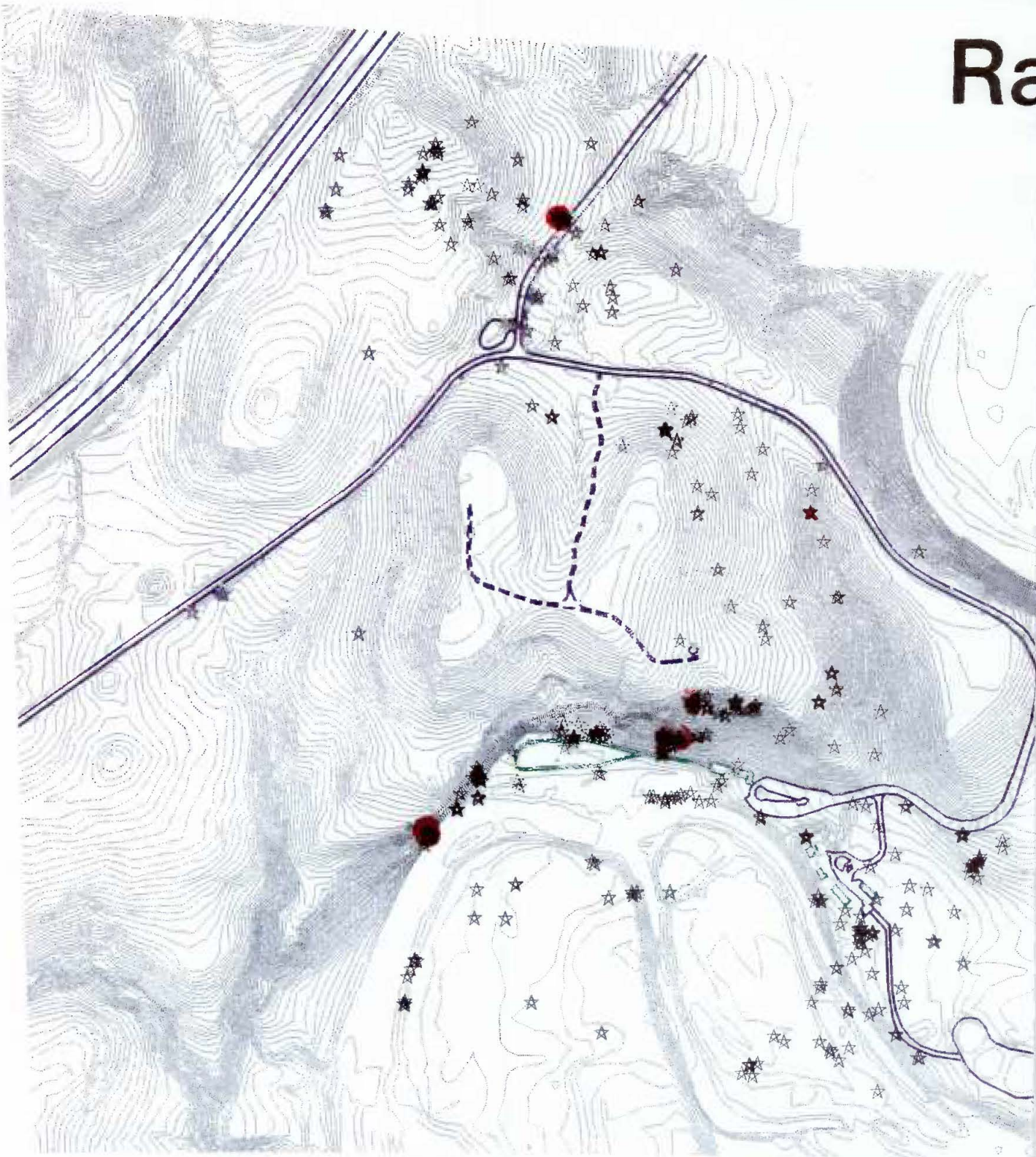
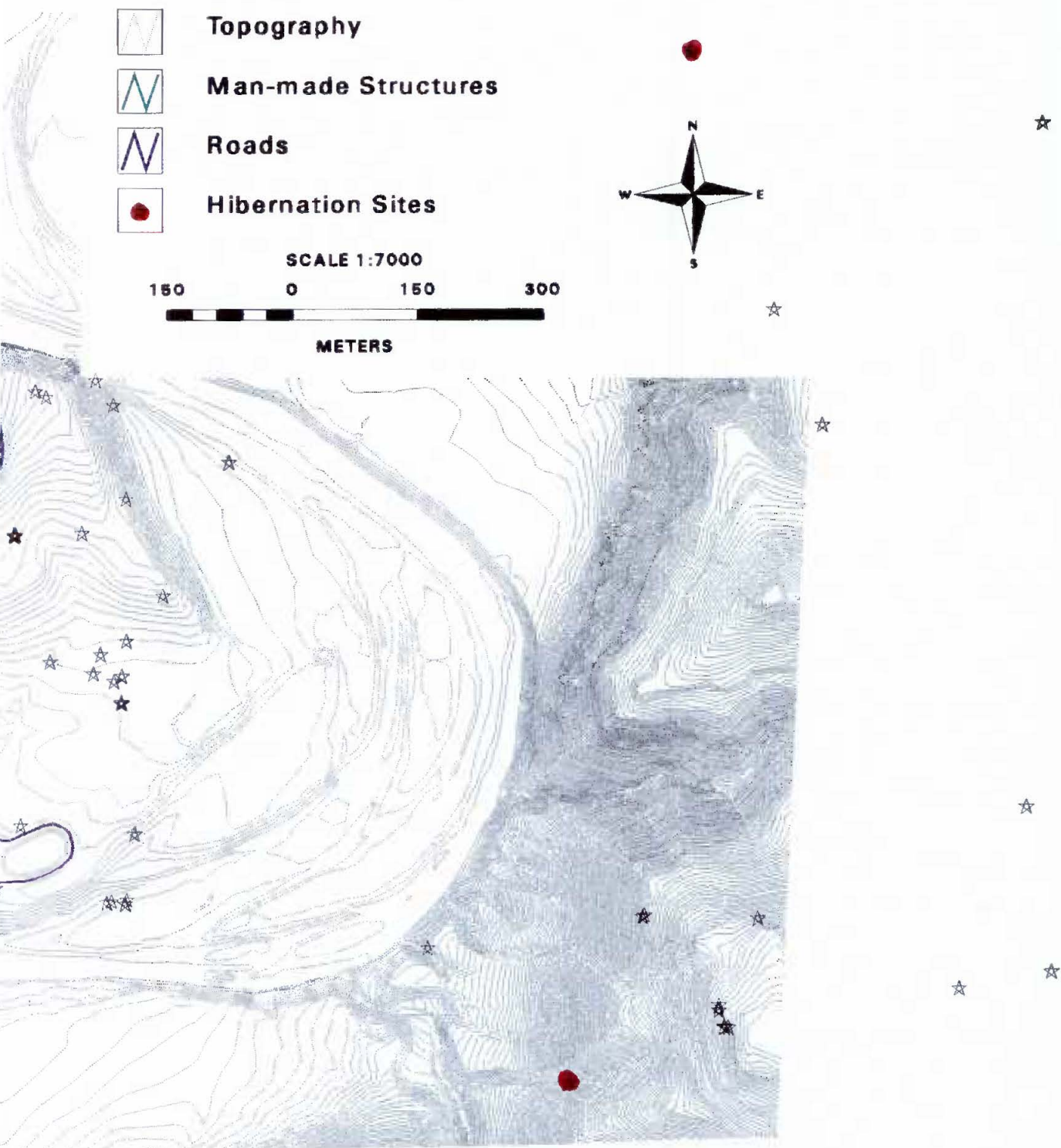


Figure 5. Hibernation sites for 9 adult and 1 subadult radio-tagged *Crotalus atrox* at Montezuma Castle National Monument, from 1994 and 1995 seasons. Sites are outlined in red.

attlesnake Hibernacula at Montezuma Castle

August 1994 to November 1995



National Biological Service
Northern Arizona University
Flagstaff, AZ 86011-8614
(520) 556-7466

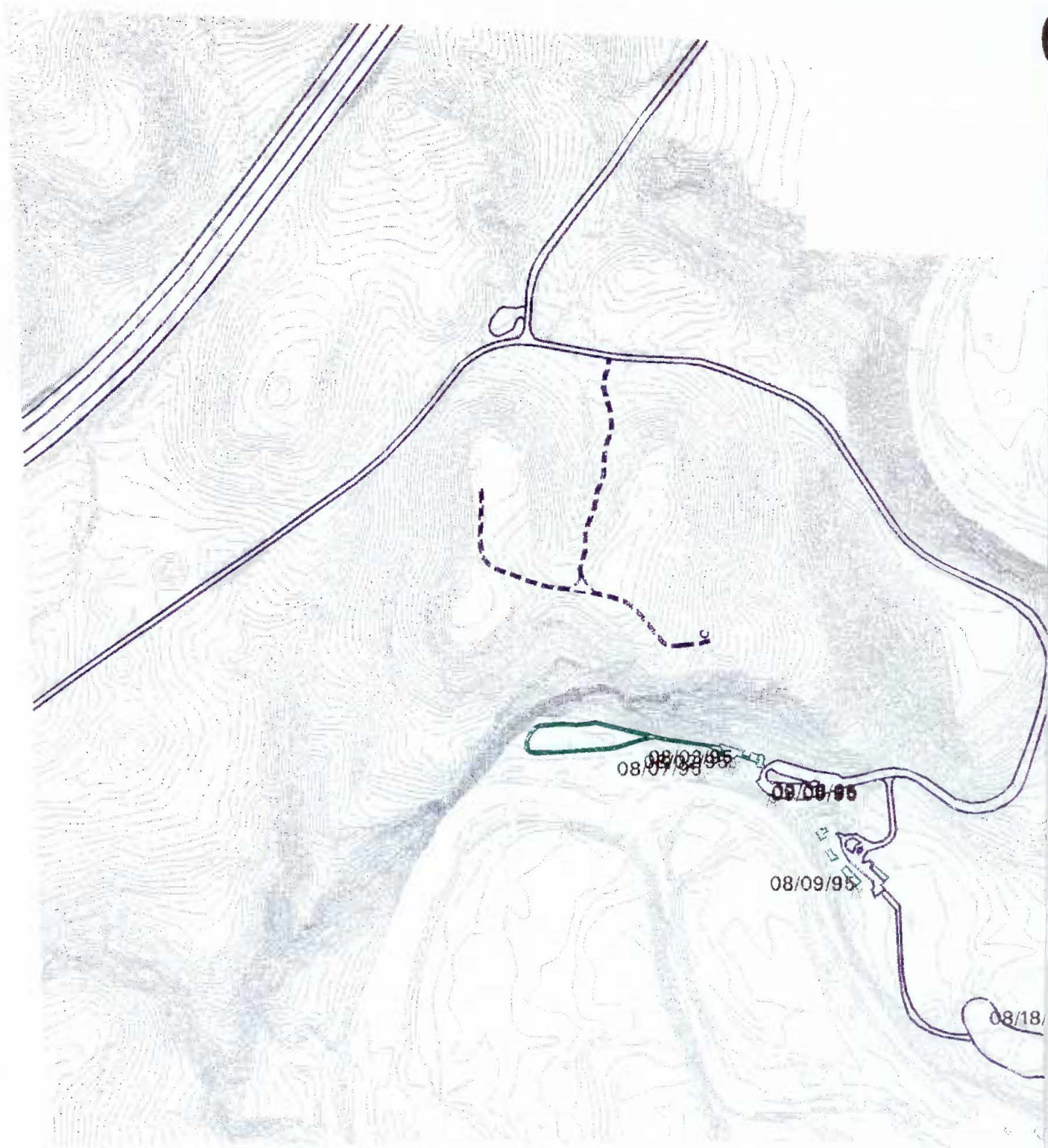


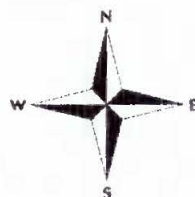
Figure 6. Individual locations of a radio-tagged adult male *Crotalus atrox* (GO-SI-GO) at Montezuma Castle National Monument, from August 1995 to November 1995.

Data by Erika M. Nowak, 1995
GIS by Valerie Coombs
Colorado Plateau Research Station

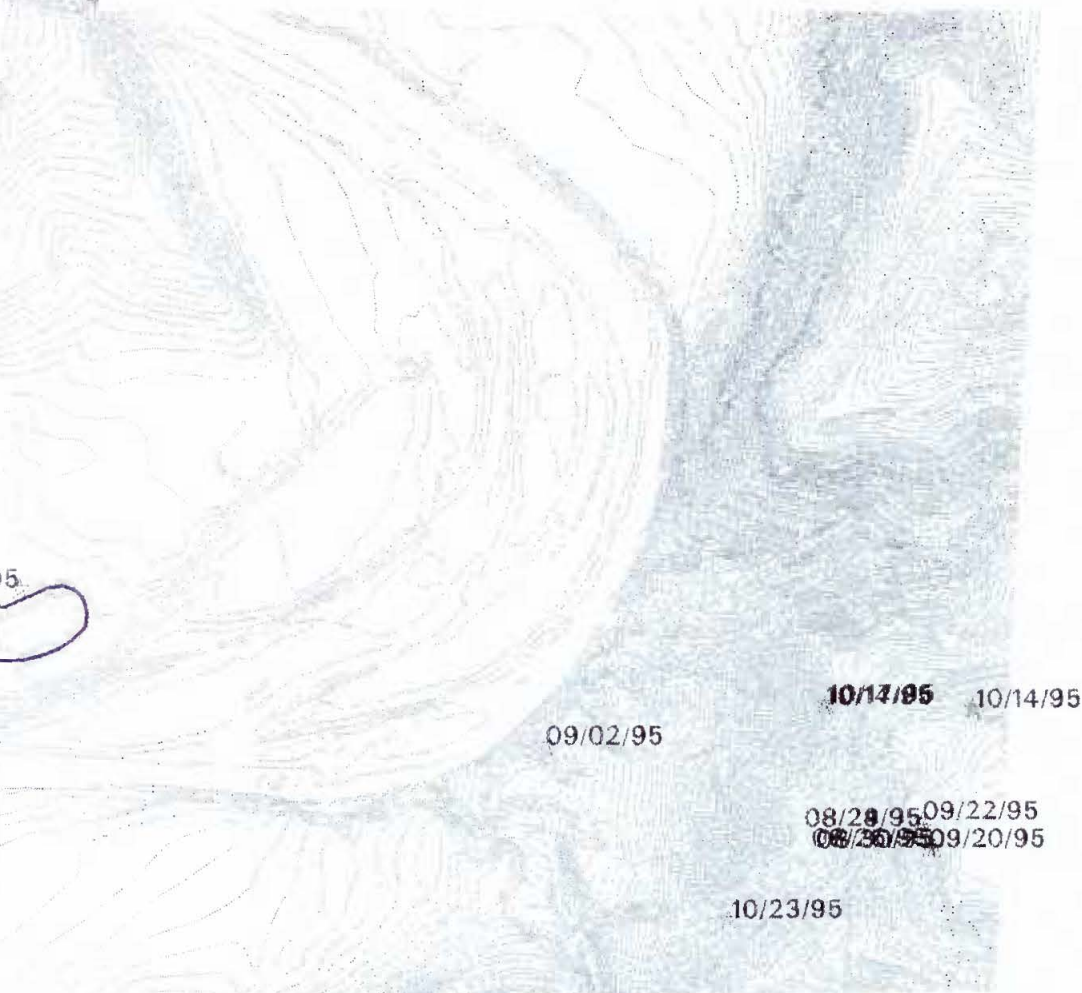
GO-SI-GO Locations at Montezuma Castle

August 1995 to November 1995

-  Topography
-  Man-made Structures
-  Roads
-  GO-SI-GO Locations



SCALE 1:7000
150 0 150 300
METERS



National Biological Service
Northern Arizona University
Flagstaff, AZ 86011-5614
(520) 556-7466