

FINAL REPORT

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ECOLOGY OF THE MEXICAN ROSY BOA AND THE AJO MOUNTAIN WHIPSNAKE

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EXECUTIVE SUMMARY

The objective of this study was to provide natural history and ecological data on two snake taxa, the Mexican rosy boa (*Lichanura t. trivirgata*) and the Ajo Mountain whipsnake (*Masticophis bilineatus lineolatus*), known primarily at and near Organ Pipe Cactus National Monument (ORPI), Arizona. We used radiotelemetry to study these taxa at two sites in and adjoining their rocky habitats, in Arizona Upland Sonoran desertscrub. Study Area 1 was relatively dry, whereas Study Area 2 was somewhat more mesic. We also obtained significant data on these species from other areas at ORPI, and, for the whipsnake, elsewhere in the deserts of south-central Arizona.

Radio transmitters were implanted in six Mexican rosy boas, of which five yielded substantial data, and in seven Ajo Mountain whipsnakes, of which only two yielded substantial data. Transmitter problems, ascribable to the manufacturers, were primarily responsible for difficulties in obtaining more data for whipsnakes, although we are currently gathering more data. We obtained data on an additional 27 Mexican rosy boas and 18 Ajo Mountain whipsnakes at ORPI. Herein we present the first available quantitative data on the life history and ecology of either snake.

Both species at ORPI are members of a desert rockpile snake assemblage that has a community structure parallel to, but involving several species replacements with, the desert valley snake assemblage. Both species extensively use the rocks and the surrounding upper bajada "flats" (slope < 5%) in the course of their yearly activity cycles. Both commonly used heteromyid (pocket mouse) soil burrows and rodent-excavated burrows among rocks as shelters. In contrast to boas, whipsnakes spent a substantial amount of time aboveground, were diurnal rather than primarily crepuscular and nocturnal, moved frequently and extensively over a large home range, and were very strongly associated with foothill palo verde. Rosy boas were sometimes found climbing in low shrubs, apparently foraging; whipsnakes were quite frequently observed at two or more meters above ground apparently resting, thermoregulating, waiting for prey, or avoiding predators, and usually in palo verde trees.

We were able to obtain a large data set on snake body temperatures by utilizing temperature-sensing transmitters. Whipsnakes maintained warm season body temperatures at or above 30 °C during the day, even when they were underground; when active aboveground, their body temperatures frequently exceeded the 33 °C they presumably prefer. A maximum body temperature of 40 °C was observed, but given the whipsnakes' ability to move rapidly to cover, the chance of overheating mortality would be remote. Rosy boas maintained far lower body temperatures, usually 24-29 °C; despite limited basking, they maintained remarkably stable body temperatures throughout the year, and are probably fairly precise thermoregulators. In the cool season, boas were more active and had higher body temperatures than whipsnakes, and were observed sun basking, as well as subsurface basking by contact with sun-warmed rocks.

Site fidelity was observed in both species, and was best documented for the rosy boa, with up to five known visits to a specific shelter by one boa over two years of study. Home ranges were well-defined in both species (rather than shifting). Rosy boa home ranges were stable from year to year. Both species used specific features (such as wash-side burrows), and sometimes separate regions (such as a small rocky hill), of their home ranges for varying purposes. Whipsnakes hibernated on north-facing slopes, but spent the warmest months primarily on the flats or south exposures. In contrast, the more winter-active rosy boa was observed primarily on southerly, warmer exposures in winter, and on the flats or on northerly exposures during the warmest part of summer. During very dry times, the boas we followed moved to subsurface

retreats in more mesic habitats. The spatial ecology of both species is complex, and suggests subtle and important responses to extremes of drought and heat, as well as active mobilization and behavioral change when opportunities exist.

Some of our observations have management and conservation implications. Our results indicate that the Ajo Mountain whipsnake is more widespread than formerly thought, and may be fairly abundant in rocky habitats in much of the Arizona Upland desert of southern Arizona. Aside from the potential for sensitivity to climatic change, we think it is facing no substantial threats at the population or subspecific level.

Our study confirmed there is great interest in collecting the rosy boa, including illegally at ORPI. We can confirm an ongoing, active poaching interest for this species on the National Monument. Failure to control poaching may lead to local depletion of boa populations. We report two cases of severe, long-lasting habitat destruction associated with past collecting activity; this type of destruction is almost undoubtedly continuing.

Our long-standing work on-site, together with successful location of numerous rosy boas in remote areas of the monument, indicates that highway traffic on State Route 85 in Organ Pipe Cactus National Monument has decimated the population of the Mexican rosy boa that once occurred in habitats adjacent to the road. However, our movement data indicate that the effect probably extends no more than 1.2 km (0.75 miles) into the wilderness area, and perhaps less. The rosy boa remains abundant in many remote areas of the monument, and presumably elsewhere in its range, and highway mortality, absent new pavement construction in previously undisturbed habitat, does not pose a threat to the species or subspecies populations.

The Mexican rosy boa is a sedentary snake, living a relatively long life if undisturbed. Heavy collection pressure could substantially, though only temporarily, deplete populations. Habitat destruction, often wreaked by unscrupulous and unthinking reptile collectors using heavy tools, causes essentially permanent damage to what our findings suggest are key features of the rosy boa's rock habitat. We recommend that collecting of this species be regulated in Arizona, and that habitat destruction by collectors be prohibited.

INTRODUCTION

The Mexican rosy boa (*Lichanura t. trivirgata*) and the Ajo Mountain whipsnake (*Masticophis bilineatus lineolatus*) are considered sensitive subspecies by the Arizona Game and Fish Department (AGFD) Heritage Program primarily because they have restricted geographic distributions in the United States. Both taxa are also on the Organ Pipe Cactus National Monument Red List for special concern species of amphibians and reptiles (Lowe and Rosen, 1992). The Mexican rosy boa has been found in the U.S. only at and near ORPI (Stebbins, 1985). It is a primarily Mexican form of a species that is widely sought by collectors and reptile fanciers. The Ajo Mountain whipsnake is a desert-restricted subspecies of the wide-ranging Sonoran whipsnake. This subspecies was first discovered and described at ORPI from the Alamo Canyon snake trap tinaja (Hensley, 1950). It has recently been reported from near Ajo (Boundy and Ford, 1989); further, we have observed it near Quijotoa, and have found snakes bearing the subspecific diagnostics at several other desert locations in southern Arizona (PCR, P.A. Holm, personal observations). This is thus probably a desert race that is poorly known because it is elusive and occurs in remote rocky areas. It appears to be marginally adapted to desert aridity, and was considered sensitive partly for that reason (Lowe and Rosen, 1992).

The Mexican rosy boa is a desert rockpile species that is infrequently observed, and is now very rarely observed on State Route 85 where apparently it was previously abundant (Lowe and Rosen, 1992). Populations of this subspecies at ORPI may be threatened by highway mortality (Rosen and Lowe, 1994), and possibly by habitat destruction associated with poaching (Goode, 1995) on the monument (Rosen and Lowe, 1996) and elsewhere, since it is the prime target for many legal and illegal collectors of snakes in the Sonoran and Mohave Deserts of the United States. Little or nothing substantial has been published on the life history or ecology of this species in the wild. It is thought to be a nocturnal and crepuscular (Hensley, 1950; Klauber, 1939; Miller and Stebbins, 1964; Soulé and Sloan, 1966) constrictor (Kurfess, 1967; Medina, 1959; Shaw and Campbell, 1974; Wright, 1921) of small mammals (Atsatt, 1913; Lowe, 1964; Klauber, 1933; Kurfess, 1967; Medina, 1959; Perkins, 1955), birds (Wright, 1921), and more rarely, snakes (Shaw and Campbell, 1974). It usually inhabits rocky areas (Burt and Burt, 1929; Grinnell and Grinnell, 1907; Johnson et al., 1948; Miller and Stebbins, 1964; Ottey, 1978; Perkins, 1938), but sometimes will be found in open rockless terrain (Klauber, 1939; Lowe, 1964), often in the vicinity of streams, oases, and wash bottoms (Grinnell and Grinnell, 1907; Linsdale, 1932; Miller and Stebbins, 1964). It is sometimes active in the daytime (Grinnell and Grinnell, 1907; Miller and Stebbins, 1964), especially in the spring (Shaw and Campbell, 1974), and has been seen crawling on the surface during driving rains (Grinnell and Grinnell, 1907). Adult rosy boas are docile and rarely bite (Klauber, 1924; Kurfess, 1967; Johnson et al., 1948; Wright, 1921). Juveniles, however, often bite or strike when handled (Kurfess, 1967). The snakes usually show no fear of humans, but when captured, may coil into a tight ball (Atsatt, 1913; Grinnell and Grinnell, 1907; Miller and Stebbins, 1964; Wright, 1921) or emit a foul-smelling liquid from their vents (Shaw and Campbell, 1974). Males use their vestigial anal spurs (occasionally visible on females) to stroke the female during courtship (Kurfess, 1967). Rosy boas are viviparous (Klauber, 1933); captive births and dissections of collected specimens indicate that they bear from 3 to 12 young in October-November (Klauber, 1933; Kurfess, 1967; Ottey et al., 1980; Soulé and Sloan, 1966). Record longevity in captivity is 18.5 years (Perkins, 1955). One instance of albinism has been reported (Hensley, 1959; Klauber, 1956).

The Ajo Mountain whipsnake is abundant in desert rockpiles, but poorly known scientifically. It may be trophically important as a vertebrate consumer, but little has been published of its habits and nothing on its populations or activity. The species is only a little better known: the Sonoran whipsnake is diurnal, semi-arboreal (Lowe, 1964; Ortenberger, 1928;

Ortenberger and Ortenberger, 1927; Stejneger, 1903), feeds on lizards (Shaw and Campbell, 1974), birds (Bogert and Oliver, 1945; Ortenberger, 1928; Stejneger, 1903; Van Denburgh, 1922), and frogs (Taylor, 1936), and is quick to bite when captured (Ortenberger and Ortenberger, 1927). Clutches of 6-13 eggs are known from June to July (Van Denburgh, 1922). It is a dominant serpent along desert and woodland stream courses throughout much of sub-Mogollon central Arizona, yet nothing has been published of its home range, growth, population ecology, or trophic importance. Ortenberger (1928) provided the few data on diet--all that is quantitatively known about the species' ecology.

Our study was designed to obtain basic data relevant to the ecology and management for these two taxa in the desert rockpile snake assemblage at ORPI. Primary study objectives were to (1) determine movement distances and home range size for both species, (2) evaluate their movement ecology relative to highway mortality, (3) quantify habitat selection, and activity season, time and intensity, (4) quantify season and diel profiles in body temperature, and (5) collect additional life history and ecological information on both species.

METHODS AND MATERIALS

This report is based on a radio-telemetry study of both taxa at Organ Pipe Cactus National Monument, Pima County, Arizona. Our objectives were to track as many individuals of each as possible. At the same time, we attempted to obtain ancillary natural history and ecological data for these species as a sideline to the main thrust of this and other ongoing herpetological research and survey work. This research was conducted primarily in southern Arizona from Tucson to ORPI, in the Arizona Upland subdivision of the Sonoran Desert.

Arizona Upland desertscrub is actually a depauperate thornscrub (Turner and Brown, 1982) formation that is considerably more mesic (9-12" annual precipitation) than most or all of the world's named deserts. At lower elevations of ORPI, the Arizona Upland gives way to the Lower Colorado Valley subdivision of the Sonoran Desert, a true desert with 3-8" annual precipitation. The east-west falloff of rainfall at ORPI (from 9" to 7" over less than 15 mi distance) creates a sharp transition from semi-arid thornscrub to arid desertscrub that makes climatic fluctuations potentially quite severe for the biota. Superimposed on the existing rainfall gradient is an elevationally-based thermal gradient. West of ORPI, elevation, like rainfall, decreases, bringing very high ambient temperatures. At ORPI, warmth and rainfall combine to produce a relatively warm and moist desert corridor, allowing penetration of Mexican desert forms into the United States (e.g., organ pipe, senita, and night-blooming cacti; the Organ Pipe shovel-nosed snake, and the Mexican rosy boa; the Sonoran whipsnake is also primarily a Mexican thornscrub form penetrating the U.S. in the southern deserts and in riparian or desert grasslands elsewhere).

The monument supports high diversity for yet another reason relevant to our study of snake ecology. In addition to regional climatic factors, ORPI contains much of the Ajo Mountains, a large and structurally complex desert mountain range. The enhanced rainfall, and the deep, water-concentrating canyons of the Ajo Mountains offer special opportunities for many species for which the regional climatic situation would otherwise be simply too hot and dry. Rainfall at the base of the Ajo Mountains may reach nearly 30" in some years (ORPI weather records).

Study Areas

The two primary study areas at ORPI were Study Area 1, an arid semi-desert rockpile habitat, and Study Area 2, a more mesic and productive semi-desert mountain habitat (App. A). Both study areas are in Arizona Upland desertscrub (Turner and Brown, 1982). Dominant trees and subtrees at Study Area 1 include saguaro (*Carnegiea gigantea*), organ pipe cactus (*Lemaireocereus thurberi*), foothill palo verde (*Cercidium microphyllum*), catclaw acacia (*Acacia greggii*), whitethorn acacia (*Acacia constricta*), desert hackberry (*Celtis pallida*), ironwood (*Olneya tesota*), and mesquite (*Prosopis velutina*), the last five especially common along washes. Common shrubs include brittlebush (*Encelia farinosa*), creosotebush (*Larrea tridentata*), triangle-leaf bursage (*Ambrosia deltoidea*), desert lavender (*Hyptis emoryi*), and Mexican jumping bean (*Sapium biloculare*).

At the Study Area 2, jojoba (*Simmondsia chinensis*) and *Coursetia microphylla* are also important. *Opuntia* spp., including buckhorn cholla (*O. acanthocarpa*), chain-fruit cholla (*O. fulgida*), and prickly pear (*O. phaeacantha*), are scattered throughout much of both study areas. Study Area 2 has greater diversity and biomass of plant species, and consequently is less physically and numerically dominated by any particular subgroup of species. Many species that are concentrated along washes at Study Area 1 are scattered more widely at Study Area 2.

Weather data, including precipitation, temperature at 1.5 m above ground, wind speed, and relative humidity, were recorded at seven automated weather stations throughout the monument during the study period.

Location, Processing, and Tracking of Study Animals

We captured snakes for radio-telemetry by road-cruising, visual and auditory on-foot searching, and turning rocks. We limited the size of the rocks turned to the largest that we could be sure to return to their original positions. We searched for whipsnakes in teams of 2 to 4 people so that we could surround them and catch them by hand. Later in the study, we used lizard nooses to help capture whipsnakes, and on humid nights we searched for resting whipsnakes in trees with spotlights.

Captured snakes were weighed using Pesola spring scales (Forestry Suppliers, Inc., Jackson, MS). Snout-vent length (SVL) and tail length were measured by gently stretching snakes along a metric rule until the vertebral column was visibly straight. Snakes were marked by clipping subcaudal scales (Blanchard and Finster, 1933) with scissors or hangnail clippers. Body temperatures were taken with a quick-registering reptile body temperature thermometer (Miller and Weber, Inc., Ridgewood, NJ). We photographed the dorsal head patterns of rosy boas to aid in identification of recaptures because this species appeared to be difficult to mark by scale clipping (personal observations).

We transported snakes to the Tucson office of Dr. James L. Jarchow D.V.M. for transmitter implantation. Dr. Jarchow performed most surgeries, and directed one of us (DAP) on the rest. We followed the general methodology of Reinert and Cundall (1982), with some minor modifications. Since both study species are designated as sensitive species by the Arizona Game and Fish Department, and since we were working with animals from ORPI, an International Biosphere Reserve, we consistently chose to err on the conservative side in choosing exact transmitter implantation surgery procedures. We used halothane as the gas anesthetic, and we

sutured both the peritoneum and then the skin in a double closure, rather than only the skin in a single closure as in Reinert and Cundall (1982). In whipsnakes and some boas, we placed the transmitter antenna subcutaneously. In most boas, we coiled the antenna around the transmitter and placed the entire package into the peritoneum.

Snakes were released at their original capture sites within one week of capture in most cases. Snakes collected that were in shed phase were allowed to shed before surgery. In two instances, we kept snakes out of the field for a full month. These two instances were in the late fall/early winter and we opted to keep the snakes warm following surgery to promote better healing before release. All transmitters weighed less than 5% of the weight of the snakes implanted.

We used both Telonics, Inc. (Mesa, AZ) CHP-2P (mean wt. = 6.7 ± 0.5 g) temperature-sensing and Wildlife Materials, Inc. (Carbondale, IL) SOPI (mean wt. = 4.0 ± 0.1 g) non-temperature-sensing transmitters (Table 1). Transmitters usually lasted 5 to 8 months before needing battery replacement. We tracked implanted snakes with a portable receiver (Model TR4, Telonics, Inc., Mesa, AZ) and directional H-antenna.

Radio-tracked individuals were re-located from 1 to 7 days per week during the active seasons and 1 to 4 days per month during the winter. We located snakes at all times of the diel cycle, but most often checked on rosy boas in the late afternoon and evening and on whipsnakes in the morning and late afternoon. We sometimes recorded pulse intervals (to obtain body temperature from temperature-sensitive transmitters) without attempting to pinpoint snake location. We could often detect surface activity of snakes by noting fluctuating temperatures of implanted snakes as they moved from their underground refugia to different and less thermally stable surface thermal environments.

For each snake location, we recorded the following: date, time, slope (to nearest 5%), aspect (to nearest 10 degrees), shelter type, activity, and pulse interval. We determined pulse intervals by measuring the time (in hundredths of a second) for 20 pulse beats using a stop watch, which yielded the pulse interval in milliseconds. Often snakes were sedentary, and were re-located multiple times at the same location. A "fix" is defined as one instance of determining a snake location and its associated time and position; we use the term to distinguish between locations and re-locations when it is not obvious from context.

We attached inscribed aluminum tags (or more rarely, labelled plastic flagging) to vegetation to mark pinpointed snake positions for future reference. We used global positioning system (GPS) equipment (GPS Pathfinder Pro-V, Trimble Navigation, Ltd., Sunnydale, CA) provided and operated by NPS personnel at ORPI, to obtain universal transverse mercator (UTM) coordinates for map reference points and for some of our snake locations. This allowed us to efficiently get coordinates for widely separated locations. Coordinates produced by the GPS at ORPI are within 5 m of the true coordinates. In addition to using the GPS to determine coordinates, we also used a meter tape and compass to measure distance (to the nearest 1 m if greater than 5 m, else to the nearest 0.1 m) and bearing (to the nearest 1 degree) of snake locations in relation to mappable reference points. This enabled resolution of locations that were grouped as closely as 1 to 2 m.

Thermal Biology

We frequently measured environmental temperatures (to nearest 0.1°C) near the snakes

using quick-reading thermometers, especially when snakes were aboveground. These environmental temperature readings, intended to serve as microhabitat temperature profiles for specific snake fixes, included air temperature at 1.5 m above ground, air temperature at 5 mm above ground, and surface temperature. In addition, we sampled pulse intervals throughout 24-hour periods on a bi-monthly basis to obtain diel profiles of body temperatures. We did not record diel profiles for snakes in the first month following surgery. To obtain associated diel environmental temperatures, we used temperature-sensitive transmitters and Hobo-temp miniature data loggers (Onset Computer Corporation, North Falmouth, MA) placed in specified habitat locations, and quick-registering thermometers.

Temperature-sensitive transmitters were calibrated in water baths, both before implantation and, whenever possible, after removal. Some transmitters could not be re-checked because they were not recovered, or not recovered prior to expiration of battery life. For each calibration, we determined pulse interval for seven or eight known temperatures (using carefully calibrated laboratory thermometers) spread approximately evenly from 0 - 45 °C. Pulse intervals were converted to the corresponding body or environmental temperature using equations produced by third order polynomial curves fit to the calibration curve points. Pulse intervals required logarithmic transformation to accomplish this curve-fitting procedure.

Data Analysis

We used CalHome version 1.0 software (J. Kie, U.S.D.A. Forest Service Pacific Southwest Experiment Station, Fresno, CA) to estimate home ranges by minimum convex polygon (Mohr, 1947) and harmonic means (Dixon and Chapman, 1980) methods. In the harmonic means analyses, we estimated both 95% and 50% utilization distributions, based in each case on a 50 x 50 grid cell overlay, and we report grid cell sizes.

Some snake locations were excluded from use in home range analyses in an effort to assure statistical independence of consecutive locations, as follows. First, we sorted snake locations by date. We then included in the data analyses all locations associated with dates for which there was only one location. This left cases where a date was associated with more than one location. In such cases, we eliminated all but the last location if the snake of interest was a rosy boa. For whipsnake locations, we kept all locations separated by at least six hours, provided the snake was reasonably likely to have been active over the entire duration of the six hour (or longer) period.

Spatial activity measures were calculated as presented by Reinert (1992), as follows: (1) total distance moved is defined as the sum of all linear distances between locations, (2) range length is the linear distance between the two most distant locations, (3) mean distance moved per day is total distance moved divided by the number of days over which that total movement occurred, and (4) mean distance per move is the average of all distances between locations. In analyzing these movement variables, we used only those locations that represented places that the snakes used as shelters for extended (> 1 hr) periods of time. Thus, if a whipsnake climbed into a tree and stayed briefly to explore it, its location in the tree was not counted as the endpoint of a movement. However, if the whipsnake rested overnight in the tree it was counted as the endpoint of one movement and the start point of another.

Data sets for analyses of shelter and associated slopes and aspects were similarly restricted. In addition, for pooled analyses (pooling all individuals of a species), each unique shelter or associated feature was counted only once regardless of how many times the shelter was visited by an individual snake. In seasonal analyses, a given shelter or associated feature was counted

once for each season the shelter was used by each individual snake. Our bearing data were converted to eight general directions for aspect analyses as follows: N -- 335 - 24°, NE -- 25 - 64°, E -- 65 - 114°, SE -- 115 - 154°, S -- 155 - 204°, SW -- 205 - 244°, W -- 245 - 294°, NW -- 295 - 344°.

We restricted the activity data set to prevent over-representation of the frequencies of activities that the snakes happened to be performing on the days of full diel profile study: those days would otherwise have led to over-representation of whatever variable was under consideration. For days on which we located a snake more than once, we counted each different type of activity performed by a snake on that day only once.

We divided the year *a posteriori* into five seasons (winter, spring, dry summer, wet summer, and fall) based on temperature, rainfall, and snake movement patterns. This was based on our understanding of rainfall, temperature, and their interaction to produce habitat drying, as well as on the snakes' evident reactions to these parameters. The seasons, based on temperature (Fig. 4) and rainfall (Figs. 5 and 6), were as follows: (1) winter was defined as December 2 through February; (2) spring was defined as March 1 to June 15 (for 1993) and March 1 through May (for 1994); (3) dry summer was defined as June 16 through August 26 (for 1993) and June 1 through July (for 1994); (4) wet summer was defined as August 27 through Oct. 15 (for 1993) and August through October 15 (for 1994); and (5) fall was defined as October 16 - Dec. 1. These definitions follow those of Beck (1991), with modifications to reflect observed snake movement patterns (described below), as well as the later and less predictable onset of wet summer at ORPI (e.g., summer rainfall occurred later in 1993 [Fig. 5] than in 1994 [Fig. 6]). In some analyses, we also considered early spring (March - April), or very early spring (March 1 - 15), separately from the rest of spring.

We used ArcView version 2.0d software (Environmental Systems Research Institute, Inc., Redlands, CA) to combine snake coordinates with geographic thematic layers of ORPI, including topography, vegetation, soils, roads, buildings, and washes, to produce study area maps. These themes or coverages were produced by University of Arizona Advanced Resource Technology (ART) lab personnel. Roads, buildings, topography, and washes were digitized from USGS 7.5 minute (1:24,000) quadrangles, specifically the Lukeville 1988 Provisional Edition (Study Site 1) and Mount Ajo 1990 Provisional Edition (Study Site 2). Vegetation maps were produced from 1:24,000 scale maps accompanying Warren et al. (1981), and then changed to reflect corrections supplied by P. L. Warren. Soils data came from Soil Conservation Service 1:24,000 scale maps that accompany a soil survey done specifically for the Monument (U. S. D. A. Soil Conservation Service, 1972). We provide reference vegetation (Fig. 2) and soils (Fig. 3) maps of the entire Monument.

Means are reported \pm one standard deviation (SD), with sample size (N) in parentheses and [range] in square brackets throughout the text unless otherwise indicated.

RESULTS

Data Sources

From late 1992 to May 1995, we implanted radio transmitters in six Mexican rosy boas (Table 2), and additionally captured, measured, and marked 25 other individuals. We obtained

partial data for two other dead-on-road (DOR) rosy boas. We obtained a total of six "boa-years" of telemetry-acquired data. From rosy boas B3 and B4, we got two complete years each. Rosy boas B2 and B5 yielded one year each. We recovered rosy boa B0's transmitter from inside a wall of the Resource Center, ORPI, where it had presumably been taken by a packrat (*Neotoma albigula*) 1 to 2 months after implantation. Cause of death of this snake is unknown.

The sixth boa, boa B1, went from 141 g to 87 g in weight over the course of our observations, for a snake whose size we originally considered marginal for the implanted CHP-2P transmitter. Therefore, data from this snake might not be representative of a normally behaving snake. Consequently, we sometimes provide subdivided results to both include and exclude this snake, but unless indicated otherwise, the snake is included in an analysis.

We implanted radio transmitters in seven Ajo Mountain whipsnakes from 1993 to mid-1995 (Table 3). We captured, measured, and marked an additional 10 whipsnakes and obtained partial data on 8 other individuals. Severe transmitter malfunction problems plagued study of this species. This was especially disturbing because these snakes were elusive--difficult to locate and even more difficult to capture. Furthermore, the ORPI population is principally composed of individuals with small body size, making it even more difficult to obtain snakes suitable for telemetry study as planned. Temperature units failed on some of the Telonics radio transmitters, and the Wildlife Materials units all failed after variably short intervals due to producer defects. Four of the five transmitters purchased from Wildlife Materials failed within 2 weeks of implantation, whereas the fifth failed after 3 months. For these reasons, we were able to obtain substantial telemetry-acquired data only on whipsnakes M1 and M2 thus far, although efforts are continuing. We also report on the shelter and activity data for whipsnakes M3 and M4.

It is conceivable that some of the transmitters did not fail, but were instead carried out of reception range by the snakes or by predators. This is unlikely due to the advantageous topography for reception (≥ 1 km range). Further, one Wildlife Materials transmitter that we did recover showed signs of moisture penetration through the epoxy to the electrical components. In this case, we noticed one week after releasing the snake that the signal sounded like the squelch an old radio makes when it is not tuned. We recovered the snake, and the transmitter failed completely one week later. Wildlife Materials suggests that the failures were caused by breakdown of the transmitters' epoxy coating by Zephiran, the sterilant in which the transmitters were soaked prior to implantation. This sterilant is used and recommended by many herpetologists, most notably by Reinert and Cundall (1982). However, most workers soak the transmitters in the sterilant for 1 to 3 hours; we soaked our transmitters for 24 hours, the duration recommended by J. L. Jarchow for complete sterilization. This procedure did not harm the Telonics transmitters, which are potted in a wax-paraffin mixture.

We found that road cruising and searching on foot were the most effective techniques for capturing rosy boas. In April and May of 1993, we looked under more than 5000 rocks in an effort to find rosy boas and saw none. In late May of 1993, we finally did catch one boa under a rock that was turned because we thought a whipsnake had escaped under it.

Almost all whipsnakes were captured as a result of on-foot searching. We captured three whipsnakes seen crossing roads while we were driving in the daytime. Our capture success for whipsnakes increased dramatically from about 30% or less of whipsnakes sighted to about 90+% when we started using lizard nooses for capture. We captured two whipsnakes using spotlights to find them on humid nights resting in trees.

Some weather data were lost due to ORPI weather station equipment failures. These

include Weather Station 1 precipitation data for 8/4/93 - 9/9/93, Weather Station 2 mean relative humidity data for 11/30/93 - 12/31/93, 9/1/94 - 10/6/94, and 11/5/94 - 12/2/94, and Weather Station 2 mean air temperature (at 1.5 m) data for 6/12/93 - 6/22/93, 11/30/93 - 1/1/94, and 11/5/94 - 12/5/94.

Habitat Use, Home Ranges, and Movements

Macrohabitat Use

Home range size estimates (Tables 4, 5) and movements (Tables 6, 7; Figs. 7, 8), based on varying amounts of field effort (Table 8), were smaller for rosy boas than for whipsnakes. Snakes used both flats and rock slopes and all but one home range included sections of roads (Figs. 9-11). We overlaid minimum convex polygon outlines of individual home ranges on vegetation (Figs. 12, 13) and soil (Figs. 14, 15) maps to illustrate habitat use on a coarse scale. In general, snakes used all or most of the available soils and macrovegetational categories present on the study areas, with absences possibly resulting from chance involved in the available selection of individuals for radio telemetry study.

Shelters

Both species used a great variety of cover, essentially all types available in their habitat. Mexican rosy boas and Ajo Mountain whipsnakes used many of the same types of shelters (Table 9). Both used heteromyid rodent soil burrows (pocket mouse burrows, category PB) and rock substrata ("rock holes", "rock crevices") most often for shelters (Figs. 16, 17). Rock-related shelters usually appeared to involve some kind of rodent excavation among the rocks, which the snakes utilized, rather than using completely un-modified crevices. Aboveground resting sites always involved some type of rock, vegetation, debris, or anthropogenic cover.

Whipsnakes used foothill palo verde trees as shelter sites, especially on humid summer nights (Fig. 18), and they were observed using no other tree species as shelters. Whipsnakes were observed actively climbing in and exploring desert hackberry (N=1) and whitethorn acacia (N=1) subtrees. They were also found coiled on the ground surface, resting or sheltering for extended periods, hidden by shrubs or debris. Whipsnakes used rocks as cover during various activities, as well as purposefully and to great effect for escape cover, but not for extended periods of time as resting shelters. Active whipsnakes were observed either in, or within 5 m of the trunk of, a palo verde tree approximately three fourths of the time. In addition to this apparent activity association of the snakes with palo verde trees, we observed a similar pattern for inactive snakes in shelters; inactive whipsnakes were located in shelters within 10 m of a palo verde tree trunk 90% of the time.

The primary aboveground shelters used by rosy boas were rocks, and these were considered surface shelters only when the snake was at least partially visible (i.e., basking with rock as cover). On a single occasion, a rosy boa used a teddy bear cholla (*Opuntia bigelovii*) as shelter, coiling under it on the surface at night.

It was difficult to differentiate classes of shelters associated with rock. Often a rock or pile of rocks had crevices and holes excavated or at least augmented by rodents. A radio-tracked snake, when pinpointed, could then be directly under the rock surface, or alternatively (and most likely) in a rodent burrow with an entrance at the rock's edge or within a rock crevice. Therefore, we classified snakes as under rocks only when we could confirm the category by lifting the rock

and visually locating the snake. Seventeen of 22 such attempts resulted in the discovery that the snake was in a rodent-constructed burrow rather than directly under the rock. Thus, we ascribed all doubtful instances to the shelter category "rock hole" rather than "under rock". Rock crevices posed the same difficulty. In this case, we pinpointed the snake's position as precisely as possible, and reached a determination based on evidence or lack of evidence of rodent excavation activity.

Rosy boa B5 was originally caught in late 1993 under the Superintendent's residence and spent much of summer 1994 there. This particular residence is one of two (among 12 total houses) with irrigated lawns, and additionally has a raised-bed planter for ornamental plants. A low rock wall studded with rodent holes stands next to the planter, with lush vegetation along the perimeter. It is clearly the wettest area in Study Site 1, and there is little possibility that the repeated location of both rosy boa B5 and whipsnake M2 in and around this planter was due to chance.

Rosy boas and whipsnakes were found in areas with slopes as great as 45% and 40% respectively, but the flats (< 5% slope) were also used extensively and subequally (37% and 34%, respectively, of species locations) by both species (Figs. 19, 20). Whipsnakes had a greater tendency than boas to utilize extreme slopes when they were up in the rocks, often retreating to high redoubts.

Radio-tracked individuals of both species used northwest and west facing aspects the least and east and northeast slopes most frequently (Figs. 21, 22). The boas preferentially selected the generally warmer, sunnier, southerly exposures in winter (Fig. 21), dispersed widely in the spring activity season, and apparently utilized cooler north and east exposures in wet summer, the time when they had the highest body temperatures (see below). The boas' extensive use of flats (slope < 5%), especially during wet summer, is not included in these aspect analyses, since the aspect of the flats was negligible and not recorded. The radio-tracked individuals had access to the full compass in selecting aspects, and therefore, these variations appear to reflect habitat selection behaviors by the snakes.

By contrast, the Sonoran whipsnakes were radio-tracked to north-facing exposures in the winter and fall, dispersing like the boas in spring, but selecting more southerly exposures in the limited dry summer data set (Fig. 22). The two species may have significant differences in winter habitat selection.

Both taxa displayed shelter-site fidelity. Individual rosy boas were observed to re-use 13 of 139 shelters a total of 23 times; and whipsnakes re-used 6 of 40 shelters a total of 9 times (Table 10). These are, statistically speaking, underestimates of site fidelity. Time between visits to re-used shelter sites was less than two months for 11 rosy boa and 8 whipsnake re-visits, and greater than two months for 12 rosy boa and 1 whipsnake re-visit.

The two rosy boas for which we have two years of data, B3 and B4, returned to 5 sites after a year or more had elapsed from the initially-observed use (Fig. 23). Most re-visited sites are wash-side and small-rocky-hill locations, where the boas aestivated, hibernated, and, in the early spring and fall, basked. The one site that was observed to be re-visited four times by boa B4 was an "under rock" shelter it used in July and September of 1993, and again in October 1994. This re-visited rock was a fairly ordinary, medium-sized rock that was protected and thermally buffered by a palo verde tree; however, the most important feature of this rock may have been its location along the track of various activities the snake carried out over the year, rather than uncommon physical features of the shelter itself (e.g., Huey et al., 1989). Rosy boa B2 did not

re-visit any specific shelters but did re-visit a particular area, disjunct from the rest of its locations, during late spring in 1993 and 1994 (Fig. 23). This local area was at the head of a wash that was utilized primarily 150-200 m down-drainage; it appeared to have a high rodent density, as well as dense low vegetation cover.

Activity

We recorded 6 activity types for Mexican rosy boas and Ajo Mountain whipsnakes (Table 11). Both rosy boas and whipsnakes spent the majority of their time underground (Figs. 24, 25). When they were not underground, they were most often crawling on the surface or, whipsnakes, in trees (Figs. 24, 25).

Thermal Biology

Mexican rosy boas typically had lower body temperatures than Ajo Mountain whipsnakes, as expected, in almost every season. The difference was greatest during dry summer, when surface temperatures were highest (Tables 12 - 15; Figs. 26, 27), and when whipsnakes extended aboveground activity longer into the season, while boas appeared to retreat underground relatively early. The body temperature difference was reduced again in wet summer, when rosy boas resumed surface activity, and when a less steep (but no less warm) thermal gradient exists in the ground. This is true for aboveground (Tables 12 - 15), or while active (Tables 14, 15; Fig. 28). Underground body temperatures for rosy boas, but not for whipsnakes, were often higher than aboveground body temperatures (Tables 12 - 15; Figs. 26, 27). Remarkably, rosy boas had higher body temperatures than Sonoran whipsnakes during the winter months, reversing the warm season pattern. Differences among individuals probably existed (Tables 14, 15), but they were probably not large, and were not consistent among seasons; the few individuals studied required pooling of observations.

A representative diel thermal profile for a Mexican rosy boa during the active season is shown in Fig. 26. Whereas all measured ambient temperatures varied dramatically across time, the boa maintained body temperature in a remarkably narrow range between 25 and 27 °C. This boa was not visible aboveground during the diel profile, although the temperature record suggests at least slight belowground activity at about 2100 hr, frequently a time of activity for the species. Representative active season diel profiles for Ajo Mountain whipsnakes (Fig. 27) provide a striking contrast to the boa picture. An active whipsnake (Fig. 27A) showed dramatic rises and falls in body temperature as it surfaced and submerged, and still marked, though less dramatic, fluctuations during extended aboveground activity. It reached a maximum body temperature approaching 40 °C (well above the expected preferendum), and spent many hours below 28 °C, outside the normal activity range. A resting, inactive whipsnake underground in dry summer (Fig. 27B) showed a pattern more like that of the rosy boa (Fig. 26), although it maintained a significantly higher body temperature that was nonetheless below the expected preferendum for *Masticophis* (about 33 °C; Rosen, 1991a).

Seasonal Habitat Use and Activity

Winter

During the winter, rosy boas (Figs. 19, 29A, 30A) and whipsnakes (Figs. 20, 30A) used rockslope habitats exclusively. These slopes were generally south facing for boas (Figs. 21, 29A,

30A) and north facing for whipsnakes (Figs. 22, 30A, 30E). Rosy boas B3 and B4 are the two snakes for which we have two winters of data. These two snakes spent both winters (1993-94, 1994-95) on a small, rocky hill (Fig. 29A), and it would appear that they could have selected any exposure aspect on this hill.

No radio-telemetered snake was actually observed aboveground in winter; however, the Mexican rosy boas had moved to new locations almost half the time we checked them during winter (10/22, average interval between checks 16 days). These winter movements (Fig. 7), and those until mid-March, were mostly very short (6.6 ± 7.1 m, range 1.3 - 26.6, N= 11). During winter hibernation, whipsnakes had more stable, lower body temperatures, on average, than rosy boas (Tables 12 - 15, Fig. 31). Large male M2 apparently did not move during winter, whereas M3 made a single move of approximately 100 m during late December 1994 or early January 1995.

Spring

In spring, rosy boas and whipsnakes emerged from their winter refugia and then spread out fairly widely over their home ranges (Figs. 29B, 30B). Whipsnake M2 emerged from its hibernaculum between March 28 and April 8, 1994. In 1994, two rosy boas emerged between February 19 and March 4, one between March 4 and March 28, and a fourth one between March 28 and April 8. Rosy boa emergence was probably at least two weeks earlier than for whipsnakes, and the distinction between winter activity and the onset of full spring activity was less distinct in boas than in whipsnakes.

Prior to spreading out more widely over their home ranges, rosy boas tended to stay on the rocky slopes and bask under rocks in early spring (March - April). Rosy boas were found under rocks in all seasons (Figs. 17B - F); however, shelters under rocks were used more frequently in the early spring and fall. The "on surface, shaded by rock" and "under rock" categories accounted for 7 of 44 (16%) rosy boa shelter types during early spring and fall, but only 1 of 104 (< 1%) at other times. Rocks were used as basking sites ("on surface, shaded by rock") only during the early spring and fall (Figs. 17B, C, F). At these times, snakes were observed with midbody coils projecting from rock shelters and exposed to the sun. We suspect some early spring and fall "under rock" sites may have been used as basking sites, with the snakes remaining completely under the rocks at the times we located them.

We did not obtain early spring data for whipsnakes. In late spring 1993, the large male whipsnake M2 made long movements (317 ± 246 m, range 103 - 718, N = 8) back and forth across much of its home range. Its three longest moves were made at this time, and each move was accomplished in only 1 - 3 days (Figs. 8, 32). These movements would appear to have been related to mate searching.

Dry Summer

In dry summer, rosy boas stayed in shelters that were in relatively moist habitat and microhabitat areas. All three boas at Study Site 2 stayed in xeroriparian habitat, along wash margins (Fig. 29C). Following a light rain during dry summer 1993 (July 11, Fig. 5B), boa B4 moved away from the wash to an "under rock" site (the one it revisited 4 times during 1993-94; see above, and Fig. 33); it subsequently returned (by July 31, 1993; Fig. 33) to the initially-occupied burrow site along the wash when the habitat again became dry (Figs. 33, 5A).

Rosy boa B1, the small male that lost extensive weight while radio-telemetered (see Table

2), went to a "rock hole" site consisting of large, mostly buried boulders intermixed with deep crevices in exposed bedrock adjacent to a small wash. During dry summer, and well into wet summer, this snake stayed very deep (based on transmitter signal strength) in this boulder/bedrock complex. The other radio transmitter-equipped boa at Study Site 1, boa B5, spent dry summer along a wash and, later, underneath the Superintendent's house. The snake was underneath the house (during dry summer) where an externally-mounted evaporative cooler unit dripped water to form a puddle on the ground.

Whipsnakes were active longer into dry summer than were rosy boas, and partly as a result of this tendency, whipsnakes had mean body temperatures averaging 5 °C higher than rosy boas during dry summer (Tables 12 - 15; Figs. 27, 28). However, whenever relative humidity levels were low (Figs. 5A, 27B), whipsnakes went to rock slopes on Twin Peaks, or to irrigated NPS residential areas, as exemplified by the raised-bed planter in the Superintendent's back yard (Fig. 34). During days with higher relative humidity, whipsnakes ranged more widely (Fig. 34). The lowest body temperatures for whipsnakes during summer were observed when they overnighted in palo verde trees on humid nights (Table 13).

Wet Summer

With the arrival of summer monsoonal rains, rosy boas at Study Site 2 moved widely over their home ranges (more widely than in spring; Figs. 29B, 29D). It was only during this season, both in 1993 and 1994, that boas B3 and B4 traveled to areas in the flats on the western-most portions of their home ranges (Fig. 29D). In 1994, this westward movement was followed by eastward returns by both boas on August 22 to their originally occupied end-of-dry summer xeroriparian retreats (Fig. 35). These returns coincided with a period in wet summer when relative humidity levels plunged to low dry summer levels (Fig. 6). Rain fell again at Study Site 2 at the end of August and again in early September, at which time these rosy boas resumed their activities in the westerly portions of their home ranges (Fig. 35).

Rosy boa B5 remained underneath the Superintendent's house well into wet summer, but was then often located away from the "evaporative cooler puddle." In mid wet summer, boa B1 at Study Site 1 initiated more wide-ranging movements.

During wet summer, whipsnake M2 was located both in the rocks and on the flats, but did not range as widely as during the spring activity burst. It moved onto the rocky slopes of Twin Peaks between October 1 and October 6, 1993, and remained there through the end of wet summer.

Fall

Whipsnake M2 stayed on Twin Peaks throughout fall and winter 1993-1994 (Fig. 30E). Its shelters were on relatively steep (Fig. 20) and generally north- and east-facing slopes (Fig. 22). We never observed it aboveground in fall, but it made several movements back and forth between three rock slope sites, finally arriving (between November 3 - 20) at a shelter where it remained dormant until spring emergence on or about April 1, 1994.

Rosy boas moved from their wet summer ranges to rocky slopes where they overwintered in fall (Figs. 29A, 29E; and also Figs. 19, 21). Once they reached the rocky slopes, they sometimes basked with rocks as shelters (SR and UR shelter types, Fig. 16; RB activity type, Fig. 24).

Notes on Diet and Predation

We palpated a subadult packrat (*Neotoma albigula*) from rosy boa B3 when we captured her for transmitter removal in 1995. We also observed rosy boa B4 after she had eaten a very large meal that was most likely a packrat. A road-killed adult female rosy boa from Ajo Mountain Drive, March 1993, contained mammal fur in the posterior intestine, apparently that of a cactus mouse (*Peromyscus eremicus*).

P. Holm (pers. comm.) discovered a small bird in the stomach of a whipsnake. A DOR first year Sonoran whipsnake from Ajo Mountain Drive, March 1993, contained the remains of a lizard, and an adult female DOR on Rt. 85 in June 1993 had unidentified mammal hair in the posterior intestine. Stomach bulges observed in whipsnake M2 on two occasions appeared to be large lizards. In the laboratory, Sonoran whipsnakes readily take mice and small lizards, and are especially fond of patch-nosed snakes (*Salvadora hexalepis*).

During this study, S. Sartorius (pers. comm.) observed a red-tailed hawk (*Buteo jamaicensis*) carrying an adult Ajo Mountain whipsnake in its talons in the summer of 1994, and this species of bird was abundant at Twin Peaks and Eagle Pass, where Ajo Mountain whipsnakes were observed.

Management Concerns

Use or Avoidance of Roads

Roads (mean length within home range = 214 ± 275 m, range 30 - 760, N = 6) were present within the home ranges of all of the radio transmitter-implanted snakes except one rosy boa (B1). Radio-tracked snakes all crossed these roads at least twice (mean crossings = 6 ± 3.7 , range 2 - 12, N = 6; Table 16). We recorded 14 boas on roads: 8 (LOR) on dirt roads, 1 (DOR) on paved Highway 85, 1 (LOR) on the paved Residence Loop Road, and 4 (3 LOR, 1 DOR) on paved sections of the mostly dirt Ajo Mountain Drive. We caught 3 whipsnakes after observing them crossing paved roads.

From 1987 to 1995, we recorded over 1150 snakes on Rt. 85, logging tens of thousands of miles road cruising for snakes, day and night in all seasons (Rosen and Lowe, 1994). In May 1995, Mike Lee (pers. comm.) found a DOR juvenile Mexican rosy boa on State Route 85, the first record we are aware of from this highway since September 1983. In contrast, during 1993-1994, in less than 5% of the effort and distance sampling on the highway, we found 13 rosy boas, of which only one was DOR, on back roads.

A majority of our back-road cruising effort in 1993 and 1994 was spent on Ajo Mountain Drive. This loop road, 33.3 km (20.7 miles) long, is mostly graded dirt, but has seven short sections of pavement (total paved length 3.2 km - 2 miles; = 10% of total length). We caught 4 (3 LOR, 1 DOR) rosy boas on the paved sections of this road and 7 boas (all LOR) on the dirt sections.

Poaching of Rosy Boas at ORPI

From 1993 to 1995, we observed what we suspected were snake poachers on more than 10 occasions. Five of these occasions involved observation of vehicles driving slowly at night

(apparently road cruising) in areas appropriate for boa hunting. In five other cases, we had conversations with park visitors who expressed strong interest in locating rosy boas. These people maintained that they were "only going to look at them", although we doubted this. Conversations with amateur herpetologists ("herpers") and snake enthusiasts ("snakers") indicate that poaching at the monument is common for such taxa as the Mexican rosy boa, black-tailed rattlesnake (*Crotalus molossus*), tiger rattlesnake (*Crotalus tigris*), and chuckwalla (*Sauromalus obesus*). Our impression is that the rosy boa is the most sought-after snake in Arizona's deserts.

In addition, we identified four areas (all near roads or campgrounds) of particularly obvious habitat destruction from moderate to extensive rock turning by collectors.

DISCUSSION

The radiotelemetry study was performed to high standards of initial calibration, final re-check on calibrations, surgical care and quality, adherence to transmitter size limits, and careful handling of the animals. We nonetheless detected several problems that may be widespread in telemetry work, including what appeared to be transmitter artifacts in boas and whipsnakes in which the transmitter approached, but did not reach or exceed, 5% of the snake by weight. The first boa (B0) was in this category (transmitter 4.2 % of body weight) and survived no more than 2 months, even though recovery from the uneventful surgery appeared to be complete. The second boa (B1; 4.8 %) may also have been affected, as described above. Of the two whipsnakes we tracked with success, one was relatively small (especially by girth) compared to the transmitter (2.8% of body weight), and it was killed, probably by a hawk, 84 days after implantation of the transmitter. We believe that the existing standards of transmitter weight are inappropriate for slender, fast-moving snake species, and may potentially have influenced mortality and home range results in some previous studies (i.e., Brown, 1973; Brown and Parker, 1976; Fitch and Shirer, 1971; Parker, 1973; Parker and Brown, 1980; Plummer and Congdon, 1992, 1994).

Even rosy boas implanted with radios near the 5% limit seemed to us marginally over-stuffed with transmitter. In whipsnakes the problem seemed more extreme, and would be compounded greatly by the snakes' reliance on speed for escaping predators and catching prey. Certainly our home range estimates for *Masticophis bilineatus* are much greater than earlier results on the similar *M. taeniatus* (Parker, 1973; Parker and Brown, 1980), in which transmitter diameter and weight relative to the study animals was relatively extreme. Similarly, the home range for the diminutive *Coluber constrictor mormon* (Brown, 1973; Brown and Parker, 1976) was very much smaller than in other subspecies (Fitch, 1963; Fitch and Shirer, 1971; Rosen, 1991b; Plummer and Congdon, 1994). Other explanations are possible, but we suggest that this issue requires serious exploration before firm conclusions are drawn from the literature.

Our home range estimates for the Sonoran whipsnake at 12.8 ha are more generally in agreement with values for the coachwhip *M. flagellum* in the Mojave (Secor, 1992) and Sonoran Deserts (personal observations) that were studied using relatively small transmitters and by mark-recapture. Sonoran whipsnakes have sizable home ranges at our Sonoran Desert study area, as expected for large racer-like snakes generally. Confirmation of the small home ranges of racers and whipsnakes in the Great Basin Desert would indicate a drastically different spatial ecology between the two adjacent deserts. This is indeed possible, but we re-emphasize the need to eliminate possible methodological biases.

It is conventional wisdom that transmitters implanted in snakes should not weigh more than 5% of the snakes' body mass (Plummer and Congdon, 1994; Reinert, 1992; Shine and Lambeck, 1985). However, our experience suggests that 3 to 4% would be a better rule for rosy boas. With whipsnakes and other slender, fast-moving snakes, the girth of the snake in relation to that of the transmitter should be given equal consideration as well. Rosy boa B1's significant weight loss (38% in 7 months) while implanted might be attributable to being implanted with a transmitter of too great a girth. Alternatively, the snake may have been living on an unproductive slope.

Three of the four other radiotracked boas also lost weight, but not as severely. The weight loss was to a maximum of 37%, but over long time periods (27 to 37 % over 13 - 25 months; Table 2). This weight loss was probably a result of year to year variation in food and water supplies. General declines in weight relative to SVL were seen over the same time periods in other whipsnakes and rosy boas (those captured, but not implanted with transmitters; unpubl. data) at ORPI. This overall decline in condition was expected because an exceptionally wet spring in 1993, with resultant good primary productivity, was followed in 1994 by drier conditions. The weight loss may also have been associated with reproductive expenditures, or with effects of implanted transmitters, although transmitter girths did not appear to be too large for these snakes.

Home Ranges, Movements, and Habitat Use

Macrohabitat Use

Observed movement statistics and home range size estimates for snakes as a group have been highly variable (Gregory et al., 1987, Macartney et al., 1988). Variability of movements and home range size within species, differences in sample size and time periods between studies, and differences in the statistical and field techniques from study to study make realistic comparisons difficult. There is a push to standardize techniques as much as possible to facilitate inter-study comparisons of movement and home range observations (Macartney et al., 1988; Reinert, 1992). We have therefore reported both minimum convex polygon and harmonic means estimates as these allow the best comparison to published values (although the harmonic means method has been shown to be an improper form of the statistical method of kernel estimation [Worton, 1987]). Most authors do not report grid cell sizes, which are needed to evaluate both harmonic means and kernel estimators. We strongly recommend reporting grid cell sizes; otherwise inter-study comparisons will be of dubious value.

In general, though, our observations are sufficiently detailed to allow comparisons to other studies and species. Macartney et al. (1988) summarize literature data indicating a range for estimated home range in snake of 0.002 - 207.4 ha, with most values for medium-sized taxa such as the Mexican rosy boa and Ajo Mountain whipsnake in the 2 to 20 ha range, similar to our estimates. Our data for rosy boa home range size and movement rates indicate that it is distinctly sedentary compared to other taxa similar in body size and trophic niche (Macartney et al., 1988). The Sonoran whipsnake home ranges we measured are rather large, and the movement rate fairly high, for a snake not making seasonal migration. The large range for the very large male we tracked was suggestive of rogue-male mate-searching behavior over a large range by a dominant individual. Our home range results for these taxa are not entirely unexpected, based on the locomotory abilities of the two species, but they are certainly of great importance to conservation issues.

Snake home range ecology may be classifiable into 3 general categories, or home range types: (1) migratory between hibernaculum and summer activity ranges, (2) shifting, rather than fixed (or constantly defined) home range, and (3) well defined, relatively stable home range. Mexican rosy boas and Ajo Mountain whipsnakes fall roughly into group 3, with defined home ranges that include over-wintering shelter sites. However, winter sites are quite specific, and some of the snakes could be described as locally migratory. For example, rosy boa B5 was only observed at the distant Twin Peaks shelter during winter, and seemed to be outside of its summer range then, although still close by when contrasted with truly migratory snakes in cold climates. For other snakes, winter shelters were contained within the non-winter convex polygon areas, even though they seemed to be distinctive winter shelter sites. Generally, the snakes used different portions of the home range at different times of year, and for different purposes (cold retreat, drought retreat, foraging), and thus the home range of these snakes was not spatio-temporally simple. For more extreme climates, the long-migration response can readily be seen as an extension of the pattern seen here, rather than as a qualitatively novel phenomenon.

Shelters

We expected rosy boas to use rocks as shelters more often than they did. This bodes well for conservation of the species, because boas are vulnerable to collectors when under rocks. The heavy use of mammal burrows by the rosy boa is also seen in the boa constrictor (*Boa constrictor*), which moves, on its larger scale, among burrows of armadillos and other medium-sized mammals (Montgomery and Rand, 1978). Montgomery and Rand (1978) noted that a boa constrictor "maintained a rather high and constant body temperature while underground and could thus probably both digest food and react quickly to prey which came near." The Mexican rosy boa may be employing a similar strategy of sit-and-wait foraging, combined, we suspect, with predation on rodents (especially nestlings) found when the snakes newly occupy a burrow. This conjecture is supported by our observations that rosy boas often maintain higher body temperatures underground than when aboveground and that rosy boas spend the vast majority of their time underground, and usually in rodent burrows or in rock holes/crevices adjacent to signs (feces, digging activity) of recent rodent activity. Rosy boas practice dual constriction (Medina, 1959); this ability to capture and constrict more than one prey item at a time seems likely to have evolved in a nest-raiding, and not a sit-and-wait, context.

Ortenburger (1928) found three Sonoran whipsnakes near Tucson, Arizona, all in shrubs, either desert hackberry (*Celtis pallida*) or catclaw acacia (*Acacia greggii*). We observed Ajo Mountain whipsnakes in desert hackberry (N = 1 time) and in whitethorn acacia (*A. constricta*; N = 1 time), which outnumber catclaw on the ORPI study areas. Our overall results, though, suggest that the Ajo Mountain whipsnake could be aptly re-named the palo verde whipsnake. We never observed this species, whether active or in a shelter, far (> 15 - 20 m) from a foothill palo verde tree, and this is the only tree taxon they overwintered in. Ironwood was also common along occupied washes but the whipsnakes were never observed climbing in them. This snake species is strongly cryptic among the mixed greens and grays of live and dead palo verde branches, and these small trees provide structural and thermal complexity that probably allows the snakes to combine thermoregulation, foraging for active lizards and, especially, predator avoidance in this important Sonoran Desert microhabitat.

Resting overnight in trees by the whipsnakes we tracked was often associated with having a large food bolus present, in addition to being associated with increased relative humidity. We observed a distinct bulge in whipsnake M2 on three of the times it overwintered in palo verde trees. Basking on the ground may be the strategy chosen to obtain the highest body temperatures on cool days, while overwintering in trees instead of underground may be a strategy chosen to

allow the snake to achieve optimal body temperatures as early in the morning as possible. Whipsnakes were observed to bask on the ground, partly hidden by shrubs or debris, when air temperatures temporarily cooled after summer rains, and also once very soon after being released following transmitter-implant surgery.

Natural History

Rosy boas climbing in shrubs while actively moving aboveground may have been searching for sleeping lizards and birds. When climbing on shrubs, they moved slowly and methodically flicked their tongue at a high rate. We could determine no other reason why they climbed shrubs -- most of the shrubs they climbed did not provide good cover. However, rosy boas often climbed immediately into shrubs after release from capture -- possibly a response evolved as a defense against small canid predators, which are abundant throughout the Arizona Upland.

We suspect hawk predation was responsible for the death of whipsnake M1 in 1993. This snake's transmitter was recovered hanging from vegetation on a vertical rock face that was probably inaccessible to mammalian predators. It could also have been dropped by a vulture, since both hawks and vultures nest and roost in numbers every year on Twin Peaks.

We confirmed Ortenburger's (1928) observations that whipsnakes are quick to bite when captured, like to escape under rocks and into rockpiles, and are very hard to see when climbing in vegetation. Ortenburger (1928) also reported several instances of whipsnakes feeding on birds, also confirmed by us.

Management Concerns

Management concerns for the Mexican rosy boa, and to a much lesser extent, the Ajo Mountain whipsnake, include road mortality, habitat destruction, and collecting. Additionally, both taxa may potentially be sensitive to climate change, since they are geographically or ecologically (or both) marginal in the desert region of ORPI.

The Ajo Mountain whipsnake appears to be more widespread than originally believed, and it is not at all sought after by collectors or snake keepers. This snake is, furthermore, not known to use shelters that are uncommon or are substantially damaged by collectors. With its extensive home range, the whipsnake will be threatened by urbanization, with the intensification of the road network and increase in automotive traffic. At present, neither this taxon, nor the Sonoran whipsnake as a species, are significantly threatened in any way. The monument should remain aware of the taxon as a potential indicator of climatic change or flux.

For the Mexican rosy boa, as for the species as a whole, the prognosis is much less cheery. It faces multiple impacts, the effects of which will continue to increase unless practical, though not particularly onerous or costly, measures are initiated now. Here, we discuss these impacts in turn.

Highway Mortality

Paved roads are a threat to snake populations because snakes are slow-moving, present a

broad target to the automobile as they (almost invariably) cross directly perpendicular to traffic, and because some people intentionally kill (or collect) snakes observed on roads. Furthermore, snakes in the desert readily venture across roads, and during cool seasons may even be attracted to the early-evening warmth retained by the pavement, causing them to stop moving to bask by contact. Furthermore, refuge, monument, and park managers should all be fully convinced that roads, and especially paved roads, make it much easier for collectors to obtain most of the snakes they seek, both by allowing them to road cruise, and by making it more efficient to quickly and unobtrusively access prime snake habitat and escape with their booty.

The virtual absence of rosy boas on State Route 85 indicates that this species has been severely affected by the increasing traffic on the monument. Mexican rosy boas that we radio-tracked showed no evidence of avoiding roads, either paved or unpaved, and we found them in quite substantial numbers especially on the short paved stretches of monument back roads. Traffic is variable enough on Rt. 85 that our negative results cannot be argued away by suggesting that the snakes actually avoid the road when traffic is present. Moreover, collecting along the highway is unlikely to be severe enough to account for the gross variation in relative abundance shown by our sampling. Further confirmation is of course desirable and possible, but current evidence argues strongly that the Mexican rosy boa population at ORPI has been eliminated from the vicinity of State Route 85 by highway mortality. This problem certainly will not abate, or be mitigated, unless the expected increase in traffic on State Route 85 following from the North American Free Trade Agreement is directed elsewhere.

Whereas the whipsnake is fast on the burning midday pavement (and can be observed to intentionally flee from oncoming vehicles from a distance of over 100 m), the rosy boa is very slow-moving and deliberate (Mosauer, 1935), and furthermore, is active and thermoregulating at cool times of the year. The rosy boa is therefore attracted to roads and vulnerable on them at the same time that park visitation is highest -- making its populations especially susceptible to significant roadway mortality. Other species that are winter- or spring-active, and are seen basking on the road at these and other times of year are the western patch-nosed snake (*Salvadora hexalepis*), the sidewinder (*Crotalus cerastes*), and the Organ Pipe shovel-nosed snake (*Chionactis pararostris organica*). We predict that the increase in traffic expected from NAFTA will increasingly impact other species of snakes and wildlife, these first among them.

Despite the grisly situation on the highway, our results suggest clearly that the overall ORPI and U.S. population of the Mexican rosy boa will not foreseeably be damaged by the local effect of the highway. Our home range data show clearly that this snake is highly sedentary at ORPI. This is true even in good times such as spring 1993 and summer 1994, when the environment was flush with foraging opportunities, and when snakes would be expected to have maximal home ranges. Our boa home ranges had maximum lengths averaging only 264 m, and the snakes showed substantial fidelity to local areas and specific shelter sites within their small home ranges. This fidelity is consistent with the rarity of appearance of boas on Rte. 85--since all boas with home ranges including the highway have been killed, only the occasional juvenile, moving to a new area or expanding its home range, is expected on the pavement, just as we have actually observed.

The site fidelity and low movement rates we observed in rosy boas also imply that outside a distance of perhaps 0.5 km from the highway, Mexican rosy boa populations at ORPI should be only weakly affected by the highway mortality population sink. There is no evidence of a marked dispersal phase or behavior for neonatal or juvenile rosy boas. Therefore, any adverse impacts on population dynamics produced by truncating immigration at the highway may be small. Over the long term, and assuming traffic does increase, the highway will fragment the gene pool of the

rosy boa at ORPI. Our observations suggest, however, that there are substantial population densities of this species at many areas in all major mountain groups at ORPI. The rosy boa population throughout its range is probably fragmented by mountain ranges naturally (Spiteri, 1988). Our current assessment is that genetic problems over the long term are unlikely to result from highway effects on the rosy boa at ORPI.

We conclude that Rte. 85 does not pose an expanding threat to the rosy boa population at ORPI. Snakes that once lived along the roadway corridor are long gone, and populations at a half to three-quarters of a mile away are very likely little affected. Finally, the species is widespread at ORPI, and therefore the highway affects a small minority of the species population. Consider further, however, that this highway was once the best place in the world to observe this most attractive Arizona snake species.

Habitat Destruction

Snake collectors get rosy boas by turning over rocks and prying away cap rocks in springtime (cap rock is the exfoliating sheets of the parent outcrop material, that match the general outcrop contours, and provide crevices and crawling space above the parent material; many reptiles, invertebrates, and other animals use cap rock and similar formations intensively). These capture methods are at least temporarily destructive as they break the moisture seals between the cover item and its substratum. Far worse, some substantial proportion of collectors simply toss the shelter sites aside and leave them, destroying their prime shelter qualities for many years. And worst are the collectors who attack the rock formations with crowbars, pry bars, wrecking bars, jacks, and braces, who simply demolish everything--cap rock, stones, boulders, and even talus (see Goode, 1995). Natural recovery of such wrecked rock piles will probably take millenia.

Cap rock is the substratum most severely-affected by irresponsible collecting, and it never was a widely seen feature at ORPI. Today, it is almost impossible to find large areas of cap rock at the monument. The original discovery point for the Mexican rosy boa population at ORPI, and also the best early locality, was at Eagle Pass ("66 Hills") at the "Superintendent's Locality". Dominated by paler (less basaltic) rhyolite, this site originally had large areas of cap rock and many large flat stones--an ideal target for collectors. Today, the parent material is raw and exposed, with the cap rock shattered all around. Probably every rock within a quarter mile of the road has been turned more than once by snake hunters. We have not succeeded in observing rosy boas at this site, despite some time investment, although the single, juvenile male boa found on the highway was from about a mile south of this site.

We observed similarly thorough demolition of the only other cap rock area we located at ORPI, at Arch Canyon at the east base of the natural arch, and have seen similar instances on a small scale in Alamo Canyon and other sites where tiny areas of cap rock once occurred. We have no records verifying the occurrence of rosy boas in these sites, although they probably persist there in numbers lower than prior to habitat destruction.

While obviously this existing habitat destruction is unethical, aesthetically repugnant, and damaging to wildlife in general, our results suggest that it may cause substantial disruption in the life history of the rosy boa. We found that the species at ORPI maintained moderately warm, and remarkably consistent, body temperatures through most or all of the year. The rosy boas we observed moved throughout much of the winter, and maintained elevated body temperatures via sun-basking and subsurface basking (thigmothermy). In cold to mild weather, natural cap rock clearly offers superior thermoregulatory shelter microhabitat. This is a thin sheaf of rock,

exposed to full sun on a rocky outcropping, with narrow crevices allowing full access to the snakes but not to their natural predators. We hypothesize that destruction of this microhabitat throughout the range of the rosy boa may pose a substantial, long term threat to many populations of this winter-active thermoregulator.

We recommend that long term habitat destruction, including cap rock removal, smashing of rocks, or the use of any prying implements or jacks, be strongly discouraged. Management and patrol personnel should be trained to recognize and prevent this activity, and penalties for such malevolence should equal those for the most serious current wildlife offenses. At the same time, we encourage studies to provide more direct demonstration of the population and individual benefits of natural rock habitat structure, especially cap rock. For example, we would predict that rosy boas in areas with intact cap rock would maintain higher body temperatures in winter, and possibly in fall and early spring, than those lacking this resource. If so, effects on survival and reproduction could occur. Temporary and non-destructive experimental habitat alteration might even be feasible during a telemetry study on such a site.

Rock turning by snake poachers at ORPI should also be discouraged by the fact that we turned over 5000 rocks during a moist, productive spring at ORPI, without finding a single rosy boa.

Poaching

We have no data to quantify the intensity of snake poaching at ORPI. It is worth stating here, though, that poaching of reptiles (especially rosy boas, Gila monsters, and chuckwallas) is commonly viewed among professional and amateur reptile enthusiasts as extremely widespread: it is viewed as a common phenomenon involving both inconsiderate individuals and well-prepared criminals. Undercover investigations have revealed some of how widespread the activity is, and just how dangerous the "game" can become. At the ORPI area, undercover activities could very profitably be carried out, in our opinion, based on the rather lax ambience outside the monument. Questionnaires mailed to businesses and customers in the herpetoculture industry might yield further information about how much poaching of rosy boas and other species occurs.

Our experience on this study shows that, with persistent effort, it is possible to capture rosy boas in some numbers at ORPI, presumably as elsewhere in the Southwest. We have yet to achieve a mark-recapture study of this species that allows direct measurement of population density; but the numbers we have captured in local areas appear to correspond to measured population densities of desert snakes on the same trophic level (personal observations). We therefore suggest that collecting (legal or illegal) could significantly affect rosy boa populations, over and above the related effect of habitat destruction, in accessible areas. Most habitat areas are not so accessible, but those that are offer the opportunity for completely legitimate observation, examination, and study of the rosy boa, activities that may be jeopardized by continued collecting.

LITERATURE CITED

- Atsatt, S.R. 1913. The reptiles of the San Jacinto area of southern California. Univ. Calif. Publ. Zool. 12:31-50.
- Beck, D.D. 1991. Physiological and behavioral consequences of reptilian life in the slow lane: ecology of beaded lizards and rattlesnakes. Unpubl. dissertation, University of Arizona, Tucson, Arizona.
- Bogert, C.M., and J. Oliver. 1945. A preliminary analysis of the herpetofauna of Sonora. Bull. Amer. Mus. Nat. Hist. 83:297-426.
- Brown, W.S. 1973. Ecology of the racer, *Coluber constrictor mormon*, in a cold temperate desert in Northern Utah. Unpubl. dissertation, University of Utah.
- Brown, W.S. and W.S. Parker. 1976. Movement ecology of *Coluber constrictor* near communal hibernacula. Copeia 1976:225-242.
- Blanchard, F.N., and E.D. Finster. 1933. A method of marking living snakes for future recognition, with a discussion of some problems and results. Ecology 14:334-347.
- Boundy, J. and A.W. Ford. 1989. *Masticophis bilineatus* (Sonoran Whipsnake). Geographic distribution. Herpetological Review 20:75-76.
- Burt, C.E. and M.E. Burt. 1929. Field notes and locality records on a collection of amphibians and reptiles from the western half of the United States. I. Amphibians. II. Reptiles. J. Wash. Acad. Sci. 19:455-459.
- Dixon, K.R., and J.A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology 61:1040-1044.
- Fitch, H.S. 1963. Natural history of the racer, *Coluber constrictor*. Univ. Kansas Publ. Mus. Nat. Hist. 15:351-488.
- Fitch, H.S. and H.W. Shirer. 1971. A radiotelemetric study of spatial relationships in some common snakes. Copeia 1971:118-128.
- Goode, M. 1995. Microhabitat destruction caused by unethical collectors: effects on reptile abundance in Arizona. Sonoran Herpetologist 8:68-72.
- Gregory, P.T., J.M. Macartney, and K.W. Larsen. 1987. Spatial patterns and movements. Pp. 366-395 in R.A. Seigel, J.T. Collins, and S.S. Novak (eds.), Snakes: Ecology and Evolutionary Biology. Macmillan, New York, New York, USA.
- Grinnell, J. and H.W. Grinnell. 1907. Reptiles of Los Angeles County, California. Throop Inst. Bull. 35:1-64.
- Hensley, M.M. 1950. A herpetological reconnaissance in extreme southwestern Arizona and adjacent Sonora, with a description of a new subspecies of the Sonoran whipsnake, *Masticophis bilineatus*. Trans. Kans. Acad. Sci. 53(2):270-288.

- Hensley, M.M. 1959. Albinism in North American amphibians and reptiles. Publ. Mus. Michigan State Univ. Biol. Ser. 1(4):133-159.
- Huey, R.B., C.R. Peterson, S.J. Arnold, and W.P. Porter. 1989. Hot rocks and not-so-hot rocks: retreat-site selection by garter snakes and its thermal consequences. Ecology 70(4):931-944.
- Johnson, D.H., M.D. Bryant, and A.H. Miller. 1948. Vertebrate animals of the Providence Mountains area of California. Univ. Calif. Publ. Zool. 48:221-336.
- Kearney, T.H., R.H. Peebles, and collaborators. 1964. Arizona Flora. University of California Press. Berkeley, California. viii + 1085 pp.
- Klauber, L.M. 1924. Notes on the distribution of snakes in San Diego County, California. Bull. Zool. Soc. San Diego 1:1-26.
- Klauber, L.M. 1933. Notes on *Lichanura*. Copeia 1933(4):214-215.
- Klauber, L.M. 1939. Studies of reptile life in the arid southwest. Bull. Zool. Soc. San Diego 14:1-100.
- Klauber, L.M. 1956. Rattlesnakes: Their Habits, Life Histories, and Influence on Mankind. University California Press. vxxix + 1476 pp.
- Kurfess, J.F. 1967. Mating, gestation, and growth rate in *Lichanura r. roseofusca*. Copeia 1967:477-479.
- Lehr, J.H. 1978. A Catalogue of the Flora of Arizona. Desert Botanical Garden. Phoenix, Arizona. vi + 203 pp.
- Lindsale, J.M. 1932. Amphibians and reptiles from lower California. Univ. Calif. Publ. Zool. 38:345-350, 374-384.
- Lowe, C.H. (editor). 1964. The Vertebrates of Arizona. University of Arizona Press, Tucson, Arizona. vii + 259 pp.
- Lowe, C.H., and P.C. Rosen. 1992. Ecology of the Amphibians and Reptiles at Organ Pipe Cactus National Monument, Arizona. Final Report to National Park Service Sensitive Ecosystems Program, Cooperative National Park Resources Studies Unit, University of Arizona, Tucson. 243 pp.
- Lowe, C.H., P.C. Rosen, and C.R. Schwalbe. 1992. Ecology of the Mexican Rosy Boa and Ajo Mountain Whipsnake in a Desert Rockpile Snake Community. Proposal submitted to Arizona Game and Fish Department Heritage Fund, Phoenix, Arizona, 1992.
- Macartney, J.M., P.T. Gregory, and K.W. Larsen. 1988. A tabular survey of data on movements and home ranges of snakes. J. Herp. 22:61-73.
- Medina, D.R. 1959. Observations on the feeding behavior of a captive rosy boa, *Lichanura roseofusca*. Copeia 1959(4):336.

- Miller, A.H., and R.C. Stebbins. 1964. The Lives of Desert Animals in Joshua Tree National Monument. University of California Press, Berkeley. vi + 452 pp.
- Mohr, C.O. 1947. Table of equivalent populations of North American mammals. Amer. Midland Nat. 37:223-249.
- Mosauer, W.A. 1935. How fast can snakes travel? Copeia 1935:6-9.
- Montgomery, G.G., and A.S. Rand. 1978. Movements, body temperature and hunting strategy of a *Boa constrictor*. Copeia 1978:532-533.
- Ortenburger, A.I. 1928. The whipsnakes and racers: genera *Masticophis* and *Coluber*. Mem. Univ. Michigan Mus. 1:1-247.
- Ortenburger, A.I., and R.D. Ortenburger. 1927. Field observations on some amphibians and reptiles of Pima County, Arizona. Proc. Okla. Acad. Sci. 6:101-121.
- Ottley, J.R. 1978. A new subspecies of the snake *Lichanura trivirgata* from Cedros Island, Mexico. Great Basin Natur. 38(4):411-416.
- Ottley, J.R., R.W. Murphy, and G.V. Smith. 1980. The taxonomic status of the rosy boa *Lichanura roseofusca* (Serpentes: Boidae). Great Basin Natur. 40(1):59-62.
- Parker, W.S. 1973. Comparative ecology of two colubrid snakes, *Masticophis t. taeniatus* (Hallowell) and *Pituophis melanoleucus deserticola* Stejneger, in northern Utah. Unpubl. dissertation, University of Utah. xi + 295 pp.
- Parker, W.S. and W.S. Brown. 1980. Comparative ecology of two colubrid snakes, *Masticophis t. taeniatus* and *Pituophis melanoleucus deserticola*, in northern Utah. Milwaukee Public Museum Publications in Biology and Geology 7:i-vii, 1-104.
- Perkins, C.B. 1938. The snakes of San Diego County with description and key. Bull. Zool. Soc. San Diego 13:1-66.
- Perkins, C.B. 1955. Longevity of snakes in captivity in the United States as of January 1, 1955. Copeia 1955(3):262.
- Peterson, C.R. 1987. Daily variation in the body temperatures of free-ranging garter snakes. Ecology 68(1):160-169.
- Peterson, C.R., A.R. Gibson, and M.E. Dorcas. 1993. Snake thermal ecology: the causes and consequences of body-temperature variation. Pp. 241-314 in R. A. Seigel and J. T. Collins (eds.), Snakes: Ecology and Behavior. McGraw-Hill, Inc., New York. xvi + 414 pp.
- Peterson, C.R., and M.E. Dorcas. 1992. The use of automated data acquisition techniques in monitoring amphibian and reptile populations. Pp. 369-378 in D.R. McCullough and R.H. Barrett (eds.), Wildlife 2001: Populations. Elsevier Applied Science, London.
- Plummer, M.V. and J.D. Congdon. 1992. *Coluber constrictor*. Predation. Herpetological Review 23(3):80-81.

- Plummer, M.V. and J.D. Congdon. 1994. Radiotelemetric study of activity and movements of racers (*Coluber constrictor*) associated with a Carolina bay in South Carolina. *Copeia* 1994:20-26.
- Reinert, H.K. 1992. Radiotelemetric field studies of pitvipers: Data acquisition and analysis Pp. 185-197 in J.A. Campbell and E.D. Brodie (eds.), *Biology of the Pitvipers*. Selva Press, Tyler, Texas. xi + 467 pp.
- Reinert, H.K., and D. Cundall. 1982. An improved surgical implantation method for radio-tracking snakes. *Copeia* 1982:702-705.
- Rosen, P.C. 1991a. Comparative field study of body temperatures in gartersnakes. *J. Herpetol.* 25:301-312.
- Rosen, P.C. 1991b. Comparative ecology and life history of the racer (*Coluber constrictor*) in Michigan. *Copeia* 1991:897-909.
- Rosen, P.C., and C.H. Lowe. 1994. Highway mortality of snakes in the Sonoran Desert of southern Arizona. *Biological Conservation* 68:143-148.
- Rosen, P.C., and C.H. Lowe. 1996 *in press*. Ecology of the Amphibians and Reptiles at Organ Pipe Cactus National Monument, Arizona. Tech. Rep., Cooperative Park Studies Unit, National Biological Service, Tucson.
- Secor, S.M. 1992. Activities and energetics of a sit-and-wait foraging snake, *Crotalus cerastes*. Unpubl. dissertation, University of California, Los Angeles, California.
- Shaw, C.E., and S. Campbell. 1974. *Snakes of the American West*. Alfred E. Knopf, New York. xii + 332 pp.
- Shine, R., and R. Lambeck. 1985. A radiotelemetric study of movements, thermoregulation and habitat utilization of Arafura filesnakes (Serpentes: Acrochordidae). *Herpetologica* 41(3):351-361.
- Soulé, M., and A.J. Sloan. 1966. Biogeography and distribution of the reptiles and amphibians on islands in the Gulf of California, Mexico. *Trans. San Diego Soc. Natur. Hist.* 14(11):137-156.
- Spiteri, D.E. 1988. The geographic variability of the species *Lichanura trivirgata* and a description of a new subspecies. Pp. 113-129 in H.F. Delisle, P.R. Brown, B. Kaufman, and B.M. McGurty (eds.), *Proceedings of the Conference on California Herpetology*. Southwestern Herpetological Society. Special Publ. No. 4. Van Nuys, California.
- Stebbins, R.C. 1985. *A Field Guide to Western Reptiles and Amphibians*. Second ed. Houghton Mifflin Company, Boston, Mass. 336pp.
- Stejneger, L.H. 1902. The reptiles of the Huachuaca Mountains, Arizona. *Proc. U.S. Natl. Mus.* 25:149-158.

- Taylor, E.H. 1936. Notes on the herpetological fauna of the Mexican State of Sinaloa. Univ. Kansas Sci. Bull. 27(20):505-537.
- Turner, R.M., and D.E. Brown. 1982. Sonoran desertscrub. Pp. 181-221 in D. E. Brown (ed.) Biotic Communities of the American Southwest -- United States and Mexico. Desert Plants 4(1-4).
- United States Department of Agriculture Soil Conservation Service. 1972. Soil Survey, Organ Pipe Cactus National Monument, Pima County, Arizona : a special report. The Service, Phoenix, Arizona
- Van Denburgh, J. 1922. The reptiles of western North America. Occ. Papers Calif. Acad. Sci. 2:617-1028.
- Warren, P.L., B.K. Mortenson, B.D. Treadwell, J.E. Bowers, and K.L. Reichhardt. 1981. Vegetation of Organ Pipe Cactus National Monument. Cooperative National Park Studies Unit Tech. Rep. No. 8. 79 pp.
- Worton, B.J. 1987. A review of models of home range for animal movement. Ecol. Model. 38:277-298.
- Wright, A.H. 1921. The California or rosy boa (*Lichanura roseofusca* Cope). Copeia 1921:35-36.