Natural History of the Rosy Boa, (*Charina trivirgata*)

Prepared for:
US Geological Survey - Species at Risk

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Introduction

The rosy boa (*Charina trivirgata*) is one of two boid species native to the United States (Stebbins, 1985). Recent work on the phylogeny of these species has concluded that they are primitive members of the Erycine boid family that is most closely related to the African burrowing python in the genus (*Calabaria*) (Rieppel, 1978; Kluge, 1991; Kluge, 1993). Recent taxonomic recommendations have changed the names from *Lichanura* and *Calabaria* to *Charina*, although most other literature has not adopted this yet (Kluge, 1993). Traditionally, the rosy boa is considered to be a single species throughout its natural range of California, Arizona, and Mexico (Stebbins, 1985; Spiteri, 1988), with up to five subspecies (Ottley, 1978; Spiteri, 1988). Limited to the arid southwest, it has long been one of the defining reptiles of the region. Until recently, nothing was known of their movement patterns or home range size (Macartney et al. 1988; Parizek et al., 1996), with very little known about the natural history of the species.

To gain a better understanding of the habitat requirements, life history attributes, and movement patterns of the rosy boa (*Charina trivirgata*), radio telemetry techniques were used, following the methods of Parizek et al. (1996) and Dorcas and Peterson (1998). In a study provided for Arizona Game and Fish Department Heritage Fund, Parizek (1996) studied a population of rosy boas from the Sonoran desert at Organ Pipe National Monument in 1992 and 1993. Dorcas and Peterson (1998) conducted research on the only other boa species native to the United States, the rubber boa (*Charina bottae*), at a location near Pocatello, Idaho. The secretive nature of the rosy boa necessitated radio telemetry in order to gain a significant amount of data regarding the natural history of these animals.

The rosy boa is a moderately sized species that occurs in several distinct color phases. It has gained popularity in the pet trade, but lacked a well understood natural history (Spiteri, 1988). Native populations may be at risk to wide spread declines due to various factors, ranging from roads, habitat loss, increased fire frequency, urban light pollution, and poaching (Rosen and Lowe,1994). This research has built on existing data

to help examine the life-history attributes of the rosy boa especially relative to reserve design.

Materials and Methods

Telemetry Equipment

A combination of readily available wildlife telemetry equipment was used over the course of the field effort. In addition, a new method for monitoring a subject animal's body temperature was devised in order to allow data collection while researchers were not physically at the study site. Radio telemetry efforts began in the field in May 1999 using equipment acquired from the USGS offices at Piedras Blanca, California and Dixon Field Station, California. The use of this equipment allowed for the field aspect of the study to begin immediately, while we purchased our specific materials. This equipment included radio receivers, antennas, and transmitters. The receivers, model TRX-1000S, were made by Wildlife Materials Inc, Carbondale, Illinois, and covered the radio frequency of 164 MHz. Directional antennas for these receivers were model RA-2AK from Telonics, Inc., Mesa, Arizona, and were calibrated for a range of radio frequencies from 164 - 166 MHz. Two types of transmitters were used, models SB-2 and SI-2T (Holohil Systems Ltd., Carp, Ontario, Canada). The smaller transmitters, the SB-2, weighed 5.5 g, with an outer dimension of 9 mm wide by 19 mm long. The SB-2 transmitters functioned for locating purposes only, and were used with snakes that were deemed too small for the SI-2T. Standard practices call for a radio transmitter to be no more than 5% of a snake's body weight (Hardy and Greene, 1999). The SI-2T transmitters are equipped with a temperature sensitive component that modifies the period of the radio pulse as the animal's body temperature fluctuates. These transmitters were 9.5 g in weight, 10 mm wide and 33 mm long. The life expectancy of both models of transmitters was 12 months. Upon the radio frequency approval from the US Geological Survey radio officer, addition transmitters (same models as described above) were ordered from Holohil in the frequency range of 169 MHz. TR-4 receivers, made by Telonics, Inc, were used through the remainder of the project. This receiver covered the frequency range of 166 -169 MHz.

In order to monitor body temperature fluctuations in the animals on a 24-hour basis, a computer program was designed that was capable of making digital recordings of the radio pulses received by the radio equipment. The program, named "SnakeByte", was written by Donald Gray of Odcombe, England. It runs on a laptop computer and stores recordings as ".Wav" files on the computers hard drive. "SnakeByte" was designed to make recordings from any receiver plugged into a computer's mic-in port. The receiver and the computer were connected using an 1/8-inch to 1/8-inch mono miniplug audio cable from Radio Shack, model 42-2420A. One end of the audio cable was plugged into the earphone jack of the receiver, and the other end was connected to the computer through the built in mic-in jack on the computer. Used in conjunction with the receivers listed above, "SnakeByte", set to make a recording every 15 minutes, provided 24-hour body temperature data for any single snake within the radio receiver's frequency range.

"SnakeByte" has additional utility when combined with a programmable scanner-receiver, the AR-8000, by AOR, Tokyo, Japan. This scanner-receiver, in conjunction with an interface unit, model #CU8232 Remote Control Interface for the AR8000, AOR, can automatically change the radio frequency to which it is tuned, based on a pre-defined list of frequencies entered into "SnakeByte". This combination results in body temperature data generation for up to ten snakes over the same monitoring interval. Due to the nature of electronics and radio signals, this technique produced varied results, ranging from hours of minute long recordings of static, to insightful data related to the activity patterns of the subject animals.

"SnakeByte" and the computer required several additional components in order to operate automatically in the field. Both the laptop computer and the receiver, either the Telonics TR-4, the TRX-1000S, by Wildlife Materials Inc, or the AR-8000, by AOR, were powered by an 80 amp/hour, Champion deep cycle marine battery. Power is supplied to the computer and receiver through the use of a 12VDC battery terminal adapter accessory outlet, model 270-1527, and a two outlet Y-adapter, model 270-1535. A notebook laptop DC-to-DC adapter, model 273-1825, ran between the two outlet Y-adapter and the laptop. The selected receiver was connected to the power source by means of the cigarette DC adapter provided by the respective manufacture. The AR-8000 was plugged into the power source using a universal DC auto adapter, model 273-1810.

The 80-amp/hour battery provided for approximately 36 hours of continuous operation. For this portion of the telemetry work, an omni-directional outdoor scanner/Ham discone antenna, model 20-043, mounted on a 10-foot mast, model 15-863, with a heavy-duty 3-foot tripod mount, model 15-517, was connected to the selected receiver using a 25-foot length of coaxial cable with male BNC connectors on both ends. All non-radio parts listed above are from Radio Shack, unless otherwise stated. This assemblage of equipment, collectively called the "radio base station", was housed in a large, sealed, plastic container located on a hillside above the study site at the San Diego Wild Animal Park.

A second automated system was established in the form of a TR-5 Automated Scanning Receiver with a Data Acquisition component (Telonics, Inc). The TR-5 was purchased with funds provided through a San Diego State University Faculty Grant and Aide Award. Operating much the same as “SnakeByte” and the AR8000 scanner, the TR-5 was programmed to switch through selected radio frequencies and record body temperature data at a specified time interval. The two automated systems were ran interchangeably at the radio base station, using the same power source and antenna setup. The extensive body temperature data generated by the TR-5 and “SnakeByte” will be analyzed at a later point to detect seasonal trends in activity patterns and body temperature.

Environmental temperatures, important factors for all reptiles, were gathered over the course of the study to describe the microhabitats and thermal gradients across the study site. When an animal was tracked to a specific location, temperatures at the site were measured using a Raytek MT4 "Non-Contact Thermometer". This device has an accuracy of ±2.0 C, and measurements taken with it are assumed as such. Additionally, environmental temperatures were measured at the radio base station at the San Diego Wild Animal Park using several products from the Onset Computer Corporation, Pocasset, MA. To determine the subterranean thermal gradient , a HOBO H8 4-Channel External data logger, part no. H-08-066-04, was used in conjunction with four wide-range temperature sensors, model #TMX6-HA. The TMX6-HA temperature sensor has an accuracy of ±0.5 C. Three of these probes were buried in the ground at depths of 45 cm, 30 cm, and 15 cm. The forth probe was placed at ground level in the center of a nearby

bush to estimate the temperature of the ground surface in the shade. The main component of the data logger was housed in the plastic container of the radio base station. A second data logger, a HOBO RH/Temp/Light/External, model H08-004-02, collected data on ground surface in the sun as well as ambient air temperatures. This data logger was elevated to a height of one meter off of the ground and was shaded by an inverted five-gallon plastic bucket. The unit's internal temperature sensor collected data on the ambient temperature, while a wide-range temperature sensor, same as above, monitored the temperature of the ground surface in direct sunlight. Dirt covered the tip of this probe to minimize the amount of sunlight absorbed by the probe itself. The temperatures thus recorded were used to approximate thermal habitats available to the rosy boa.

A global positioning system (GPS) served to measure the location of the research animals as they moved through their environment. All GPS equipment was produced by Garmin Corporation, Olathe, Kansas. A handheld GPS tracking unit, model #GPS-12XL, was hard-wired to a differential beacon receiver, model #GBR-21, using a Garmin power data cable. The power data cable allowed the tracking unit to communicate to the differential beacon receiver in order to acquire a more accurate position reading, and for the GPS system to be powered by a 12VDC power source. Typical location data collected by this unit had an accuracy of ± two to three meters.

Study Sites

The initial plan included radio tracking snakes at coastal southern California locations and comparing these to a sample of animals from sites in the Mojave Desert, with a minimum sample size of at least six animals at each site. Over the course of the research, the minimum sample size was achieved in San Diego and Riverside counties. Animals large enough for receivers were more difficult to locate in the Mojave Desert region. The lack of animals collected in the desert sites is reflected by the data. Figure 1 shows the location of the study sites in San Diego County and Figure 2 outlines the sample efforts in the desert regions. The survey and collection efforts resulted in three study sites in San Diego County and two in Riverside County. Efforts were also put forth to locate desert study animals in Joshua Tree National Monument and the Burns Piñon Ridge Reserve, operated by the University of California, Irvine.

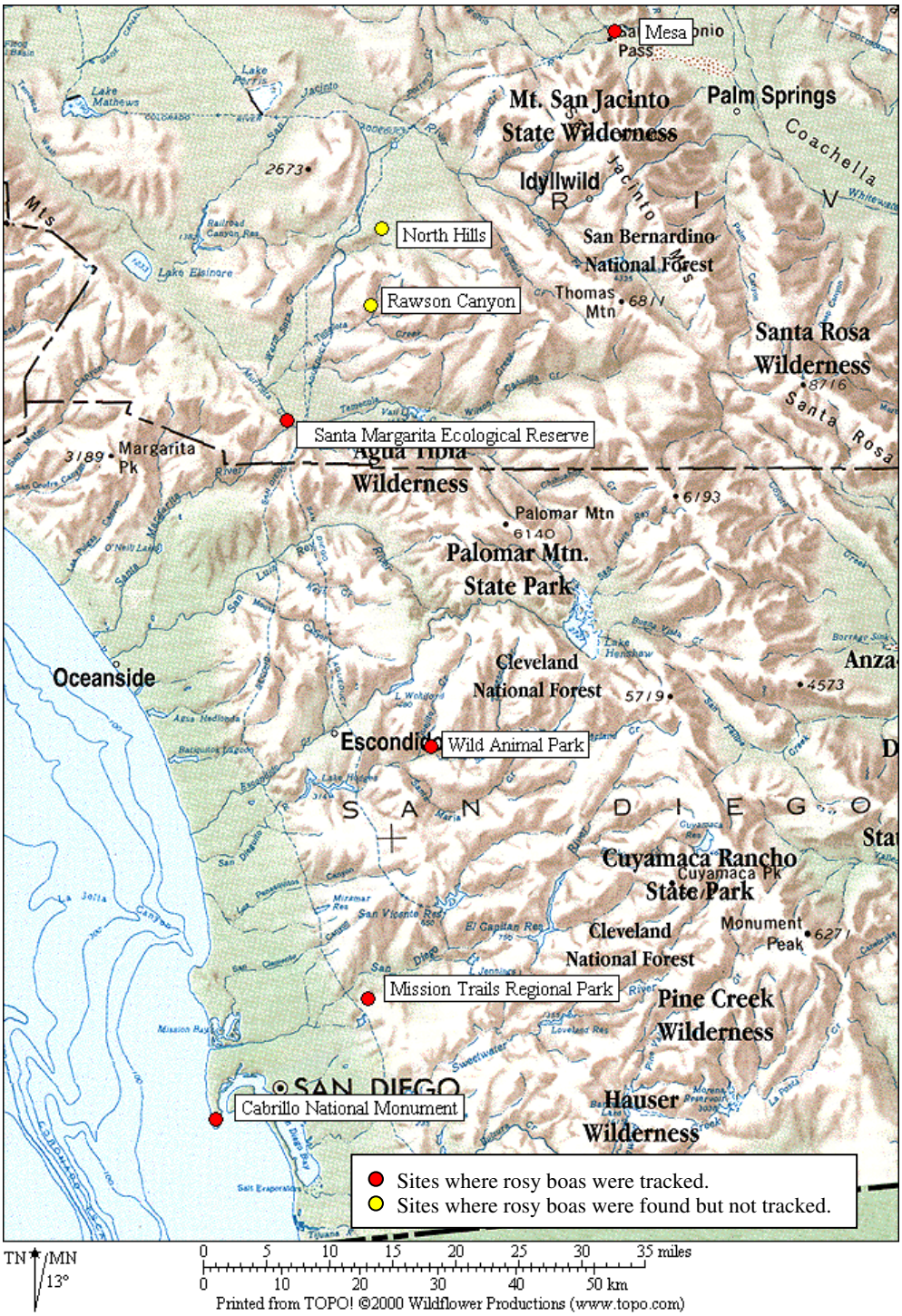


Figure 1 Rosy boa (*Charina trivirgata*) were tracked at various study sites throughout San Diego and Riverside Counties. In the three sites in San Diego, twenty rosy boas were documented over the course of the study. Riverside County produced thirteen snakes from four different sites. Not all snakes were radio tracked.

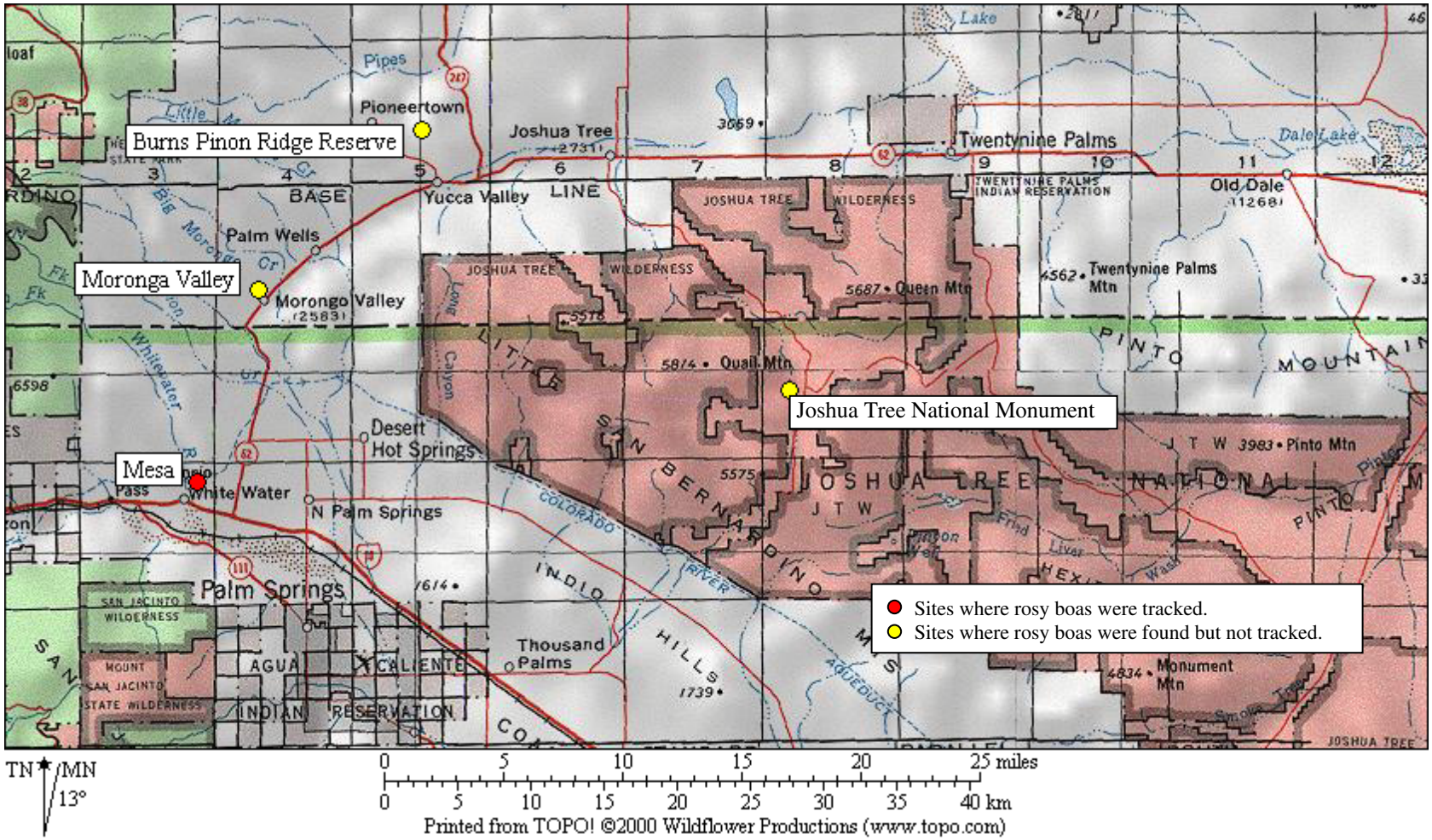


Figure 2 Efforts were put fourth to radio track rosy boas (*Charina trivirgata*) at several sites in Riverside and San Bernardino Counties. Of the eight snakes documented in the area of this map, only two were of suitable size for radio transmitters, they were at the Mesa study site.

Data was first collected in San Diego County at the San Diego Zoological Society's Wild Animal Park, located roughly 33.09465 □N and 116.98253 □W, Fig. 1. The Wild Animal Park (WAP) occupies approximately 2100 acres on the north side of the San Pasqual Valley, just east of Escondido, California. The rosy boa was known to occur at this site in relative abundance due to an on-going reptile and amphibian study being conducted at the site by the United States Geological Survey (Fisher and Case, 2000). The Zoological Society has developed only 800 of the 2100 acres, leaving the remaining acreage in a relatively undeveloped state, Fig. 3. One advantage of choosing the Wild Animal Park as a study site was the security represented by the ever-present on-site work crew, security guards, and 12-foot perimeter fence. As a closed piece of property, there has been little to no collecting of animals historically. The plant communities on the south facing slopes are classified as coastal sage scrub, dominated by laurel sumac (*Malosma laurina*), California buckwheat (*Eriogonum fasciculatum*), and California sage brush (*Artemisia californica*). The northern slopes are covered by a mixture of chamise (*Adenostoma fasciculatum*) and open oak woodland. The research area is bisected by a four-meter-wide dirt road maintained by the park, which receives only light traffic, Fig. 3. Elevation across the study area ranges from 140 to 255 meters. Although there were signs of running water after light rains, no permanent water source exists at the site within the home ranges of the study animals.

Cabrillo National Monument was the second study site in San Diego County, at 32.66912 □N and 117.24107 □W, Fig. 1. Cabrillo National Monument and the Point Loma Ecological Reserve are located near downtown San Diego, at the tip of the Point Loma peninsula. The National Monument represents a large fragment of undeveloped habitat that is completely isolated from any other suitable habitat. Cabrillo National Monument is surrounded by the Pacific Ocean to the west, San Diego Bay to the south and east, and the vast sprawl of San Diego City to the north. A rosy boa collected by the park rangers of Cabrillo National Monument brought this unlikely site into the study. Additional interest in radio tracking the rosy boa at this site arose from the fact that in three years of reptile and amphibian monitoring with pitfall traps, it was the only rosy boa

Fig. 3 A dirt road divides the study site at the lower portion of the San Diego Zoo's Wild Animal Park. Five rosy boas are known from the hillside in this view. Only WAP-1 was detected to have crossed the road.

Fig. 4 Three rosy boas were radio tracked at the Santa Margarita Ecological Reserve operated by the San Diego State University – Field Station. The yellow arrow indicates the steep cliffs that SMER-1 occupied, while the red arrow shows a stream-side position that SMER-3 once occupied.

documented at the site (Fisher and Case, 2000, Case and Fisher, 2001). Cabrillo National Monument has public access trails in the area where the snake was collected by park rangers. Risks at this site included the possible loss of the animal due to visitor collection and removal. In the area where the snake ranged, there is a mix of habitats. The majority of the hillsides are covered by Maritime Succulent Scrub, characterized by cliff spurge (*Euphorbia misera*), various cactus species, and dudleya (*Dudleya sp.*). Coastal sage scrub also occurs on site. Exotic plants in the area include iceplant (*Carpobrotus* sp.), eucalyptus trees (*Eucalyptus* sp.), and acacia (*Acacia* sp.). Efforts were being made by the Park Service to remove these exotics, some of which occurred during the radio tracking effort. Elevation at this site ranges from 22 to 109 meters above sea level. The home range of the snake is bisected by both a paved and a dirt road. Both roads are approximately four meters wide. The dirt road is closed to vehicle traffic; however, the paved road serves a small military station on the site. No fresh water source is known within the animal's home range.

The third site used in San Diego County is Mission Trails Regional Park, 32.81066 □N and 117.03789 □W, Fig. 1. Mission Trails is located four miles to the northeast of the San Diego State University campus and includes a study site run by the San Diego State University - Field Stations. The study site here consists mostly of west facing slopes covered by open coastal sage scrub. The most predominant plant species being the Laurel sumac (*Malosma laurina*). Other notable features include extensive vertical rock faces and rock piles of medium to small rock fragments. Mission Trails Regional Park is a popular wilderness area and is heavily visited by the public. In addition to extensive hiking trails, Mission Trails is also bordered by urban housing projects built in the early 1960's. Elevation in the study area ranges from 165 to 215 meters. During rains, water ran off through the ravines, but never persisted for any length of time following the rains.

The Santa Margarita Ecological Reserve (SMER), also operated by San Diego State University - Field Stations, served as one of the study sites in Riverside County, 33.45768 □N and 117.17044 □W, Fig. 1. The distinguishing feature of this site is the steep-sided canyon created by the flowing waters of the Santa Margarita River, Fig. 4. The base of the canyon is at approximately 790 meters in elevation, while the upper

region is nearly 1120 meters high. The streambed and the associated lowland areas consist of exposed granitic bedrock and oak riparian woodland. Coastal sage scrub, rocky outcrops, and the facilities research station cover the upper reaches of the hills. The reserve is gated and, ideally, closed to the public with signage stating the scientific purposes of the site. Hikers, swimmers, dirt bikers, and undocumented migrant workers were observed on the property.

The study site known as Mesa is located just to the north of Interstate 10, in Riverside County, in the San Gorgonio Pass, at 33.95500 □N and 116.65712 □W. The dominant feature at this site is the windmill farm located along the ridges throughout the area. Each windmill is located upon its own independent concrete pad, with many dirt service roads criss-crossing the site. The plant community is a mix of several community types, including coastal sage scrub, chaparral, and various desert types. Typical plants include creosote bush (*Larrea tridentata*), cholla (*Opuntia spp.*), and Our Lord's Candle (*Yucca whipplei*). The two rosy boas tracked at this site were first collected as a result of a desert tortoise (*Gopherus agassizii*) radio tracking project being conducted by the US Geological Survey (Lovich and Daniels, 2000). No standing water occurred at the site during the time of this study. Elevation ranges from 750 to 850 meters.

Study Animals

Beginning in early spring of 1999, efforts were made to locate as many rosy boas as possible in the field for the purpose of radio transmitter implantation. All rosy boas monitored were collected by hand during manual surveys at the study sites or by road cruising when possible. In all, 39 rosy boas were collected or documented at various sites in southern California between 1999 and 2000. At the sites where animals were radio tracked, all animals from the site are outlined in Table 1, including animals not tracked for one reason or another. Each animal is identified by the name of the site were it was collected, followed by a sequential number, Table 1. To ensure future re-identification of these study animals, PIT tags were implanted in appropriately sized animals.

Three of the rosy boas at the Santa Margarita Ecological Reserve were collected by San Diego State University students while on a field trip to the site. The forth, a

Table 1 At the study sites where rosy boas (*Charina trivirgata*) were radio tracked, all animals are shown, even where the animal may not have been included in the radio tracking effort. Throughout the course of the study, several animals had to have their radio transmitters replaced.

Animal	Radio Transmitter Frequency	Transmitter Type	Transmitter Serial #	Implant Date	PIT Tag Number	Sex
Wild Animal Park, Escondido, CA						
WAP-1	164.613	SI-2T	41078	5/24/99	AVID-034-086.068	M
	166.912	SI-2T	41090	4/24/00		
WAP-2	164.513	SI-2T	41074	5/31/99	AVID-034-077-348	M
	169.937	SI-2T	41091	5/5/00		
WAP-3	164.710	SI-2T	41082	6/7/99	AVID-034-310-582	M
WAP-4	164.662	SI-2T	41080	6/9/99	AVID-033-854-603	M
	169.073	SB-2	51203	2/10/00		
WAP-5*				8/5/99		
WAP-6	164.462	SI-2T	41072	9/10/99	AVID-034-075-835	
WAP-7	169.032	SI-2T	51209	3/16/00	AVID-033-853-258	F
WAP-8*				3/12/00		
WAP-9	169.183	SI-2T	51215	4/10/00	AVID-033-841-786	F
WAP-10	169.057	SI-2T	51210	5/12/00	AVID-033-854-595	M
WAP-11	169.106	SI-2T	51212	5/23/00	AVID-034-085-864	F
WAP-12	169.009	SI-2T	51208	6/18/00	AVID-034-100-311	F
WAP-13*				7/7/00		F
WAP-14*				10/7/00		M
Santa Margarita Ecological Reserve, Riverside, CA						
SMER-1	164.246	SB-2	42290	5/5/99	AVID-034-082-534	F
	164.540	SI-2T	41075	4/22/00		
SMER-2	164.104	SB-2	42287	5/5/99	AVID-033-860-583	M
SMER-3	164.562	SI-2T	41076	5/12/99	AVID-034-081-052	M
SMER-4*						
Mission Trails Regional Park, San Diego, CA						
MT-1	166.737	SI-2T	41083	7/9/99		F
MT-2	164.104	SB-2	42287	7/9/99		M
MT-3	169.049	SB-2	51202	3/20/00	AVID-034-364-112	F
MT-4	169.158	SI-2T	51214	3/20/00	AVID-033-852-863	F
MT-5	169.022	SB-2	51201	3/20/00	AVID-034-365-569	F
Cabrillo National Monument, Pt. Loma, CA						
Loma-1	164.540	SI-2T	41075	5/12/99	AVID-033-850-888	M
	164.155	SB-2	42288	8/6/99		
	169.148	SB-2	51206	5/12/00		
Mesa, Riverside, CA						
MESA-1	165.480	SB-2	45820	3/21/00	AVID-033-850-522	M
MESA-2	165.445	SB-2	45817	3/30/00	AVID-033-856-879	F

* These animals were documented at the study sites during the time of the study, but were determined to be unsuitable for radio tracking, either due to weight limitations or for timing reasons. The date listed in the "Implant Date" refers to the date that the animal was collected.

juvenile, was collected on the road by another researcher during bat surveys at the field station. At Mission Trails Regional Park, the first two snakes were collected by Dr. Tod Reeder. The remaining three were discovered during visual search efforts. As stated earlier, the Point Loma snake was collected by a park ranger. Of the 14 rosy boas at the San Diego Wild Animal Park, two were discovered while road cruising, eight were found during manual searching, and four were found while radio tracking other snakes. These last four individuals were located near one of the snakes which already had a transmitter implanted.

In addition to the animals noted at the final study sites in Table 1, thirteen animals were collected at other locations throughout southern California, but were deemed as unsuitable for radio tracking. Four adult snakes documented at the US Geological Survey's reptile and amphibian study site in Rawson Canyon, located in southwest Riverside County. Another three came from the study site known as North Hills in southwest Riverside County. Rawson Canyon and North Hills are located northwest of the city of Temecula, between Temecula and Hemet. One came from the Morongo Valley just east of Joshua Tree National Monument, one from the Burns Piñon Ridge Reserve near Pioneertown, California, and four from within the Joshua Tree National Monument itself. These 13 snakes were not included in the radio telemetry aspect of the project due to one of two reasons: the snakes were either too light in weight, as was the case with all four snakes from Joshua Tree National Monument; or they had been collected in an area that could not be monitored on a regular basis due to time constraints. Based on the dimensions of the Holohil SB-2 transmitter described above, which weighs 5.0 grams, the smallest snake that could be radio tracked would have to weigh no less than 100 grams.

Implantation

Surgical procedures utilized throughout the study followed the guidelines put forth by Reinert and Cundall (1982), Hardy and Greene (1999), and a protocol approved by the Animal Use Committee of San Diego State University. Their procedures are the standard in this field of research. Training on transmitter implantation techniques was provided by Norm Scott of the United States Geological Survey and Jeff Tracey, a

graduate student at the University of California, San Diego, who is conducting a similar study on the red diamond rattlesnake (*Crotalus ruber*).

Prior to the surgery, the animal, tools, transmitter, and surgery station were prepared for the operation. Sterilization of the radio transmitters used a non-heating technique with ethylene oxide. Surgical instruments, such as needle holders, forceps, and surgical drapes were sterilized using high temperature autoclaves. The surgical station was cleaned using bleach and water. The snake is prepared for the implantation process by first anesthetizing the animal using Isoflurane and the drop method (Hardy and Greene, 2000). Several drops of the Isoflurane are placed on a cotton ball, which is then placed in the anesthetizing chamber. The Isoflurane vapors are allowed to collect in the chamber before the snake is introduced to the system. A surgical plane of anesthesia is reached in approximately five to twenty minutes.

While the snake is being anesthetized, several other steps were performed. The surgical equipment is laid out on a sterile drape. A disposable #10 scalpel, a package of non-absorbing suture (3-0 Ethilon with a cutting X-1 needle), and a self-absorbing suture (3-0 Vicryl with a cutting FS-1 needle), both manufactured by Ethicon, were opened and added to the equipment pile. The location of the heart was determined and marked so that the snake's heart rate may be monitored during the procedure as an indicator of the animal's status. The sex of the snake was determined through the use of a lubricated blunt probe. The length of the snake, from snout to vent, was measured in order to determine the position of the incision site. The incision was placed at a distance of 25% of the snake's snout-to-vent length anterior to the vent. When the rosy boa was nearing the operating plain of anesthesia, the skin around the incision site and the hands of the operator were scrubbed using Betadine solution. The animal's state of consciousness was measured by the ability of the animal to right itself if rolled onto its side and the presence or absence of muscle tune. While the snake sedated, an incision, approximately two to three cm long, was made using a #10 scalpel, between the first and second scale rows. The incision was made using a zigzag pattern between the first and second scale rows, to avoid cutting directly through a scale. Once the skin had been sufficiently separated from the underlying muscle layer to reach the ventral edge of the ribs, an incision through the internal oblique and the transverse abdominal muscles was made, opening up the

peritoneal cavity. Necessary caution was used at this point to avoid damage to the internal organs, as the intestines are located in this area of the body. The transmitter was inserted through the opening into the peritoneal cavity, first perpendicular to the body, then rotated so that the long dimension of the transmitter was parallel to the snake's body, with the antenna was pointing towards the head of the animal. Using the antenna needle as a guide, the antenna was run through the body wall to a position under the first and second scale rows. The antenna needle was run under the skin, under the first and second scale rows, from the incision site towards the head, for a length 1 cm longer than the antenna of the transmitter, then out through a second, smaller incision in the skin. The antenna was then fed through the posterior end of the antenna needle. When the entire length of the antenna was in the antenna needle, the antenna needle was withdrawn from the exit hole, leaving the antenna under the skin of the animal. With the antenna in place, the transmitter was secured using the non-absorbing suture to attach the transmitter to a rib.

With the transmitter in place and secured, procedures began to close the incision and revive the animal. The snake's head was removed from the anesthesia chamber before the suturing process began. Using a self-absorbing suture, the incision in the skin is closed with five to seven sutures, as necessary. The second, small incision where the antenna needle exited is also closed with a single suture. At this point, a Passive Integrated Technology (PIT) tag was implanted into each animal for future identification purposes. PIT tags require no power source and serve as an indefinite means of uniquely identifying each animal, even after the end of this project. The snake was then monitored to determine its state of anesthesia. If necessary, the snake would be intubated to aide in the removal of the Isoflurane from its lungs. An intubation tube was inserted through the epiglottis, down into the lungs. The lungs were inflated by blowing into the external end of the intubation tube, until the lungs were visibly inflated. With light pressure, the breath was expelled, and repeated as necessary. Upon signs of recovery, the animal was returned to a heated enclosure and further monitored. The temperature in the enclosure was elevated in order to increase the animal's metabolic rate to assist in the healing process. Animals were returned to the site of collection as soon as possible, which ranged from two days to a month.

Tracking

During the spring and summer seasons, snakes were located up to four times a week. During the winter and fall, snakes were located once or twice a week. The telemetry equipment used for this project allowed each animal's location to be pinpointed to an area of one meter or less in diameter. When tracking each animal, a visual search was performed to confirm the animal's presence and relative position in the environment.

When a snake's position had been determined, specific data was collected regarding the tracking effort, the subject's location, and the animal itself. Date and time of day were recorded to provide a reference for movement, body temperature, and activity measurements. It was determined if the animal was in a new location, or appeared to have remained at the same site as the last tracking effort. A site was deemed to be new if the animal had clearly moved away from a previous site or there was a distinct change in the cover that the animal appeared to be utilizing. A snake was considered to be at the same site if the present location could not be clearly distinguished from the previous site. A position was recorded using the Garmin 12-XL GPS handheld unit.

A visual survey was used in order to determine the animal's state of activity at the time of tracking. Five states of activity were observed in the rosy boa over the course of the study. They were: UnderGround (UG), Surface Cruising (SC), Surface Basking (SB), Tree Basking (TB), and Tree Cruising (TC). For consistency, each state had a strict definition. UnderGround (UG) had several qualifying elements. If an animal was not visible from the surface, it was underground. If the rosy boa was visible but in a deep rock crevice or rock pile, it was considered to be underground. Surface Cruising (SC) described animals that were on the surface of the ground and were laying with their body length stretched out. This definition evolved following the encounter of animals actively moving about the surface and animals stretched out on the surface but not moving. Observations showed that snakes which were stretched out when first encountered but stationary, would eventually continue moving given enough time. Surface Basking (SB) is distinguished from surface cruising by body position and from the underground

category by the presence or absence of direct sunlight on the skin of the animal. While surface basking, a snake is typically coiled upon itself or another object, opposed to surface cruising where the snake is stretched out. Animals found with a portion of their body protruding from an underground retreat in direct sunlight, were also considered surface basking. The complete definition of surface basking includes being coiled upon oneself on the ground surface or receiving direct sunlight on the skin. Animals partially exposed but not receiving direct sunlight were classified as underground.

The activities described above functioned as the full range of noted behaviors until the spring of 2000, when several of the rosy boas were found in plants, elevated off of the ground. These behaviors resulted in the addition of two more activity classes, Tree Cruising (TC) and Tree Basking (TB). As with surface basking, tree basking is distinguished by the snake being coiled upon itself. A rosy boa was considered to be tree cruising if its body had few self-contact points, and was stretched out for the majority of its length. Regardless of the plant that the animal was located in or the animal's height off of the ground, it would be described in one of these activity states if there was no contact between itself and the ground.

Descriptive factors about each site were documented in an effort to develop an understanding of the rosy boa's habitat requirements and preferences. These factors are collectively called cover, and are broken down into the following categories: Cover 1, Cover 2, Cover 3, and Cover 4. These four fields are used to stratify the habitat in which the snake was located. Cover 1 was the habitat in most immediate contact to the snake vertically, Cover 2, the habitat element above that, Cover 3, above that, and so on in a series directly up from the animal's location. An example of a typical series would be: Cover 1 - Rodent burrow, Cover 2 - Leaf litter, Cover 3 - Laurel sumac.

A cover layer would be assigned a cover type, beginning with the snake's position and continuing upward to open air. Some of the common cover types are described below.

Rodent burrow (RB): When a snake was underground and not visible, it was defined as being in a rodent burrow. The rodent burrow cover type could

only be used in the Cover 1 data field. The substrate at the study sites was typically very hard, and was prohibitive to burrowing by the rosy boa (Riepple, 1978). No attempt was made to determine the species of rodent that created each burrow. Rodent burrow served as a default cover type, and if the animal could not be seen, it was concluded to be underground in a rodent burrow.

Rock crevice (RC): If an animal could be visually determined to be between a rock and the ground or between two rocks, rock crevice was used as the Cover 1 field. If the animal could not be detected visually in a rock pile, rodent burrow (RB) would be used as the Cover 1 field, with rock crevice in the Cover 2 section.

Bare Dirt (BD): Open, un-vegetated soil was classed as bare dirt. Paths through vegetation, either made by human activities or animals, also fell into this category. In the case of surface cruising on bare dirt, this could be used as Cover 1. More typically, bare dirt was used as Cover 2.

Dead Brush (DB): Indistinguishable dead plant materials were labeled as dead brush.

Leaf Litter (LL): Fallen leaves collected under or adjacent to the base of a plant. Typically used in the Cover 2 position, leaf litter was also used as a primary cover by several snakes, placing it in the Cover 1 position on occasion.

Neotoma Nest (NN): Woodrats (*Neotoma sp.)* build large mounds of broken twigs in which rosy boas were found. Much like the rodent burrow class above, neotoma nest is never used outside of the Cover 1 field.

Urban (U): Apart from trails, any human structures or introduced plants associated with structures were considered urban. In this study, urban

cover included backyard storage sheds, landscape plants such as iceplant (*Carpobrotus sp*.) and aloe vera (*Aloe sp.*) near developed areas, and military structures.

Vegetation: As a cover type, vegetation could be used in any of the cover layers, depending on the animal's location and activity. The species of vegetation was typically recorded as a four-letter code comprised of the first two letters of the genus and species, eg. Laurel sumac (*Malosma laurina*) was recorded as MALA, California buckwheat (*Eriogonum fasciculatum*) as ERFA, and so on.

Each location was further described by the current weather conditions and several temperature readings. The temperature at one meter off of the ground was used to estimate the ambient air temperature. Ground temperature was recorded as a measure of the thermal environment in most immediate contact to the animal. Weather was classified as clear, foggy, overcast, precipitating, or some combination of these.

To determine the animal's body temperature, the pulse period of the radio beeps generated by the transmitter was measured using a stopwatch. Starting on a pulse and using that as the zero point, ten consecutive pulses were timed to determine an average pulse period, this helps to reduce the amount of human error. Prior to implantation, the SI-2T, temperature sensitive transmitters were calibrated using a water bath at various temperatures and a calibration curve was calculated, which could be used to determine the relationship between the pulse period and the temperature of the transmitter. Following a log transformation of the pulse period, the data was fitted to a third order regression to generate an equation using Statview 5.0, $R^2 = 1$. This equation could then be used to convert a pulse period into a temperature. When possible, transmitters were recalibrated after removal from a snake to check for any changes in calibration. No significant drift from the original calibration was detected.

Using the GPS data gathered during the process of radio tracking, each animal's home range was estimated. Minimum convex polygons were calculated using Cal Home: Home Range Analysis Program produced by U.S. Forest Service Pacific Southwest

Research Station and California Department of Fish and Game. Fixed Kernel estimates were made with the aide of The Home Ranger 1.5 developed by Fred Hovey. Both were downloaded from the Illinois Natural History Software server.

Seasons

For the purposes of this report, winter was defined from the Winter Solstice, December 21st, to the Vernal Equinox, March 20th. March 21st, the Vernal Equinox, marked the beginning of the Spring season. June 21st through September 21st represented the Summer season, and Fall ran from September 22nd to December 20th.

Results

Between the spring of 1999 and the fall of 2000, twenty-one rosy boas across five different localities were implanted with radio transmitters. Fifteen of these snakes were implanted with temperature sensitive transmitters, for either a portion of the study or its entirety. Each animal was tracked on a regular basis, ranging from once to four times a week, depending on the season and the study site where each animal lived. The sampling effort for each animal is outlined in Table 2. The data gathered as a result of this study was analyzed to detect trends in habitat selection, home range estimates, and body temperature regulation.

As Table 2 shows, the San Diego Zoological Society's Wild Animal Park contained the most telemetered snakes. The seven seasons over which the study was conducted produced a total of fourteen rosy boas. Due to the secure nature of this site, the Wild Animal Park was selected as the base of operations for the body temperature diel profile monitoring that was performed using the computer program "SnakeByte" and a laptop computer. As such, it generated the most data regarding both movements and body temperatures of individuals.

Of the twenty-one individuals implanted with radio transmitters, five were lost over the course of the study. Two snakes, WAP-6 and SMER-3, were lost due to complications with the implantation process. Data from both of these snakes is not included in the following calculations unless otherwise noted. Three more animals were lost from the project, two to predation and one unknown. SMER-2 and WAP-3 were

Table 2 Summary results of rosy boas at the five study sites in southern California where animals were radio tracked. Field efforts began in May of 1999, and ran through October, 2000.

Animal Identification	Implant Date	Days Monitored	Disposition**	Sex
Wild Animal Park, Escondido, California				
	5/99	336		
WAP-1	4/00	163	A	M
	Total:	499		
	5/99	340		
WAP-2	5/00	152	A	M
	Total:	492		
WAP-3	6/99	243	P	M
	6/99	207		
WAP-4	2/00	194	A	M
	Total:	400		
WAP-5*	8/99		R	
WAP-6	9/99	117	D	M
WAP-7	3/00	201	A	F
WAP-8*	3/00		R	
WAP-9	4/00	177	A	F
WAP-10	5/00	145	A	M
WAP-11	5/00	134	A	F
WAP-12	6/00	109	A	F
WAP-13*	7/00		R	F
WAP-14*	10/00		R	M
Santa Margarita Ecological Reserve, Riverside, California				
	5/99	353		
SMER-1	4/00	165	A	F
	Total:	518		
SMER-2	5/99	5	P	M
SMER-3	5/99	52	D	M
Mission Trails Regional Park, San Diego, California				
MT-1	7/99	448	A	F
MT-2	7/99	60	U	M
MT-3	3/00	197	A	F
MT-4	3/00	197	A	F
MT-5	3/00	197	A	F
Cabrillo National Monument, Pt. Loma, California				
	5/99	86		
Loma-1	8/99	280	A	M
	5/00	145		
	Total:	425		
Mesa, Riverside,Califonia				
MESA-1	3/00	112	U	M
MESA-2	3/00	150	U	F

* These animals were documented at the study sites during the time of the study, but were determined to be unsuitable for radio tracking, either due to weight limitations or for timing reasons. The date listed in the "Implant Date" refers to the date that the animal was collected.

** Disposition at the time of the report preparation.

Disposition:

A - Alive and Active
P - Predated
R - Released at capture site without a radio transmitter
D - Dead, due to complications
U - Unknown disposition, due to radio transmitter failure

killed by raptors. Both San Pasqual Valley and the Santa Margarita Gorge are known to be home to several red-tailed hawks (*Buteo jamaicensis*), as well as a pair of golden eagles (*Aquila chrysaetos*). The fate of MT-2 is unknown. On September 9, 1999, the transmitter was found, by itself, lying on the ground, no sign of the snake. Data from MT-2 is not included in the calculations below. SMER-2 only generated two position fixes besides its capture point, it has also been excluded from calculations. WAP-3 appeared to be behaving in a manor consistent with the other snakes at the site and, as such, was left in the data set. Only its last position is not included in the home range estimates.

Body Temperature

In recent years, many researchers have taken advantage of temperature sensitive transmitters in order to better understand the temperature regulation process in reptiles (Stine and Lambeck, 1985; Stine, 1987; Dorcas and Peterson, 1998). Body temperature data collected was analyzed as two separate sets, that collected in the process of regular radio tracking fixes and that collected by means of the computer program, "SnakeByte".

A body temperature was taken for each snake whenever an animal was located in the field. However, data collected in this fashion has the potential to be biased by the sampling effort. The estimate of average body temperature would most likely be skewed upward due to the fact that most radio tracking was done between the hours of 7 AM and 10 PM, a time period when the animal would be expected to have a higher body temperature due to greater ambient temperatures. While possibly skewed, this data is still of value in looking at the overall trends in body temperature over the course of a longer time period, as well as providing the ability to directly identify the animals position in the habitat and activity state at a particular time and body temperature.

Diel temperature data collected by means of automation allows for continued monitoring during those hours when fieldwork is impractical. These techniques allow for a massive numbers of data points throughout the course of the day, resulting in the detection of activity patterns and body temperature trends. However, these temperatures lack associated information about the animal's activity or position in the environment.

Body Temperatures from Radio Tracking

Radio tracking efforts produced nearly 700 body temperature measurements for the thirteen rosy boas that were implanted with temperature sensitive transmitters. Initially, this data was analyzed in an effort to detect differences in temperature regulations patterns between males and females. Figure 5 shows this data, each column representing the mean body temperature for the season. No temperatures were available for females in the spring of 1999. No consistent pattern of difference between the mean body temperature of the male and female rosy boas monitored by this study was found. The data for the two sexes is combined in Figure 6 and outlined in Table 3 showing the seasonal variations. The overall pattern, averaged across all animals, was for the highest body temperatures to be in the summer, followed by spring, then fall, and lastly, winter. However, this pattern does not hold true at an individual level, some snakes had higher temperatures in spring, decreasing steadily until a minimum in winter.

Body Temperature Measurements Produced by Means of Automation

The computer program, "SnakeByte", was set to collect data every 15 minutes in the form of a ".Wav" file. Each .Wav file represented a one minute long sound recording of the beeps produced by the receiver, which could then be processed at a later date to determine the pulse period between the beeps. With this technique, detailed daily and hourly variations in body temperature were observed. All four daily body temperature patterns reported by Dorcas and Peterson (1998) for the rubber boa (*Charina bottae*),were also detected for the rosy boa. These patterns were: smooth, plateau, oscillating, and inversion.

Figure 7A shows a smooth pattern, characterized by low body temperature variation. Over the course of the day, the snake's body temperature ranged from a low of 28.2 °C to a high of 30.3 °C. The mean body temperature maintained by WAP-10 for the day was 29.3 °C, with a standard error of ± 0.096. The position fix shows close agreement between the data collected through "SnakeByte", located nearly one kilometer from the animal's position, and that collected by the field technician while radio tracking. WAP-10 was underground at the time of the location fix and appears to have remained so

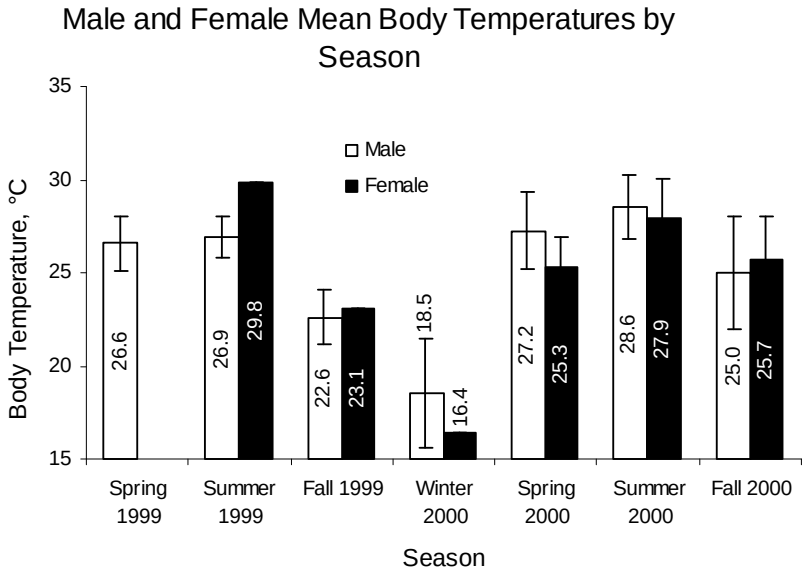


Figure 5 The average body temperature, with error bars, for male and female rosy boas across seasons shows no consistent pattern between the two sexes. Only one female was implanted with a temperature sensitive transmitter for the first four seasons, hence, there is no associated variability.

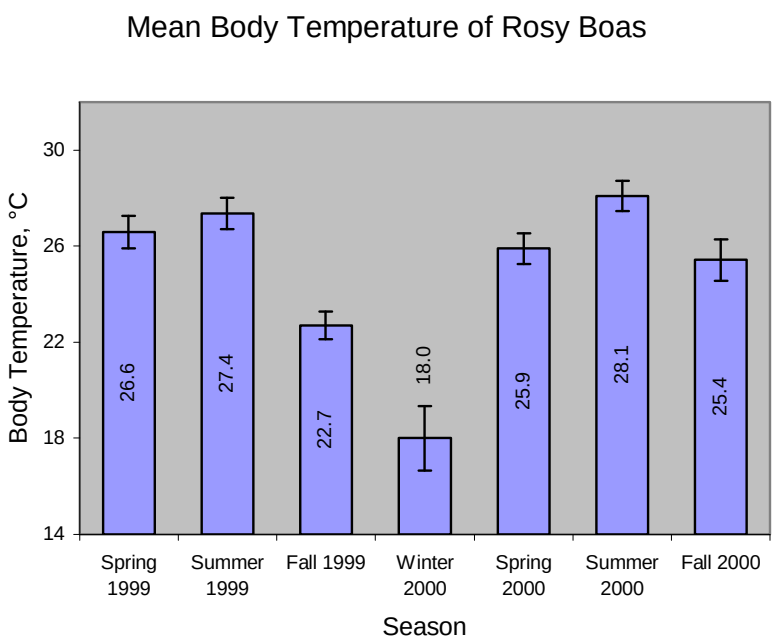


Figure 6 Mean body temperatures for rosy boas, males and females combined, for seven seasons of field research. Winter 2000 not only had the lowest temperatures, but also the largest standard error. Each bar represents the mean for the season, error bars show plus and minus one standard error.

Table 3 Summary body temperature statistics for rosy boas radio tracked from the Spring of 1999 through the Fall of 2000. Only those snakes with temperature sensitive transmitters are included. Seasons are defined by the Summer and Winter Solstices and the Vernal and Autumnal Equinox. Mean body temperature is followed by the standard error in parenthesis ( ). Below is the sample size and the range, in brackets [ ],

Identification	Spring 1999	Summer 1999	Fall 1999	Winter 1999/2000	Spring 2000	Summer 2000	Fall 2000
LOMA-1	25.7 (1.6) 10 [21.2 - 33.1]	25.8 (1.3) 7 [21.8 - 29.6]					
MT-1		29.8 (0.4) 25 [25.6 - 33.2]	23.1 (1.2) 16 [13.8 - 31.4]	16.4 (0.8) 20 [11.2 - 23.0]	24.9 (0.9) 19 [19.1 - 33.1]	26.2 (0.5) 8 [24.4 - 28.4]	22.9 NA 1 [22.9 - 22.9]
MT-4					26.9 (1.0) 23 [18.4 - 33.2]	26.5 (0.7) 8 [24.4 - 31.1]	
SMER-1					22.7 (1.4) 10 [16.3 - 28.9]	25.0 (0.9) 4 [22.3 - 26.5]	
WAP-1	25.3 (0.9) 16 [18.4 - 30.4]	27.9 (0.3) 47 [22.3 - 33.7]	24.4 (0.9) 20 [18.2 - 31.9]	16.0 (1.1) 13 [10.3 - 23.4]	28.4 (0.9) 27 [18.9 - 34.7]	30.1 (0.6) 20 [25.7 - 33.5]	27.9 (1.9) 2 [25.9 - 29.8]
WAP-2	27.3 (0.5) 8 [25.7 - 29.8]	25.8 (0.2) 30 [22.6 - 28.9]	21.0 (1.0) 18 [14.6 - 26.7]	17.8 (1.7) 15 [13.0 - 34.4]	28.5 (0.7) 38 [18.7 - 36.0]	28.9 (0.4) 19 [26.8 - 33.1]	25.3 (0.5) 2 [24.8 - 25.8]
WAP-3	28.8 (1.6) 5 [24.6 - 32.2]	28.0 (0.3) 42 [23.3 - 34.8]	23.2 (0.6) 23 [17.6 - 28.5]	21.8 (2.2) 6 [17.8 - 29.7]			
WAP-4	25.9 (1.6) 5 [22.1 - 29.3]	26.8 (0.3) 31 [23.4 - 30.8]	21.8 (1.1) 18 [12.3 - 28.0]				
WAP-7					24.6 (0.9) 23 [18.3 - 33.8]	27.8 (0.8) 20 [21.3 - 33.6]	25.8 (1.2) 2 [24.6 - 27.0]
WAP-9					27.2 (0.9) 19 [15.8 - 32.2]	31.0 (0.5) 18 [27.6 - 35.5]	25.1 (1.2) 2 [23.9 - 26.2]
WAP-10					24.8 (1.5) 8 [18.9 - 28.2]	26.7 (1.0) 16 [20.5 - 38.4]	21.8 (0.5) 2 [21.3 - 22.3]
WAP-11					25.2 (0.4) 4 [24.5 - 26.2]	30.3 (0.4) 15 [28.0 - 32.5]	29.3 (0.2) 2 [29.1 - 29.5]
WAP-12						28.4 (0.7) 12 [25.5 - 32.3]	25.3 (0.2) 2 [25.2 - 25.5]
Total	26.6 (0.7) 44 [18.4 - 33.1]	27.4 (0.6) 182 [21.8 - 34.8]	22.7 (0.6) 95 [12.3 - 31.9]	18.0 (1.3) 54 [10.3 - 34.4]	25.9 (0.6) 171 [15.8 - 36.0]	28.1 (0.6) 140 [20.5 - 38.4]	25.4 (0.9) 15 [21.3 - 29.8]

for the entire day. The plot of the snake's body temperature closely follows that of temperature measurements taken at 30 cm underground.

WAP-2 displays a plateau pattern in Figure 7B. With a plateau pattern, the animal maintains an elevated body temperature after all measured ambient temperatures have started to drop off. Until approximately 1:00 PM, WAP-2 closely followed the temperature measured at 15 cm underground. Between 1:00 and 5:00 PM, the snake was able to elevate its body temperature to between 28 and 31 °C. After which time it dropped back down to approximately that of 15 cm underground. Average body temperature for the day was 23.3 °C with a range of 16.1 °C to 31.1 °C and a standard error of ± 0.617 °C.

An inversion combined with an oscillating pattern can be seen in Figure 8A, for WAP-9 on June 17, 2000. The snake's body temperature initially followed underground temperatures. At approximately 10:00 AM, it dropped by 2 °C to 26 °C for two hours. As the snake's temperature started to rise, the radio signal was lost for the hours from12:26 PM to 2:11 PM. Afterwards, body temperature fluctuated until it leveled off around 7:00 PM, resuming the temperature pattern of the underground environment.

A pattern not consistent with any of those described by Dorcas and Peterson (1998) for the rubber boa was detected several times and is depicted in Figure 8B. On April 8, 2000, WAP-2's body temperature was elevated to 32 °C for only 45 minutes between 12 noon and 12:45. Both before and after its body temperature closely followed underground temperatures. Environmental temperatures indicate that warmer temperatures were available for a longer period of time than the snake maintained this elevated body temperature. WAP-2's mean body temperature for the day was 24.3 °C, with a standard error of ± 0.481 °C over a range of 33.2 °C to 21.4 °C, n=41. However, Peterson et. al. (1993) did describe a similar pattern for a postpartum Great Basin Rattlesnake (*Crotalus viridis*). It is suggested that the animal warmed during a short emergence and cooled after retreating, repeating this process several times during the day. WAP-2 may have expressed the same pattern, but with only a single heating and cooling episode.

Body temperature data gathered during radio tracking has indicated several points of interest. Number one being the amount of variability between individuals and within a

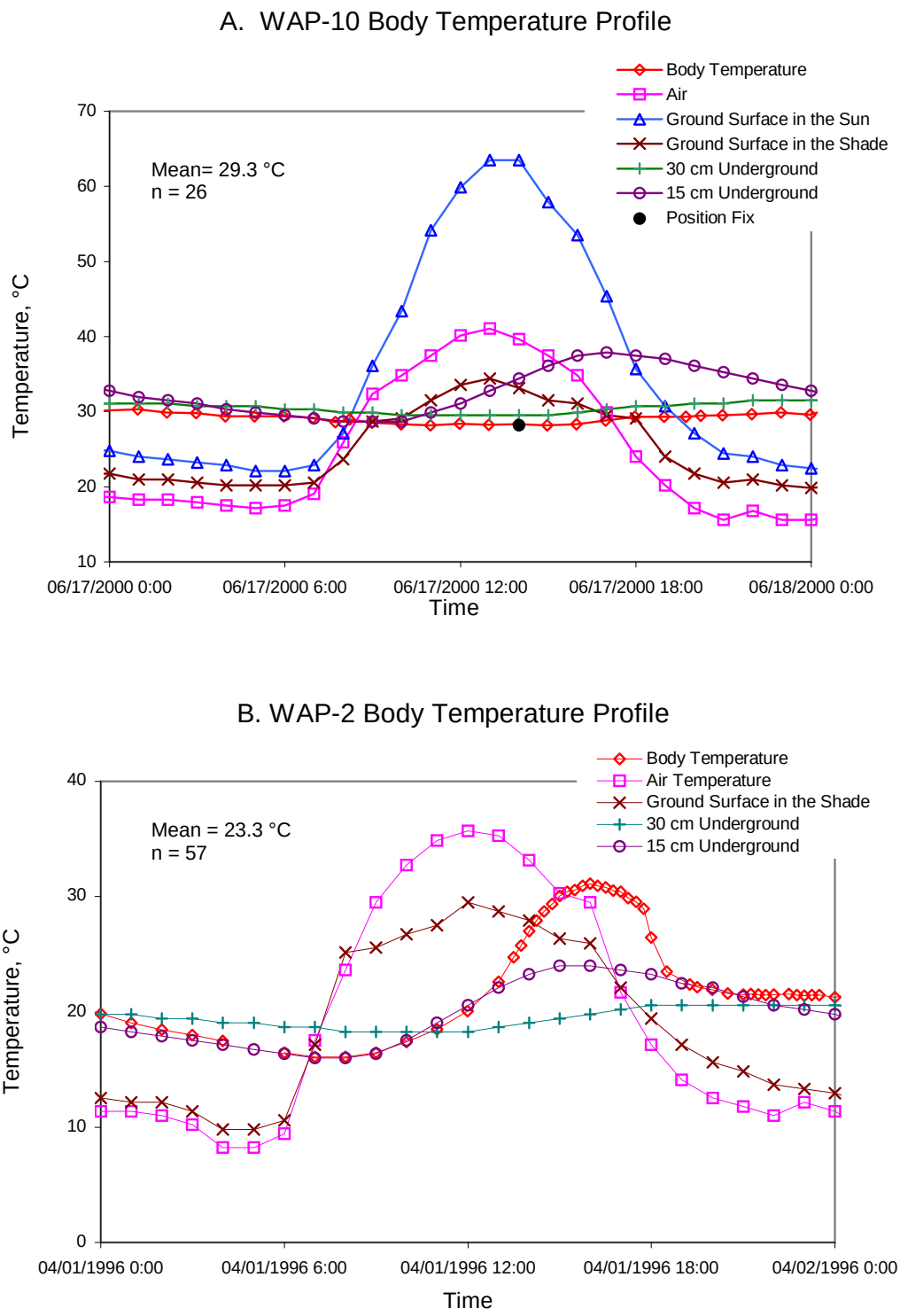


Figure 7 Data collection by means of automation allows for body temperature measurements to be made on a regular basis throughout the entire day creating a picture of a snake's activity while researchers are not present in the field. **A.** On June 17, 2000, WAP-10 demonstrated at smooth curve with little variation in body temperature, a pattern typically associated with remaining underground. WAP-10 was confirmed as underground by a position fix at 2:00 PM, at which time the body temperature measured in the field closely matched that recorded by "SnakeByte". **B.** WAP-2 showed a plateau pattern on the afternoon of April 2, 2000. For the majority of the day, WAP-2 followed underground temperatures, then rose to 32 °C for nearly four hours.

single animal. Over the time period that these snakes were monitored, several showed a body temperature range of as much as 20 °C. WAP-2 showed this much variability within one season, Winter 2000. Secondly, when compared to the other variables that have been measured by this study, highest seasonal average body temperature does not align with the peaks of other measured factors. The averaged body temperature peaked in summer, both in 1999 and 2000. However, activity, measured as the percent of fixes underground (Figure 9), average distance moved (Table 7), and home range estimates (Table 10 and Table 11) all peaked in spring. The simple explanation would be that the elevated summer temperatures resulted in the increased body temperatures, while hindering movement. However, body temperature profiles presented in Figure 7 and Figure 8 would indicate that cooler temperatures were available if an animal wanted to avoid the higher temperatures of summer.

Activity

With each location fix, an animal's activity state was determined, based on the five activity types described above. The activity data was analyzed by month, with the sampling effort outlined in Table 4 to show the number of activity fixes per month and the number of individuals that contribute to that number. The Underground activity type shows the most defined pattern and has been presented graphically in Fig. 9 to show the changes in the percentage of activity fixes represented by this activity by month for each sex. While 100% of the fixes for November, December, and January were underground, several animals did show slight movements, as noted in Figure 18 below, under movement results. Figure 10 displays the remaining four activity types, surface basking (SB), surface cruising (SC), tree basking (TB), and tree cruising (TC), by sex. These four activity types represent above ground documentation of the rosy boas. Tree activity, basking or cruising, occurred mostly during the three months of May, June, and July, with a single record in October. Both males and females were observed performing these activities. The percent of fixes per activity class was calculated by first determining the percent of fixes per activity type for each individual in a given month, and then averaging across individuals for the month.

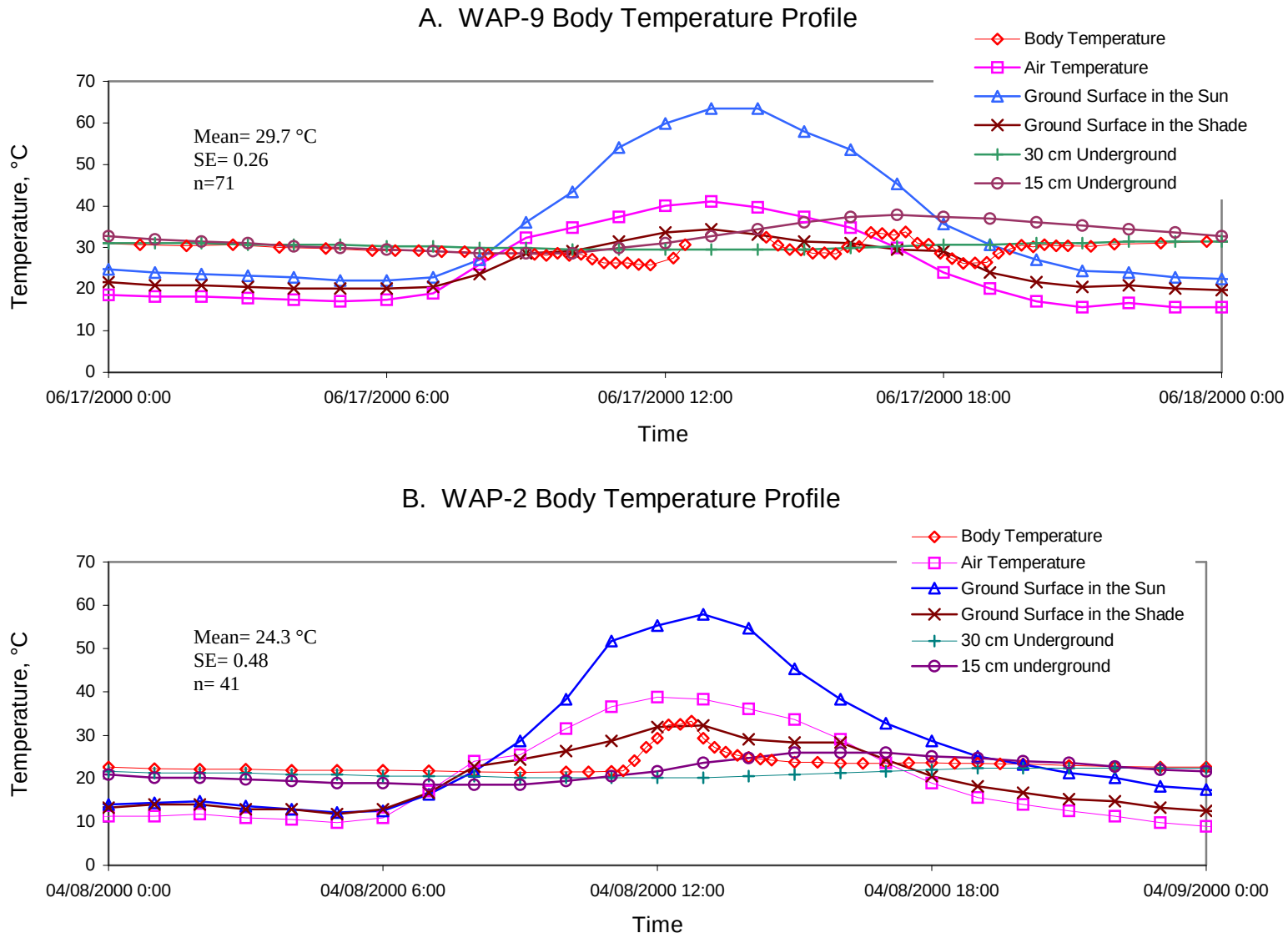


Figure 8 A. On June 17, 2000, WAP-9 displayed an oscillating pattern with an inversion. The radio signal weakened and became inaudible from 12:26 PM through 14:11 PM. B. The dial temperature profile for WAP-2 for April 8, 2000, shows the snake's body temperature spike to 33 °C for 45 minutes near the middle of the day., then return to that of underground conditions.

Body Temperature and Activity

These radio tracking efforts have produced a large number of field collected body temperature measurements which can be directly linked to a known activity state. Previous reports of body temperature for rosy boas came from opportunistic encounters with snakes (Brattstrom, 1965), and may have been biased due to the nature of the specimen. Using telemetry techniques, body temperatures were measured even when a snake would not have been physically available to measure its temperature by traditional means. In Figure 11, body temperature is summarized based on four of the five observed activity states.

Cover

Every time that a location fix was made for a snake's position in the environment, the habitat at that location was recorded. This data was analyzed to estimate patterns of habitat selection among rosy boas and is highlighted in Table 5. When the cover type was a species of vegetation that had a low frequency of occurrence, it was combined into a cover type labeled "VEG. "VEG" includes *Rhus integrifolia, Rhamnus crocea, Brassica nigra, Encelia spp., Adenostoma fasciculatum*, and *Euphorbia misera*. The percent of all fixes in the Cover(1) field represented by these fourteen cover types is calculated in the far right column of Table 5.

Rodent burrow (RB) was the only cover type utilized by all rosy boas in the study, as well as being the cover type of highest frequency. Rock crevice (RC) occurred as the next highest cover type in the Cover(1) field, and as the most frequent cover type in the Cover(2) field. The Cover(2) field has been outlined in Table 6 to show the relationships between the Cover(1) and Cover(2) fields. While rodent burrows were the most common cover in immediate contact to the animal, many of these fixes also had some form of rock crevice associated with the location. Of the 665 counts of rodent burrows, 195 of those show rock crevice as the second type of cover. Likewise, bare dirt occurred with rodent burrows 120 times. Leaf litter and *Malasma laurina* typically appeared together, the leaf litter being generated by the *Malasma laurina* .

Use of rodent burrows was confirmed on occasion when a snake was dug out of the ground. Early in the project, WAP-1 was carefully removed from a rodent burrow in

Table 4 The number of activity fixes per month is shown along with the number of individuals that contributed to these numbers. Lower numbers in the first two and last two months are the product of many animals being found in the second spring of the study. These numbers represent all activity types, and are pooled across the two years of the study.

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Female	No. of Individuals	2	2	7	8	8	10	10	10	9	9	2	2	10
	No. of Activity Fixes	5	11	30	60	79	57	82	35	34	21	5	4	423
Male	No. of Individuals	4	3	5	5	6	7	7	6	6	6	5	5	7
	No. of Activity Fixes	25	14	15	42	48	70	79	33	61	38	19	22	466
Total	No. of Individuals	6	5	12	13	14	17	17	16	15	15	7	7	17
	No. of Activity Fixes	30	25	45	102	127	127	161	68	95	59	24	26	889

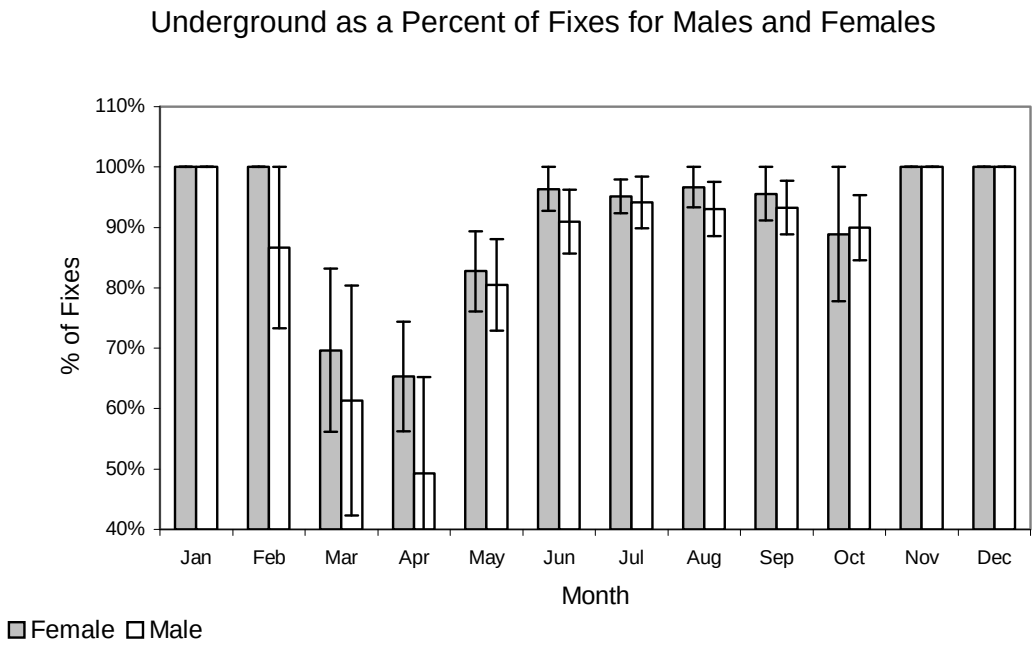
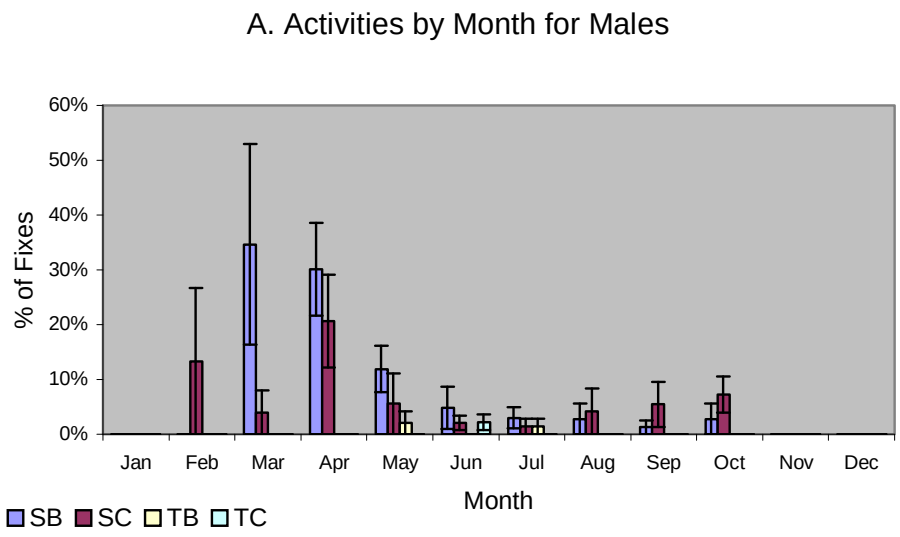


Fig. 9 The percent of fixes that animals were underground is compared between the sexes. Females show a larger portion of fixes underground than males for each month. It also appears that males may be more active earlier in the year when compared to the females.



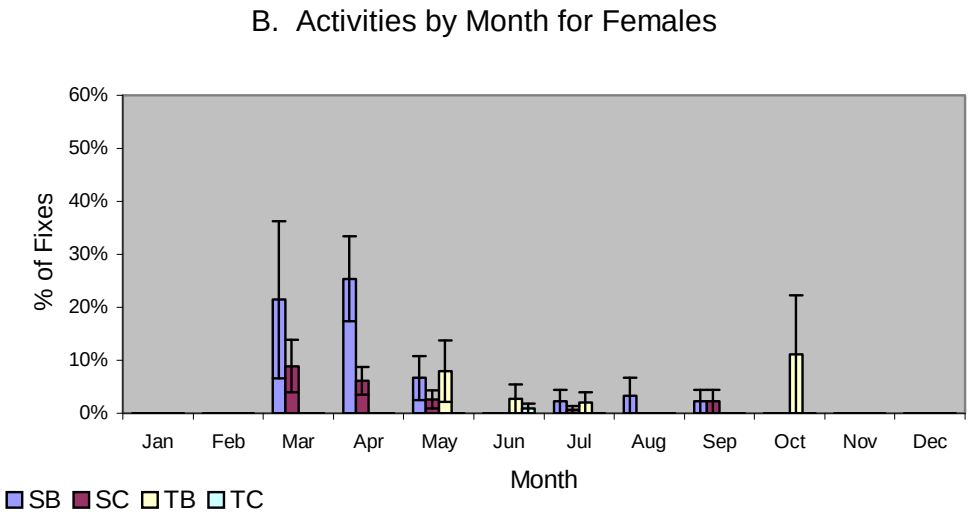


Figure 10 Above ground activities are shown for each sex, males in **A**, females in **B**. Above ground activities include: Surface Basking (SB), Surface Cruising (SC), Tree Basking (TB), and Tree Cruising (TC). Most of the above ground activity occurred during the months of March, April, and May. A slight, second increase in activity occurred during August, September, and October. With the decline of the initial increase in above ground activity, the rosy boas showed an increase in the two types of tree activities.

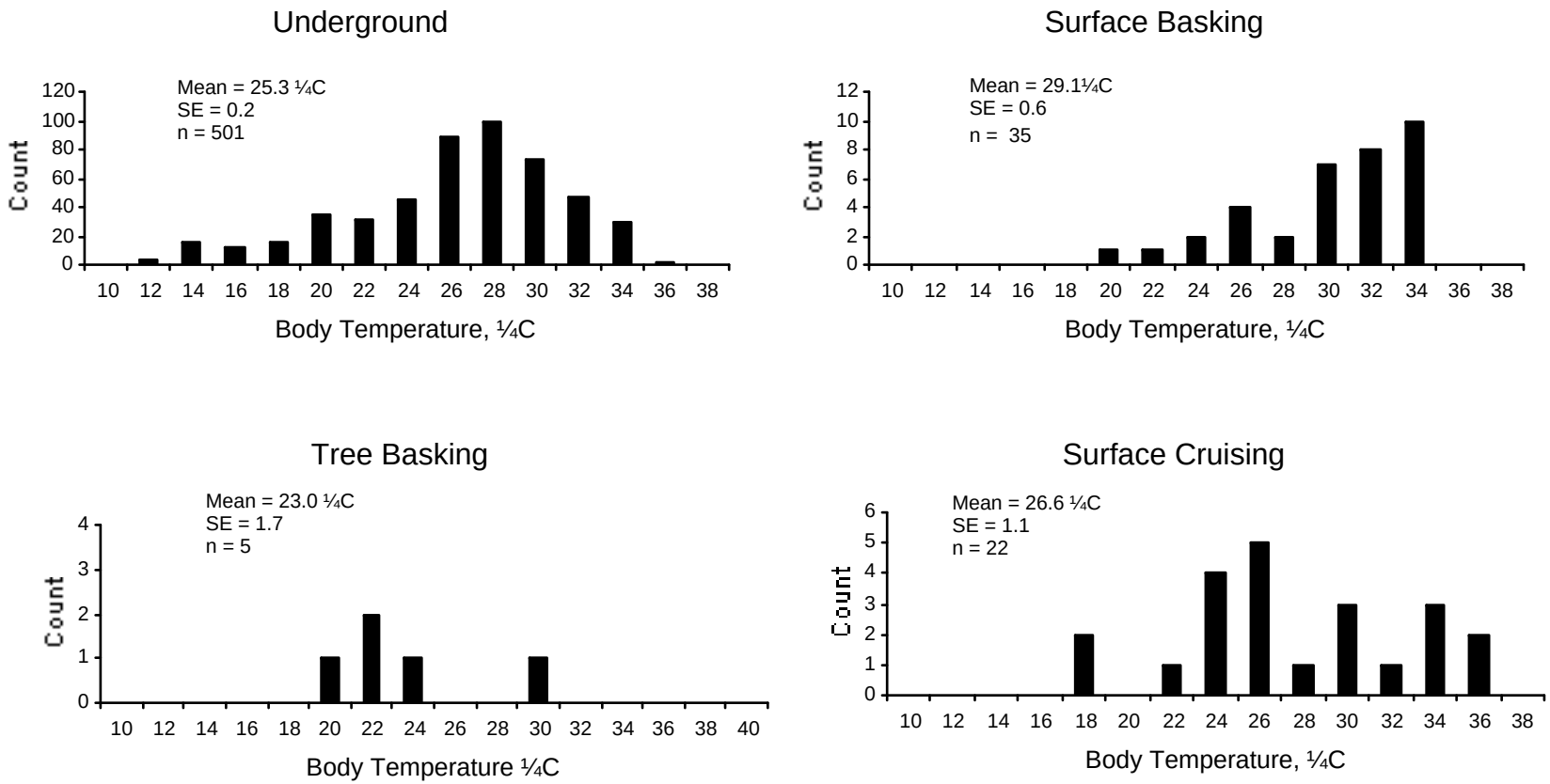


Fig. 11 Body temperature varies with activity. These four activity types represent over 550 field collected body temperatures where the animal's activity and position in the environment was known. Most opportunistically collected field body temperatures would be limited to the three activity classes of surface basking, surface cruising, and tree basking, which would only represent 12% of the data here. Tree cruising was not included, there was only one body temperature associated with this activity, 24.5 ºC.

order to assess the healing of its incision. Once the rodent burrow was encountered in the digging process, it was followed to one side, where the snake was resting. Similarly, WAP-4 was located in and removed from a rodent burrow. WAP-4's radio transmitter died over the Winter 2000 season. Digging at the snake's last known location, produced the snake coiled within a burrow.

No attempt was made to differentiate habitat selection patterns from one site to the next. The Wild Animal Park, Mission Trails Regional Park, and the Santa Margarita Ecological Reserve typically are classified as the same habitat type, coastal sage scrub. While the study sites at Mesa and Cabrillo National Monument are distinctly different with respect to plant communities, only one animal was monitored at Cabrillo and two rosy boas at Mesa. Further work is necessary to determine if a significant difference exists between the various habitats and habitat selection by rosy boas over the geographic range where rosy boas occur.

Movement

The location data collected was use to estimate movement patterns such as total distance moved, home range size, frequency of road crossings, and urban habitat use. A site is defined as the animal's physical location in the environment. It is possible for an animal to be at the same site for several fixes in a row.

Distance moved was calculated based on the straight-line distance between an animal's last known position and the new position. Sampling effort and move statistics are outlined in Table 7. In the column labeled "Number of Moves / Number of Fixes", a percentage is shown indicating the frequency with which an animal was at a new site when radio tracked. For the purposes of this report, "Mean Move per Day" is defined as the distance moved from the last known site to the new site, divided by the number of days between the two fixes. These measurements are then averaged for each individual snake to produce the "Average Mean Move per Day", Fig. 8.

Figures 12 through 17 show each snake's relative position at the study sites and how the animals were distributed about the site. Included in several of the figures are selected man made structures with which the study animals may have interacted.

Table 5 The percent of fixes associated with the top 14 cover types listed as Cover(1) is shown for each individual snake. Cover types are: AN-annuals, ARCA-*Artemisia californica*, DB-dead brush, DERFA-dead *Eriogonum fasiculatum*, ERFA-*Eriogonum fasiculatum*, EUMI-*Euphorbia miserus*, MALA-*Malasma laurina*, NN-*Neotoma* nest, OPEN-animal in open with no cover, OPLI-*Opuntia litoralis*, RB-rodent burrow, RC-rock crevice, URBAN-man-made structure or landscape plant, VEG-a composite group of vegetation species with low occurrence. The final column represents the percentage that these 14 cover types made up for each rosy boa. The only cover type to be utilized by all seventeen rosy boas was RB (rodent burrow), which has a combined percent usage of 67.4%. Several cover types were only used by one or two animals, and on rare instances.

	Cover Type														Total
Identification	AN	ARCA	DB	DERFA	ERFA	EUMI	MALA	NN	OPEN	OPLI	RB	RC	URBAN	VEG	
LOMA-1		4.1%	1.4%		4.1%	5.4%		14.9%	1.4%		40.5%		12.2%	9.5%	93.2%
MESA-1											88.9%	11.1%			100.0%
MESA-2								26.9%			69.2%				96.2%
MT-1											61.6%	34.9%			96.5%
MT-3					25.0%						52.8%	16.7%			94.4%
MT-4		2.6%			5.1%		7.7%				56.4%	25.6%			97.4%
MT-5		2.6%			2.6%			2.6%			28.9%	5.3%	31.6%	7.9%	81.6%
SMER-1		1.4%	6.8%								74.0%	12.3%		1.4%	95.9%
WAP-1	0.6%				1.9%		2.5%	6.3%	0.6%		50.6%	2.5%		1.3%	66.5%
WAP-T											96.6%				96.6%
WAP-E											89.3%				89.3%
WAP-V											94.1%				94.1%
WAP-2	2.1%						4.8%	0.7%			63.4%	3.4%		0.7%	75.2%
WAP-3							5.7%	13.2%	1.9%		75.5%	1.9%			98.1%
WAP-4	1.0%		1.0%	1.9%	1.9%			1.0%			71.4%	2.9%			81.0%
WAP-7	5.7%			1.9%	1.9%		7.5%	7.5%			52.8%	11.3%		5.7%	94.3%
WAP-9				2.2%					2.2%	8.9%	80.0%				93.3%
Combined Percentage	0.5%	0.6%	0.5%	0.4%	2.5%	0.3%	1.7%	4.3%	0.4%	0.5%	67.4%	7.5%	2.6%	1.5%	90.8%
Standard Error	0.3%	0.3%	0.4%	0.2%	1.5%	0.3%	0.7%	1.8%	0.2%	0.5%	4.6%	2.5%	1.9%	0.7%	2.2%
No. of Individuals	4	4	3	3	7	1	5	8	4	1	17	11	2	6	17
No. of Hits	8	6	7	4	21	4	21	42	4	4	665	82	21	17	906

Table 6 The most frequent types of cover to occur in the Cover(2) field. Here, Rock Crevice (RC) and Bare Dirt (BD) are ranked first and second, respectively.

Cover Type	No. of Fixes
Aloe spp.	3
Dead *Malasma laurina*	3
Ephedra spp.	3
Woodpile	3
Yucca schedigera	4
Dead Grass	6
Encelia spp.	6
Annuals	7
Opuntia littoralis	9
Dead *Brassica nigra*	13
Artemisia californica	16
Dead *Eriogonum fasciculatum*	16
Rhus integrifolia	16
Eriogonum fasciculatum	60
Dead Brush	64
Malasma laurina	82
Leaf Litter	86
Bare Dirt	120
Rock Crevice	195
Total	712
Total Cover(2) Fixes	736

To assess rosy boa use of and response to human structures, the movements of the snakes are displayed with respect to paved roads, dirt roads, urban habitat, and chain link fences. An animal was assumed to have crossed a road if a straight line from the previous position to a new site crossed a road. If the snake was found on the road, this too was scored as a road crossing event. We only counted cases where it was obvious that the animal had to cross through a chain link fence to arrive at its new site. Urban habitat is defined as man-made structures, non-feral landscape plants, and household backyards. This includes piles of firewood, a storage shed, aloe and iceplant, a decommissioned military bunker, and concrete foundations for power generating windmills. Table 8 outlines this data on an individual basis. Only one snake, LOMA-1, had any paved roads within its home range. In four cases, snakes with dirt roads in close proximity to their home ranges did not cross these roads. Instead, they tended to move along one edge of the road or away from the road.

Site fidelity was measured as the frequency with which a snake returned to a site that it had previously left. Table 9 shows the results for the 17 rosy boas with reliable data. The column "N = 0" indicates sites where the individual snake never returned after leaving. Such a site may have been recorded for more than one fix, but to which the snake never returned once it had moved off of the site. Only WAP-4 returned to a site more than one time. Not indicated in this table is the frequency with which a snake was located at a site previously used by a different snake, which did occur on several occasions. If a snake returned to a general area, but to a different site within that area, this was not counted as a revisit. Most snakes had an area of high use, with multiple sites in close proximity.

Home Range

Home range estimates for the 17 rosy boas with sufficient sample size were calculated in several formats. Table 10 details the 95% and 100% MCP estimates by season and across the entire sample effort. Table 11 details the results of 95% and 100% Fixed Kernal (FK) estimate analysis generated by the Home Ranger application. Means

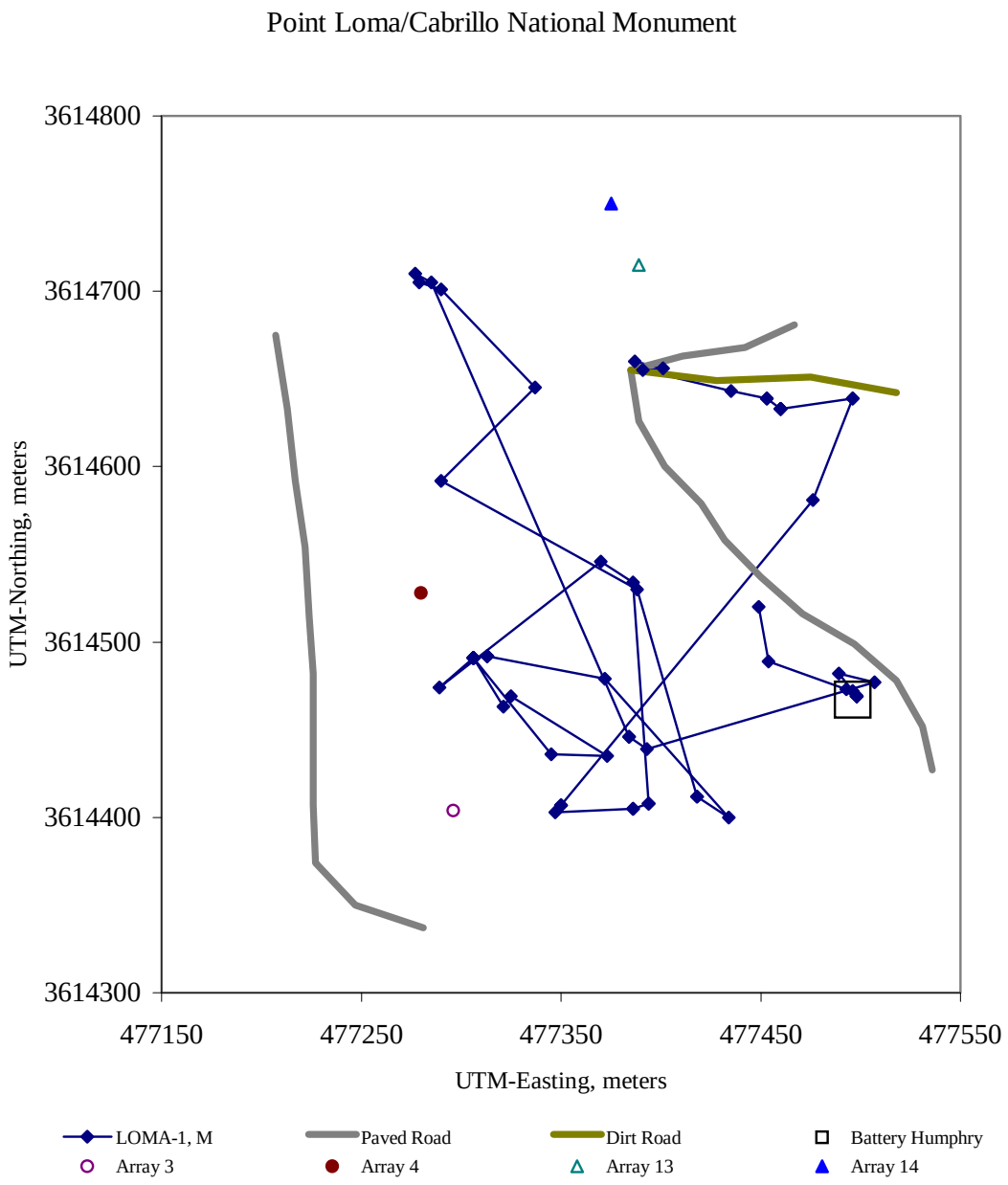


Figure 12 LOMA-1 was the only rosy boa tracked at the Point Loma/Carbrillo National Monument. It was collected on the paved road by a park ranger, where it was under attack by a California Kingsnake (*Lampropeltis getula*). LOMA-1 crossed the paved road one more time, as well as spending time in Battery Humphry, a military installation located at the end of the Point Loma peninsula. For several fixes, LOMA-1 was physically inside one of the structures on the facility, and in native vegetation within the batteries chain-link perimeter fence. LOMA-1 was never documented by the four small vertebrate pitfall arrays located near its home range. These pitfall traps have been in operation since 1995.

Lower Wild Animal Park Study Site

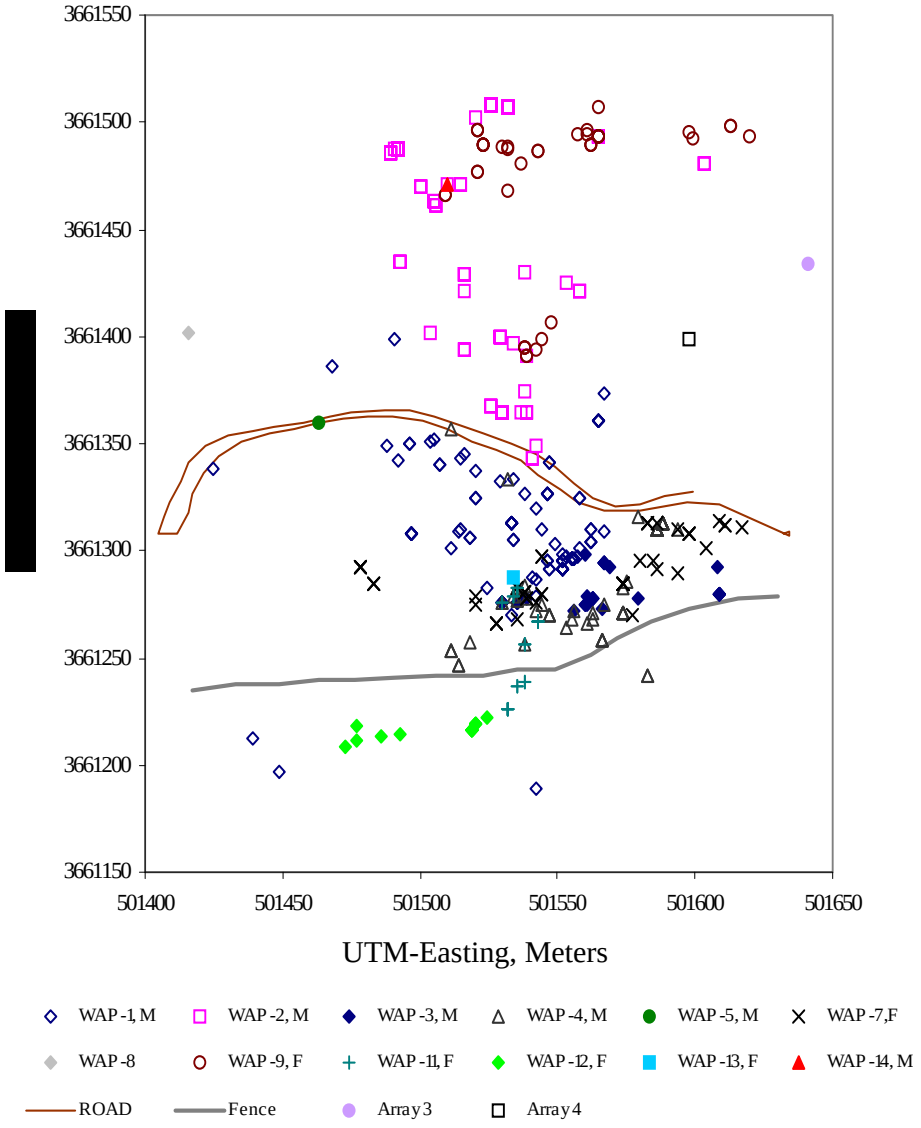


Figure 13 The lower portion of the study site at the Wild Animal Park shows a high abundance of rosy boas. In all, 12 rosy boas were documented in an area 250 meters wide by 400 meters long. Only two of these snakes were juveniles estimated to be of only one or two years in age. The positions of the snakes are overlain with the dirt road, 12-foot high chain-link fence, and two small vertebrate pitfall arrays (Fisher and Case, 2000). Only the snake referred to as WAP-1 was collected as a result of sampling efforts at Array 4. Array 3 has produced only one rosy boa record in five years of pitfall trapping.

44

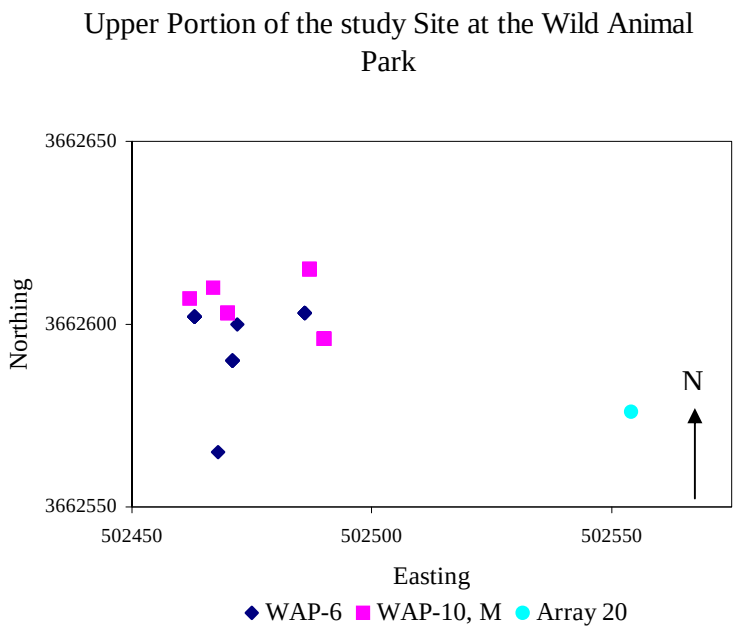


Figure 14 WAP-6 and WAP-10 were located at a site 1.5 km away from the Lower Wild Animal Park site. Both snakes returned to one or more site, resulting in a low number of total sites for each. WAP-6 has not been included in the analysis due to complications with the implantation process. Array 20 has been sampling small vertebrates in the area for the five years previous, but has never produced a rosy boa.

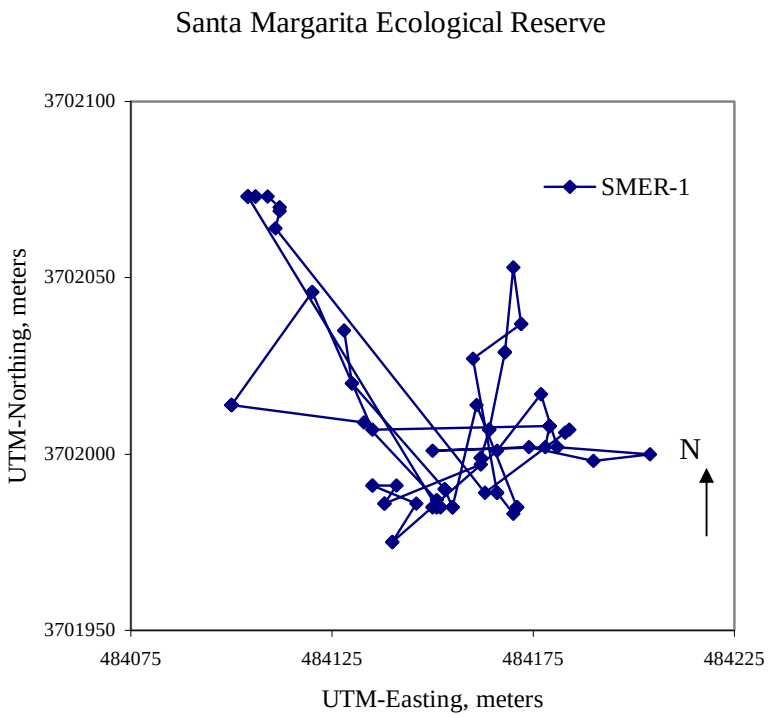


Figure 15 SMER-1 was found within the fence line of the facility operated by the San Diego State University Field Station. SMER-2 and SMER-3 are not included due to compromised data. The area where SMER-1 spent the study period is dominated by large rock outcrops and coastal sage scrub.

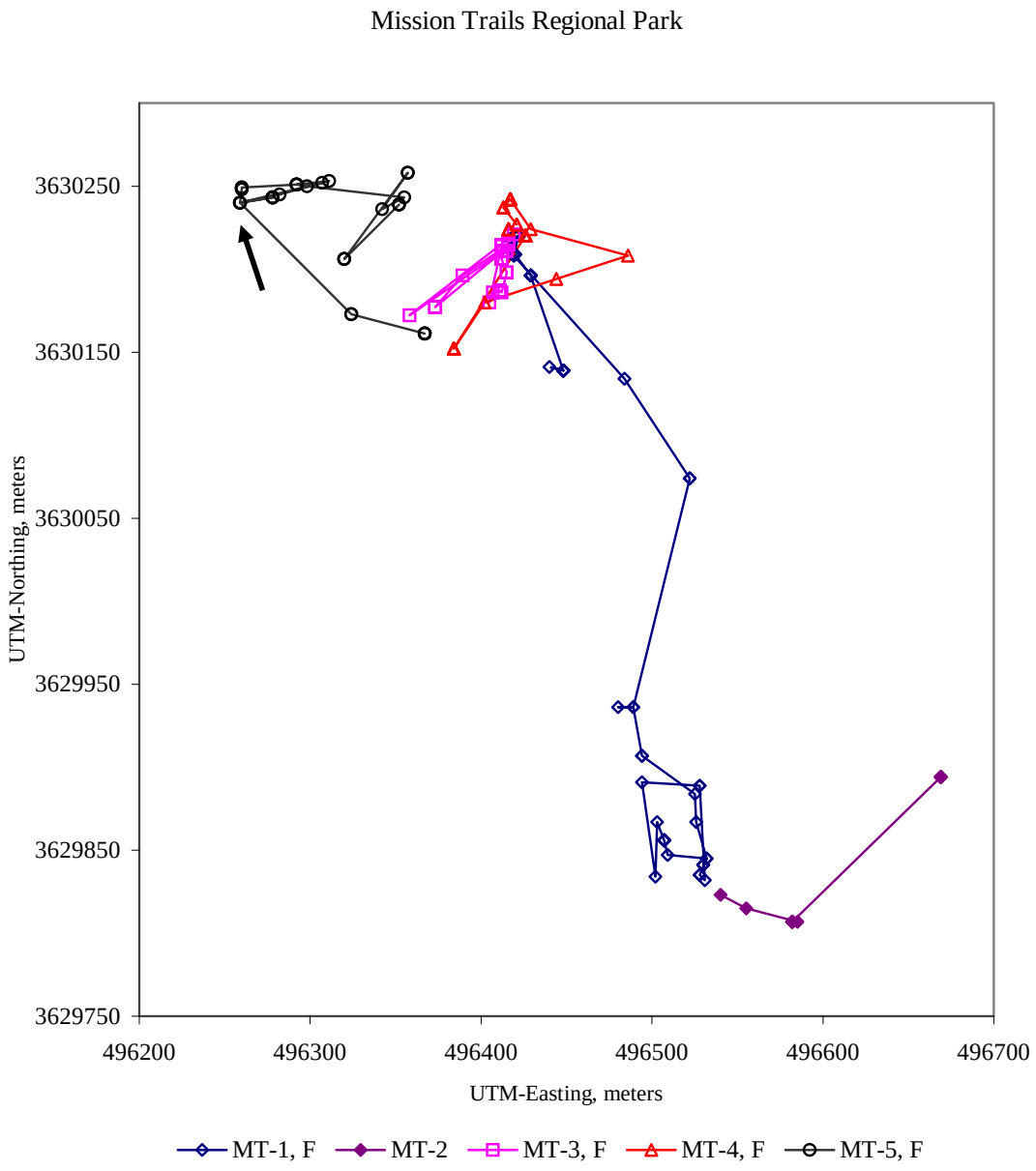


Figure 16 Five rosy boas were followed from Spring 1999 through Fall 2000 at Mission Trails Regional Park. MT-1, MT-3, and MT-4 were all located within five meters of each other in the spring of 2000 in a talus slope. During spring 2000, MT-1 made several, large moves to the south to occupy an area completely separate of the area which it had used the year before. MT-2, although shown here, is not included in any of the other data analysis due to possible complications with the implantation and recovery process. The arrow indicates sites where MT-5 was located within urban backyards, to which it made two separate visits.

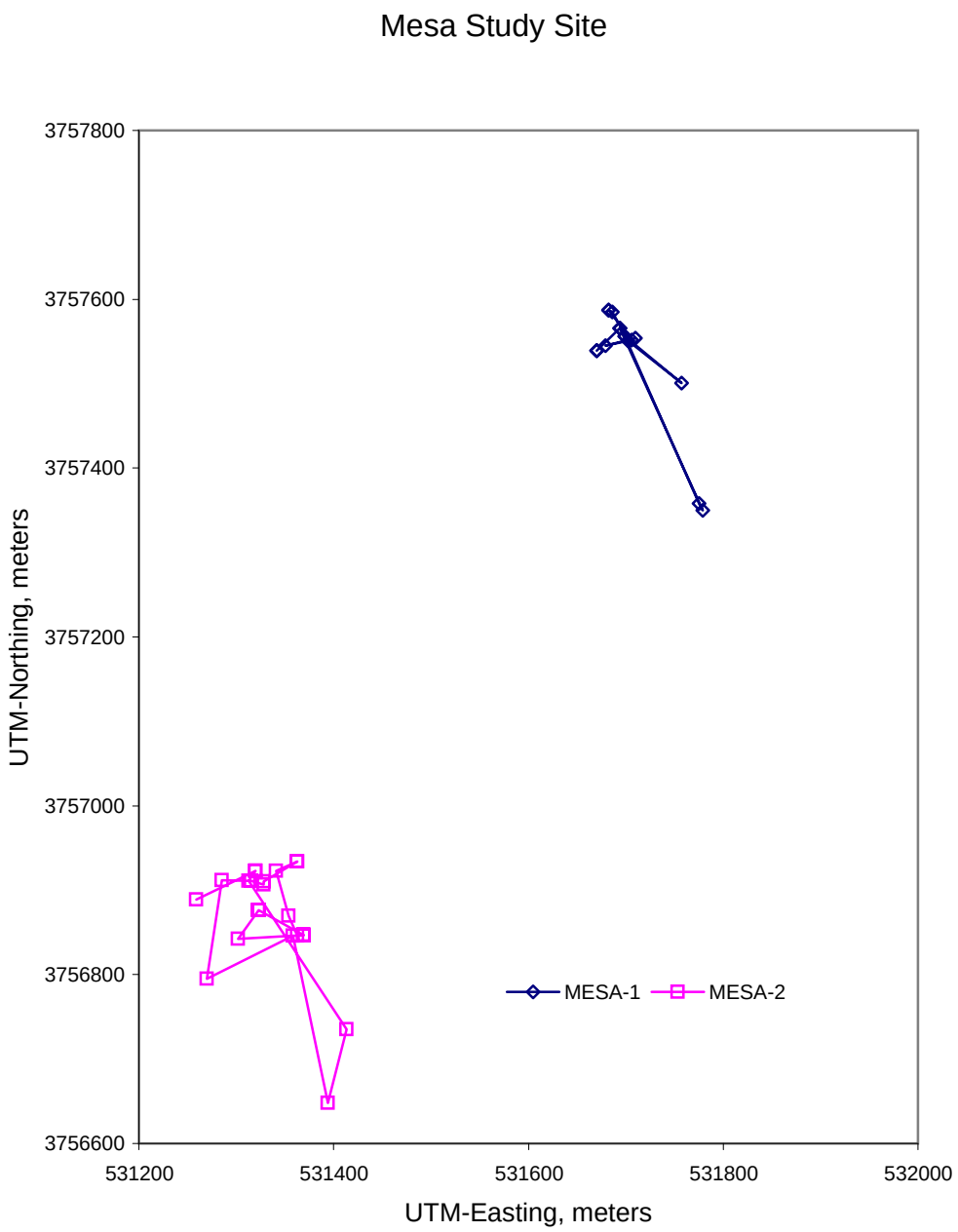


Figure 17 Two rosy boas were monitored at the Mesa study site, a male, Mesa-1, and a female, Mesa-2, during the spring and summer of 2000. The radio signal was lost on both animals, neither snake was recovered at the end of the study.

Table 7 Move statistics for rosy boas radio tracked from the Spring of 1999 through the Fall of 2000. A Fix is defined as the act of locating the animal in the field. Means displayed across the bottom are the averages of the values in the column above it.

Identification	Number of Days Monitored	Sex	Number of Fixes	Number of Moves	Total Distance Moved, meters	Number of Moves / Number of Fixes	Average Mean Move per Day, meters	Maximum Mean Move per Day, meters	Minimum Mean Move per Day, meters
LOMA-1	425	M	65	41	2038	63%	6.7	56.2	0.1
MESA-1	112	M	18	11	788	61%	10.7	27.0	0.9
MESA-2	150	F	26	18	1205	69%	12.4	29.1	1.5
MT-1	448	F	76	26	802	34%	3.5	71.0	0.3
MT-2	60	M	12	4	174	33%	5.3	10.3	1.5
MT-3	197	F	34	15	353	44%	3.6	34.5	0.2
MT-4	197	F	35	9	313	26%	2.9	22.3	0.4
MT-5	197	F	36	18	570	50%	7.9	28.7	0.5
SMER-1	518	F	81	44	912	54%	4.7	33.0	0.2
WAP-1	499	M	102	55	1767	54%	7.7	64.0	0.2
WAP-2	492	M	113	30	921	27%	4.2	35.5	0.4
WAP-3	243	M	33	12	181	36%	1.4	7.6	0.1
WAP-4	400	M	85	35	717	41%	8.4	59.5	0.6
WAP-7	201	F	51	27	473	53%	3.4	15.4	0.5
WAP-9	177	F	44	26	579	59%	4.4	32.4	0.5
WAP-10	145	M	29	5	76	17%	3.0	11.3	0.6
WAP-11	134	F	27	7	89	26%	2.3	15.1	0.2
WAP-12	109	F	17	8	70	47%	1.1	5.3	0.4
Total	4704		884	391	Mean	44%	5.2	31.0	0.5
					SE	3.5%	0.7	4.7	0.1

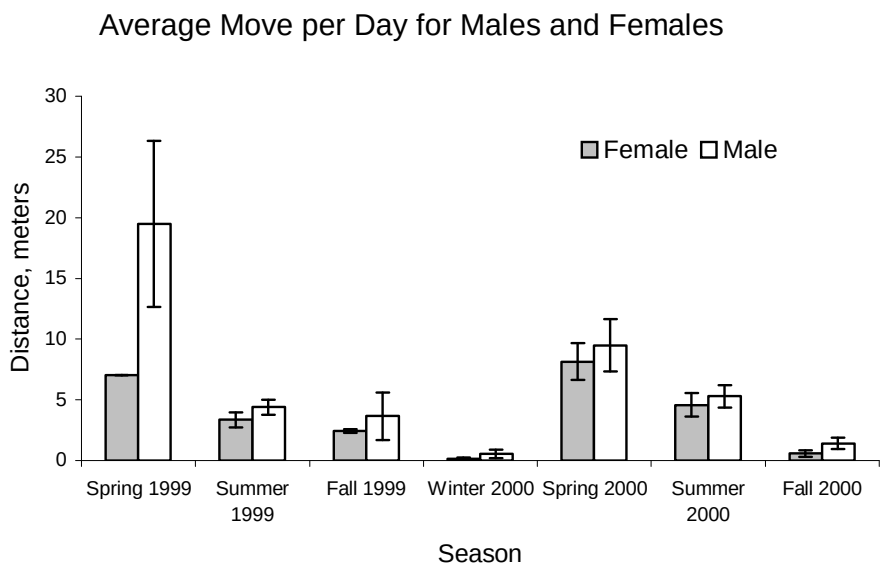


Figure 18 Male and female movement patterns by season showing the mean and standard error. Only one female was radio tracked in Spring 1999, thus there is no associated variability.

and standard errors are shown for males and females separately, and combined. The data from both methods is presented graphically in Figure 19.

For animals which were radio tracked over both 1999 and 2000, a 95% MCP was generated for each year and for the entire field effort. Data from fixes gathered from spring 1999 through winter 2000 were used as the basis for the 1999 home range estimate. Spring and summer 2000 serve as the data set for the year 2000 home range estimate. Table 12 includes the numeric summaries of the yearly and combined home range estimates. The area enclosed by both yearly home range polygon estimates is labeled as the "Overlap", that area used by the animal over both years. "Novel" area is that which is outside of the "Overlap", the area used only during that particular year. Four of the six cases show partial overlap from one year to the next, one snake used completely separate areas for the two years, and for the last snake, the 1999 range was within the 2000 range, Fig. 20. "% Novel Area" calculates the percent of each years home range which is unique to that year.

Home range has further been broken down by the number of location fixes used to determine the home range estimate. Figure 21 shows how the 95% MCP home range estimates grow as the number of location fixes increases in 10 step increments. Home range continues to grow the longer the sampling effort, only leveling out occasionally or during winter rest periods.

Discussion

The strongest point from the data collected and statistics generated is the variability and flexibility expressed by individuals within the rosy boa species. The most notable commonality across animals, sites, and measured variables appears to be the result of aestivation during the winter months. For most other variables, calculated standard errors were nearly as large as the means. Even with this variability, patterns did appear given a large enough sample effort.

Body Temperature

Table 8 Rosy boa use of man made structures and introduced plants.

Identification	Paved Roads Within Home range	Known Crossings of Paved Roads	Dirt Roads Within Home range	Known Crossings of Dirt Roads	Urban Habitat Within Home range	Number of Fixes Within Urban Habitat	Chain-link Fence Within Home range	Chain-link Fence Crossings
LOMA-1	Yes	2	Yes		Yes	9	Yes	2
MESA-1	No		Yes		Yes		No	
MESA-2	No		Yes	1	Yes		No	
MT-1	No		No		No		No	
MT-3	No		No		No		No	
MT-4	No		No		No		No	
MT-5	No		No		Yes	12	Yes	4
SMER-1	No		Yes	2	Yes	1	Yes	3
WAP-1	No		Yes	5	No		Yes	4
WAP-2	No		Yes		No		No	
WAP-3	No		No		No		No	
WAP-4	No		Yes	1	No		Yes	2
WAP-7	No		Yes		No		No	
WAP-9	No		No		No		No	
WAP-10	No		No		No		No	
WAP-11	No		No		No		Yes	2
WAP-12	No		No		No		No	
Total		2		9		22		17

Table 9 Site fidelity of rosy boas radio tracked starting in the Spring of 1999 through the Fall of 2000. N = 0 equals sites that a snake never returned to. Some snakes never returned to a site, Wap-4 was the only snake to return to a site more than once.

Identification	Number of Sites with N Revisits				Total Number of Sites Detected	Number of Fixes
	N = 0	N = 1	N = 2	N = 3		
LOMA-1	37	2			39	65
MESA-1	11				11	18
MESA-2	18				18	26
MT-1	24	1			25	76
MT-3	13	1			14	34
MT-4	9				9	35
MT-5	14	2			16	36
SMER-1	44				44	81
WAP-1	53	1			54	102
WAP-2	28	1			29	113
WAP-3	12				12	33
WAP-4	25	3	1	1	30	85
WAP-7	25	1			26	51
WAP-9	24	1			25	44
WAP-10	3	2			5	29
WAP-11	7				7	27
WAP-12	8				8	17

Table 10 Minimum Convex Polygon home range estimates, in meters square, for 17 rosy boas tracked starting in the spring of 1999 through the summer of 2000. Where possible, the mean and standard error is calculated, for each sex separately and also the two combined. Where home range estimates are zero (0), Cal Home was unable to calculate an area due to the animal using either one or two sites only over the course of the season, even though the animal may have been tracked more frequently.

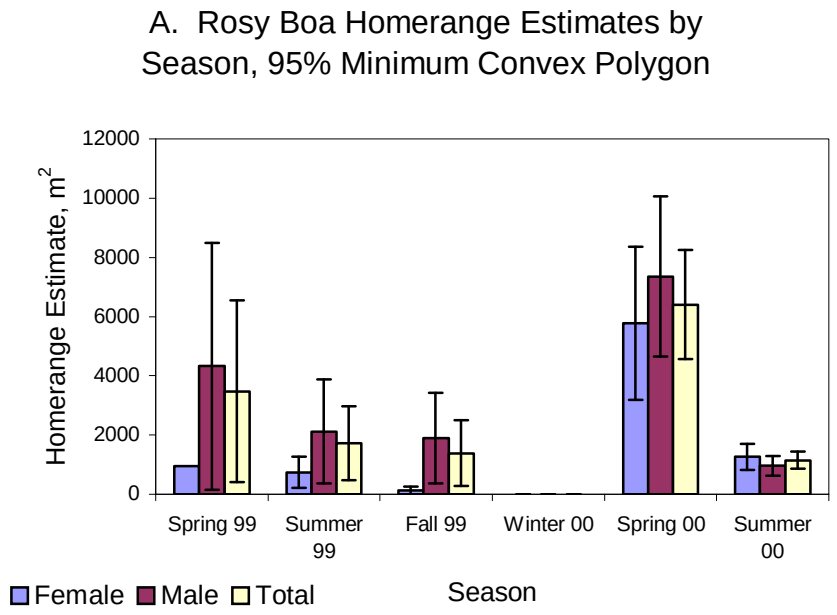
Sex	Animal ID	Spring 1999			Summer 1999			Fall 1999			Winter 2000			Spring 2000			Summer 2000			Across all Seasons		
		95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n
Female	Mesa-2													20760	20760	9	4455	4455	17	18520	25310	26
	MT-1				209	209	13	0	0	16	0	0	14	17320	18260	27	1047	1047	10	16310	18450	81
	MT-3													148	176	23	357	357	9	832	1020	34
	MT-4													2150	3764	23	0	0	10	2150	3764	35
	MT-5													2869	2887	26	1963	1963	9	6325	6325	37
	SMER-1	942	942	17	1264	1535	24	265	265	10	0	0	5	1679	1679	17	1580	1580	13	5143	6422	86
	WAP-7													1392	1844	26	2441	2795	21	3159	3822	51
	WAP-9													5666	6207	23	469	469	19	5798	6801	44
	WAP-11													7	7	8	94	94	17	436	436	27
	WAP-12																227	227	15	324	324	17
	Mean	942	942	17	737	872	19	132	132	13	0	0	10	5777	6176	20	1263	1299	14	5900	7267	44
	SE				528	663	6	132	132	3	0	0	5	2583	2605	2	443	455	1	2046	2604	7
Male	Loma-1	268	268	8	9104	9104	9	7911	7911	13	0	0	8	17270	17270	15	109	109	10	49300	54380	65
	Mesa-1													7781	7781	10	689	689	7	8563	8563	18
	WAP-1	12660	12660	10	984	984	8	1520	1520	19	9	9	16	11370	13180	27	1019	1127	20	9732	23860	102
	WAP-2	41	41	6	4	49	21	0	0	19	0	0	16	7417	7417	30	1397	2027	21	9598	10750	115
	WAP-3				517	762	21	0	0	11										1033	1318	35
	WAP-4				0	193	21	29	29	19	**	**	**	292	1089	22	2286	2286	17	3218	7024	85
	WAP-10													0	0	10	257	257	17	262	279	29
	Mean	4323	4323	8	2122	2218	16	1892	1892	16	3	3	13	7355	7790	19	959	1082	15	11672	15168	64
	SE	4169	4169	1	1755	1730	3	1533	1533	2	3	3	3	2699	2736	4	329	371	2	6452	7165	14
Both	Mean	3478	3478	10	1726	1834	17	1389	1389	15	2	2	12	6408	6821	20	1149	1218	15	8277	10520	52
	SE	3067	3067	2	1243	1228	2	1107	1107	1	2	2	2	1836	1855	2	298	309	1	2884	3334	7

** The radio transmitter in WAP-4 died over the winter. The animal was removed from the field for the duration of the winter until spring when a new transmitter could be re-implanted.

Table 11 Fixed Kernal home range estimates, in meters square, for 17 rosy boas tracked starting in the spring of 1999 through the summer of 2000. Where possible, the mean and standard error is calculated, for each sex seperately and also the two combined. Where home range estimates are zero (0), the program Home Ranger was unable to calculate an area due to the animal using either one or two sites only over the course of the season, even though the animal may have been tracked more frequently.

Sex	Animal ID	Spring 1999			Summer 1999			Fall 1999			Winter 2000			Spring 2000			Summmer 2000mer 00-F			Total		
		95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n	95%	100%	n
Female	Mesa-2													19762	42045	9	1012	2311	17	2823	6267	26
	MT-1				113	260	13	0	0	16	0	0	14	2302	5008	27	83	179	10	8595	18105	81
	MT-3													62	141	23	17475	37693	9	451	983	34
	MT-4													1432	3339	23	0	0	10	1048	2412	35
	MT-5													840	1730	26	975	2131	9	888	1893	37
	SMER-1	83	190	17	886	1766	24	57	130	10	0	0	5	18	38	17	472	1080	13	1284	2649	86
	WAP-7													518	1100	26	1341	2682	21	2220	4119	51
	WAP-9													2771	5900	23	122	265	19		4981	44
	WAP-11													5	13	8	84	197	17	169	362	27
	WAP-12																46	110	15	111	252	17
	Mean	83	190	17	500	1013	19	29	65	13	0	0	10	3079	6590	20	2161	4665	14	1954	4202	44
	SE				387	753	6	29	65	3	0	0	5	2112	4491	2	1708	3684	1	883	1666	7
Male	Loma-1	14225	29779	8	8215	16580	9	1792	4023	13	0	0	8	8581	18581	15	12	30	10	24251	48330	65
	Mesa-1													1308	2923	10	490	1089	7	1179	2489	18
	WAP-1	2787	6703	10	104	191	8	138	321	19	4	9	16	3077	6560	27	376	764	20	4108	7799	102
	WAP-2	44	98	6	98	234	21	0	0	19	0	0	16	2430	5542	30	161	346	21	3178	7128	115
	WAP-3				205	458	21	0	0	11										451	989	35
	WAP-4				129	328	21	2	6	19	**	**	**	269	559	22	917	1909	17	2059	4419	85
	WAP-10													0	0	10	51	122	17	62	152	29
	Mean	5685	12193	8	1750	3558	16	386	870	16	1	3	13	2611	5694	19	335	710	15	5041	10187	64
	SE	4343	8997	1	1616	3256	3	352	791	2	1	3	3	1290	2789	4	139	290	2	3248	6451	14
Both	Mean	4285	9192	10	1393	2831	17	284	640	15	1	2	12	2892	6232	20	1476	3182	15	3305	6666	52
	SE	3375	7034	2	1142	2301	2	252	566	1	1	2	2	1331	2835	2	1072	2312	1	1495	2808	7

** The radio transmitter in WAP-4 died over the winter. The animal was removed from the field for the duration of the winter until spring when a new transmitter could be re-implanted.



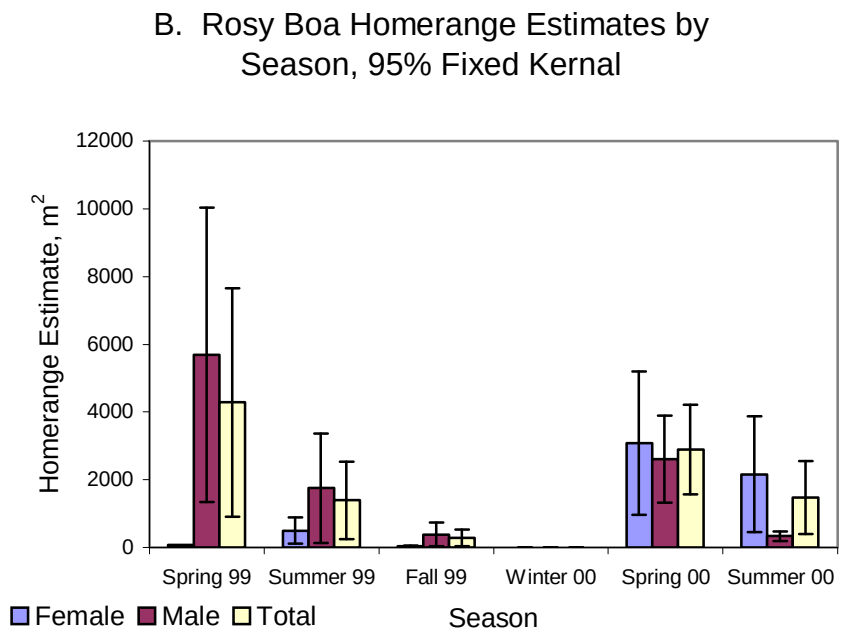


Figure 19 A. The mean 95% Minimum Convex Polygon home range estimates for males and females, separately and combined. B. The mean 95% Fixed Kernel home range estimates for males and females, separately and combined.

Table 12 1999 and 2000 home range estimates, 95% MCP, are compared for those rosy boas were data was available for both years. "Area" is the 95% MCP estimate, "Overlap" is the area bound by both the 1999 and 2000 polygon, and "Novel" refers to the portion of the "Area" outside of the "Overlap". These statistics are graphicaly summarized in Figure 20 . "Novel / Area" depicts the percent of each years homerange that was unique to that particular year. The extent of variablity between individuals can be seen when comparing the "Novel / Area", which ranges from as high as 100% to a low of 0%, in addition to the large standard errors.

Animal ID	1999				Overlap	2000				Total	
	Area	n	Novel	Novel / Area		Area	n	Novel	Novel / Area	Area	n
WAP-1	4392	53	2382	54%	2010	6371	49	4361	68%	9731	102
WAP-2	88.5	62	88.8	100%	0	8845	53	8845	100%	9598	115
WAP-4	630	44	459	73%	172	2231	41	2059	92%	3218	85
Loma-1	27327	38	14859	54%	12468	26646	27	14178	53%	49302	65
SMER-1	2722	56	950	35%	1772	3710	30	1939	52%	5143	86
MT-1	154	43	0	0%	154	17667	38	17511	99%	16314	81
Mean	5886	49	3123	53%	2763	10912	40	8149	78%	15551	89
(SE)	4344	4	2374	14%	1974	3853	4	2674	9%	6999	7

A significant step towards understanding the thermal requirements and body temperature patterns of the rosy boa has been made as a result of this study. Nearly 700 field collected body temperature measurements were made through the effort of radio tracking the 13 individual snakes with temperature sensitive transmitters (Table 3). 1000's of measures were made through the use of the automated program "SnakeByte", which has allowed for a more detailed look at how the body temperature of this ectothermic species might change over the course of the day (Figure 7 and Figure 8).

Patterns detected by automation show that the rosy boa shares thermoregulatory similarities with its closest relative in the United States, the rubber boa (*Charina bottae*). Although the two species come from considerably different climates, the rubber boa in the cooler mountainous reaches of the west and the rosy boa from the arid southwest, daily thermal profiles are still very comparable between the two. The four patterns described by Dorcas and Peterson (1998) for the rubber boa were also observed for the rosy boa.

One feature that was missing from the automated daily body temperature profiles was any sign of absolute nocturnal activity, the traditional label given to the rosy boa (Stebbins, 1985). All of the recorded temperature curves only showed temperature fluctuations between the hours of 6 AM and 6 PM. A change in body temperature should represent a change in position in the environment or some type of activity. Most of the temperature profiles recorded by this project to date would better be described as a crepuscular or diurnal pattern. It is possible that the rosy boa changes its daily activity patterns, from diurnal to nocturnal, based on environmental factors, as has been shown for several other species of snakes, (Heckrotte, 1962, Landreth 1973, and Sanders and Jacob, 1980). All of the rosy boas that were monitored with this technique were in the coastal region, rosy boas in a more desert environment may have a higher tendency towards nocturnal behavior as sited in a recent report on road cruising results by Toure (2001). Coastal rosy boas are known to be active at night, as evidenced by individuals being found as a result of night driving efforts during this study. But perhaps, they are not as nocturnal as previously reported. Further research is needed to determine whether a strong behavioral difference exists between the two subspecies or regions.

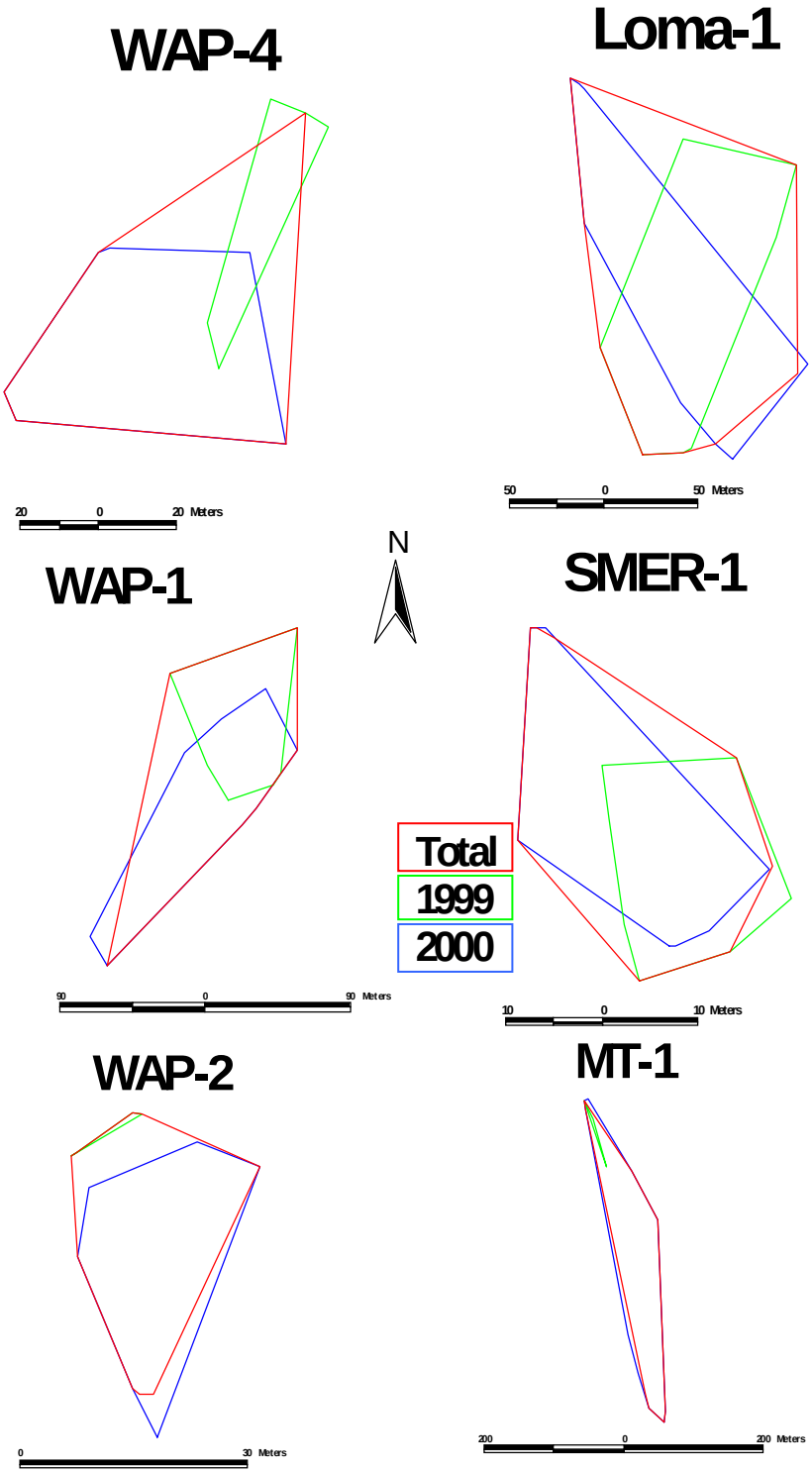


Figure 20 95% Minimum Convex Polygon estimates of home ranges are shown for six different rosy boas which were radio tracked over consecutive years. Spring 1999, Summer 1999, Fall 1999, and Winter 2000 data points were used to generate the 95% MCP for 1999, and Spring 2000 and Summer 2000 were used for the year 2000 home range estimate. While the yearly home ranges for most individual overlap, there is a large amount of novel area per year. MT-1's 1999 home range estimate was completely within the 2000 home range estimate, and WAP-2's yearly home range estimates were completely separate.

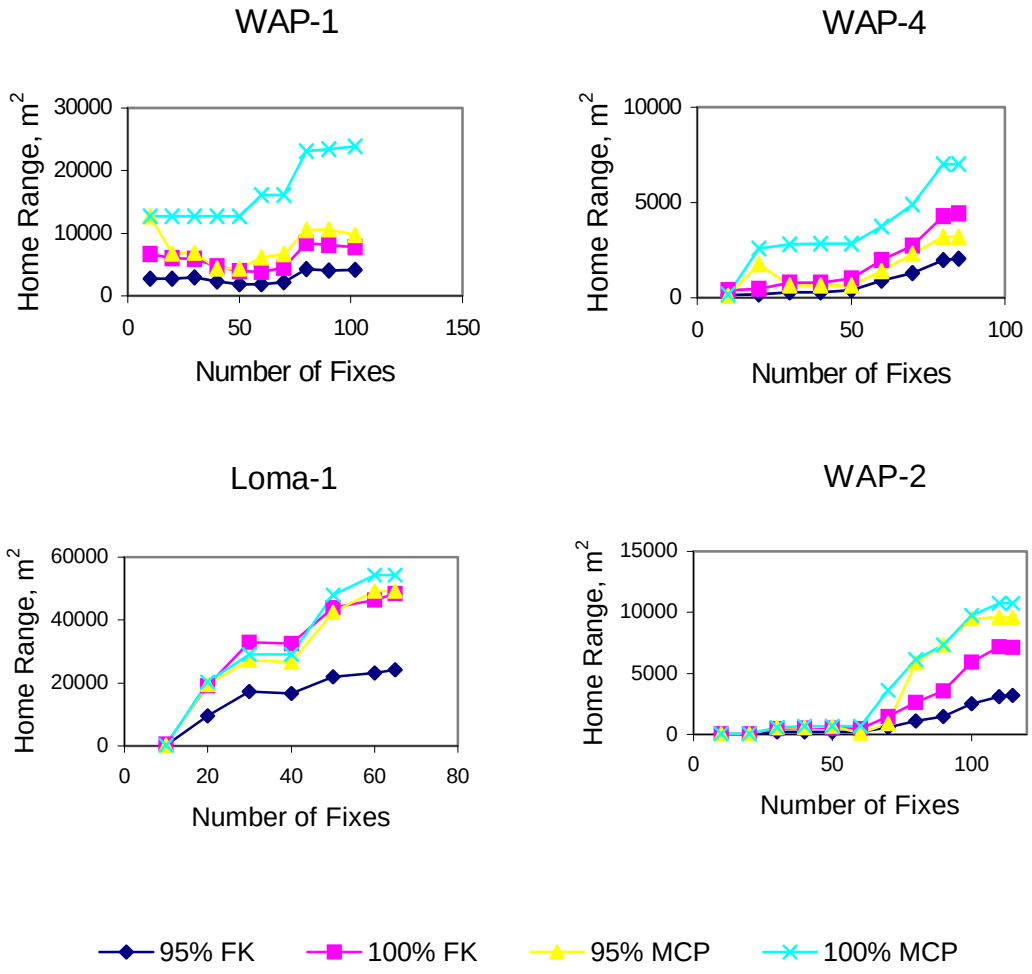


Figure 21 Home range growth curves for four rosy boas calculated for every ten location fixes. At every ten step interval, an animal's home range was determined at four levels, 95% Fixed Kernal (FK), 100% FK, 95% Minimum Convex Polygon (MCP), and 100% MCP. Loma-1 shows the clearest pattern of home range growth by season and year. Starting in Spring 1999 when it was first collected, home range steadily grows until the 30th fix where it plateaus off. Fixes 30 through 40 represent Winter 2000, a time period when the animal is known to have remained in one or two places for the entire three-month period. The same pattern of growth and plateau can be seen after the 40th fix, representing the year 2000 seasons. To some extent, the same pattern of growth and leveling out can be seen for each of the four snakes. The leveling out at the end of each of the curves should not be considered as the animals having reached its maximum home range size, but rather, that this set of ten location fixes represent the onset of Fall and Winter 2000.

Activity

Unquestionably, rosy boas spent the majority of their time hidden away in underground retreats. In all of the location fixes during the months of November, December, and January, both males and females were underground. Only in early spring did this pattern show any significant signs of variation, dipping to 50% or 60% of the location fixes. This rate is still two to five times higher then that reported for other species for the comparable season (Keller and Heske, 2000). Often, the presence of the radio tagged animals would have been difficult to impossible to detect had it not been for the electronic advantage of the radio receiver. When not underground, a rosy boa was most likely to be found surface basking, Fig. 10. The rosy boas above ground seasonal activity pattern is unimodal, as described by Gibson (1987), with the exception that the rosy boas single peak of activity occurred in early spring rather than late spring or late summer.

As noted in other reports (Parizek, 1996, Stebbins, 1985), rosy boas were occasionally found within plants, elevated above ground level. These two behaviors, tree basking and tree cruising, occurred predominately during the months of May, June, and July. And were noted in members of both sexes, as well as at three of the five study sites. It has been suggested that this behavior may be part of the rosy boas foraging strategy, they may be looking for nestling birds upon which to prey.

Cover

Since rosy boas spent the majority of their time underground, rodent burrows were the most commonly used form of cover recorded in this study. At an average of 67% of the fixes, rodent burrows occurred nearly eight times more frequently than rock crevices, which was the second highest cover type at 7.5%. The rosy boa is typically considered a saxicolus species that lives in and among rock cracks. The data here might suggest otherwise, that the rosy boa utilizes a wider range of microhabitats than previously considered. Based on Table 5 and Table 6, radio tracked snakes were less likely to be located in a rock crevice or a rodent burrow with associated rock crevices as a rodent burrow and some other type of secondary cover, such as bare dirt or leaf litter. A rock crevice is simply the position where an individual is most likely to visually

encounter a rosy boa. Any number of rosy boas may have been along the path taken to reach the rock pile, but were merely underground, out of sight, or under a Sumac bush (*Malosma laurina*) or other coastal sage scrub plant undetected.

Movement and Home Range

It would be suggested that a true lifetime home range for the rosy boa has not been determined in the course of this study. Table 12 shows that each year a snake may use as much as 100% new and novel area from the preceding year. The snakes monitored by this study used on average 78% new territory in 2000 when compared to their 1999 home range. 1999 home ranges averaged 53% unique area not used during the 2000 season. Even if this pattern of expansion occurred at a conservative rate of once every other year over a 12-year life span, a one year home range of 6,000 m^2 could potentially represent a lifetime home range from anywhere between 21,000 m^2 to 29,000 m^2. Figure 21 supports this idea that home ranges continue to grow. The more that a snake was radio tracked, the larger its measured home range continued to grow. Even at an estimated 29,000 m^2 or 2.9 ha, the rosy boa has a relatively small home range when compared to other snake species (Shine, 1987, Secor, 1995, Plummer, 2000).

At sites where more than one individual was radio tracked, extensive overlap between individual home ranges was documented. With regards to sex, all combinations of overlap occurred, male-male, male-female, and female-female. The MCP home range of WAP-1 alone included the home ranges of six other known rosy boas, in part or in total. The home ranges of two males, WAP-2 and WAP-4, as well as four females, WAP-7, WAP-11, WAP-12, and WAP-13, were within the area used by WAP-1 at one time or another. Members of the same sex were documented to be within a meter or less of one another. WAP-2 was less than 0.5 meters from WAP-14, both males, when WAP-14 was first collected.

Normal Behavior

A common concern regarding this type of study, is the impact of human actions on the natural behavior of the study animals, (Fitch, 1987). Based on several

observations, it is believed that the majority of the study animals behaved in a manner consistent with wild, un-monitored animals. On several occasions, rosy boas with transmitters were found within one meter or less of a previously undocumented snake. Indicating that the snakes with transmitters were selectively using the same habitat as snakes that had zero to little known human interactions. Radio tracking WAP-1 resulted in the collection of WAP-7, WAP-2 was responsible for leading field researchers to WAP-9 and WAP-14, and WAP-4 was just cm from where WAP-11 was first documented.

Interest in mating and reproductive success are often used as a measure of normal behavior. Several of the snakes appeared to pair with a member of the opposite sex for a short period of time in the spring of 2000. Having been found together on March 31, 2000, WAP-2, a male, and WAP-9, female, went their separate ways, only to reunite two months later on June 5, 2000. WAP-2 had traveled 360 meters and WAP-9 traveled 410 meters. They were together for the next four location fixes, over an eight day period. The site where they were located together was within the previous home range of WAP-9. WAP-2 made a 130-meter move in eight days into new territory in order to reach the shared site. Afterwards, WAP-2 returned to its former area. Likewise, WAP-4 and WAP-11 spent time together in a shared rock crevice.

Reproductive success was never documented within the study group. Such documentation proved difficult to acquire given the species tendencies to remain underground. The two females that were suspected to have mated, WAP-9 and WAP-11, were never seen above ground after spending time with a known male. However, these two females did demonstrate the top two average body temperatures, 31.0 □C and 30.3 □C respectively, for those snakes monitored during the summer 2000 season. All females, including WAP-9 and WAP-11, had a combined average body temperature of 27.9 □C for the summer 2000 season, dropping to 26.8 □C if WAP-9 and WAP-11 are removed from the group. Research has shown that gravid females of several species select higher body temperatures while gestating (Peterson, 1993). Within the study subjects, a mix of non-gravid females and gravid females may explain the absences of any consistent temperature differences between the two sexes, as noted in Figure 5.

Urban Habitat Use

While most of the rosy boas monitored in the study spent the majority of their time in native habitat, a notable amount of time was recorded in settings with signs of human impact by at least three of the snakes. All of the urban records for these rosy boas were in areas of low traffic where it was unlikely for the animals to be discovered or molested. The landowners most likely would have never known of the presence of the snakes if they had not been notified. Luckily, all landowners involved agreed to allow the snakes to remain undisturbed while within their properties. In all cases noted, the native landscape closely contacted the urban site used by the rosy boas. Additionally, each urban habitat usage required the snake to cross through a chain-link fence to enter and exit the sites.

The most notable use of urban habitat was by MT-5, who not only used a residential backyard as cover, but actually returned to it after having moved into native habitat. MT-5's first visit to the backyard area was on April 27, 2000. Over the following four location fixes, it was found in native habitat. On May 16, 2000 it returned to the same backyard, and remained in the nearby area for the next two months and ten location fixes. Between the first visit and the date of return, MT-5 visited two other sites and covered a distance of nearly 95 meters. The storage shed and surrounding woodpiles may have been serving as a food source that attracted MT-5 back. All sites within the backyard were within a fenced off portion of the yard which was closed off to the family's dog.

LOMA-1's use of human structures is also noteworthy. LOMA-1 was able to find shelter under the metal weather flashing which ran along the joint between the wall and roof of Battery Humphry, a decommissioned military bunker. Battery Humphry is partially underground, and as such, the roof is at ground level within easy reach of a snake. The snake could not be seen from inside the structure, which houses a loud power generator. For the next four location fixes, it remained under the metal flashing with no change in position. On the fifth fix, it was visually confirmed in nearby landscape plants. The following fix, the snake had returned to its position under the roof flashing.

Based on the numbers in Table 8, chain link fences pose no barrier to rosy boa movements. Six individuals were recorded to have crossed through and back on at least

one occasion. In several cases, the habitat into which the snake entered by crossing the fences was urban habitat or degraded native habitat when compared to the habitats in which the snakes spent most of their time. Any more substantial form of fencing would most likely serve as a significant barrier, impeding movement and fragmenting habitat.

Surveys

The results of this study and its related field efforts would seem to indicate that the most effective time of year to survey for rosy boas is in the early spring. Only during the months of March, April, and May, did the study animals show any significant amount of time above ground. In April, males were documented above ground at the same frequency as underground, Figure 9. All other times of the year, the rosy boas were underground for nearly 90% of the fixes or greater.

As for survey technique, visual searching and road riding located the most snakes. The San Diego Zoo's Wild Animal Park serves as a good example of this point. The United States Geological Survey has been conducting small vertebrate sampling at the site for the previous five consecutive years, starting in 1995. This sampling effort includes 140 pitfall traps, 60 funnel traps, 900 meters of drift fence distributed over 2 kilometers of study area. With 300 sample days in the past five years, only eight rosy boas were previously known from the Wild Animal Park, this includes the rosy boa identified as WAP-1. Over the course of the year and a half of visual surveys and radio tracking, an additional 13 rosy boas were found in close proximity to the five-year study plots. Figure 13 shows that in an area only 250 meters wide by 400 meters long, 12 previously unreported rosy boas were documented. If these 12 snakes are added to the two previously recorded at the nearby pitfall arrays, each snake recorded by the pitfall sampling may represent as many as seven rosy boas in the nearby study area. The eight rosy boas documented by the pitfall study could be extrapolated to represent nearly 56 rosy boas in the study area covered by the pitfall arrays.

In credit to the five-year study plots, the two closest, arrays 3 and 4, each had documented one rosy boa. Of the 12 rosy boas at the lower Wild Animal Park site with radio transmitters, only WAP-1 and WAP-2 ever came within 50 meters of a pitfall array. WAP-1 was collected within 50 meters of array 4, and after implantation and release, it

moved away from the array. For three location fixes covering six days, WAP-2 was within a 50 meters radius of the same array. All three fixes were at the same site. If a radius of 100 meters is extended from these two arrays, more snakes come into range. A 100 meters radius from array 3 would include a portion of the home ranges of three rosy boas, WAP-1, WAP-2, and WAP-9. The same distance from array 4 would cover these three snakes, plus WAP-4 and WAP-7. However, WAP-4 and WAP-7 were on the opposite side of a dirt road from the arrays. Both snakes skirted the edge of the road, but were never detected to have crossed the road. These two pitfall arrays, while near many rosy boas, were just outside of the ranges of these snakes.

At the Cabrillo/Point Loma site, there are four pitfall trap arrays in the vicinity of the rosy boa at this study site. Loma-1 spent three months within 50 meters of array 4. Of course, all three months were at the same site while the animal was down for the winter, with no recorded movement during this time period. When active, distances moved by LOMA-1 could easily have taken it to within 50 meters of all four arrays over the study area.

In addition to documenting rosy boas at the various sites, the search and tracking efforts also produced notes on other reptile and amphibian species. Across the Wild Animal Park, 15 red diamond rattlesnakes (*Crotalus ruber*) were encountered, as well as one southern Pacific rattlesnake (*Crotalus viridis*), one speckled rattlesnake (*Crotalus mitchelli*), three western toads (*Bufo boreas*), four granite night lizards (*Xantusia henshawi*), four California striped racers (*Masticophis lateralis*), one patch nose snake (*Salvadora hexalepis*), one California kingsnake (*Lampropeltis getula*), and countless western fence lizards (*Sceloporus occidentalis*) and Granite spiny lizards (*Sceloporus orcutti*). Six additional snakes were noted at the Santa Margarita Ecological Reserve. They were two speckled rattlesnakes (*Crotalus mitchelli*), three red diamond rattlesnakes (*Crotalus rubber*), and one California kingsnake (*Lampropeltis getula*). Four red diamond rattlesnakes, along with western fence lizards, were the only other reptiles noted at Mission Trails Regional Park. At Cabrillo NM/Point Loma, only the California kingsnake (*Lampropeltus getula*) that was attempting to eat the rosy boa, LOMA-1, when both were collected was observed at the site. No other snakes were observed at Point Loma during all the time spent in the field. Particularly surprising was the lack of gopher

snake observation in the area where the rosy boas was radio tracked. Gopher snakes and kingsnakes are typically very common, even in disturbed areas in California, and should have been seen more regularly.

Conservation

Public awareness and education would go a long ways in conserving both individual snakes in the wild and the habitat they require. As a mild mannered species, highly prized as pets, rosy boas often leave wildlife areas with general use visitors as well as snake hunters. Signage stating the regulations and nature of protected areas with respect to the removal of native species would aide in bringing the subject to mind as visitors enter and exit wildlife areas. In areas where collecting is known to occur and is allowed, signage indicating the type of wildlife permit required and take limits would serve to educate users on the legal aspect of their actions. A posted dollar amount for permit and take violations would function to reinforce the seriousness and severity of the laws regulating wildlife collection

In wildlife areas where the public has ready access, efforts can be made to redirect visitors away from sensitive areas. Although this study has shown that rosy boas are not restricted to rock piles and rock crevices, these locations are still where they are most often visually encountered. While the probability of finding a rosy boa is very small at any given site, elevated human presence around such a site results in an increased probability of detection and removal. As snakes are collected and removed from these target areas, there may be an extensive lag time in new animals moving in and occupying the space, based on the relatively sedentary life style of this species and small home range sizes. Where possible, redirecting visitors away from such areas will help to reduce the incidental encounters at these locations. These efforts would be most effective during the peak activity period for the species, March, April, and May, when rosy boas have been shown to be less frequently underground, Fig. 9.

As with many species in coastal southern California, the rosy boa suffers from habitat loss primarily due to development and fragmentation. Only 10% of the coastal sage scrub habitat remains. While rosy boas were not shown to have a complete avoidance of roads, paved or dirt, the tendency of those snakes monitored was to move

along the edge of the road or away from the road. Carefully examination of Figure 13, which shows the lower portion of the Wild Animal Park study site, will show that here, the dirt road served as the boundary for at least a portion of the home range of three different rosy boas. The north edge of the road marked the southern extent of WAP-2's home range. And the south side of the same dirt road, a mere four meters away, served as the northern boundary for both WAP-4 and WAP-7. Suitable habitat existed on the opposite side of the road from each of these snakes, as demonstrated by the presence of a known individual, yet each snake remained on its respective side of the road. Home range estimates and movement statistics for each animal, Table 7 and Table 10, would indicate that each snake was otherwise capable of crossing the four meters to the opposite side of the road. Comparing activity to cover type shows that only four out of 32 instances of surface cruising were documented in the open, without any form of cover at all. Since the physical distance across the road would appear not to be a challenge, the lack of cover provided by the road would be the most probable barrier to rosy boa activity.

The remainder of the time, this species is nearly undetectable in underground retreats, which both helps and hinders the species. While being secluded underground might protect the rosy boa from its natural predators and humans on foot, it does little to benefit the species from development. Intensive surveys for the species are required in order to detect even a very few animals within a population, as demonstrated by the small-vertebrate sampling at the Wild Animal Park. Surveys of a site prior to development may fail to show the presence of the species. Development and construction often begin with grading the landscape, scraping away the top layers of soil, including any snakes that may be hiding in a rodent burrow. Soil, native habitat, snake, and all are mechanically removed.

Mortality

Of the twenty-one individuals implanted with radio transmitters, two are suspected to have died due to complications related to the implantation process. The snake identified as WAP-6 received its implant near the end of September (Table 2). Subsequent tracking efforts showed this animal to have been more active about the

surface then was typical for the time of year, based on the activities of the other snakes at the site. Upon a visual inspection of the animal, it was noted that it had suffered a significant weight lose, and was down to nearly 52% of its pre-operation body weight. In the process of returning the animal to the lab, it went into shock and died shortly there after. The symptoms displayed by WAP-6 were consistent with those outlined by Rudolf et. al. (Rudolph, D. C., 1998) in a recent paper. Future snakes collected late in the season were not implanted. They received a PIT tag for identification purposes and were released immediately. SMER-3, from the Santa Margarita Ecological Reserve, also was lost due to complications. Shortly after release at the study site, it was found dead on the ground surface with the incision area open. The whip antenna had backed out from under the skin and was protruding through the opening. Tissue and muscle around the incision showed signs of dehydration.

Three more animals were lost from the project, two as a result of predation and one unknown. The third attempt to track SMER-2 indicated that the snake had crossed the Santa Margarita River, moved 400 meters up stream, and climbed a 15 meter rock face, all in a two day time period. With the aide of rope and harness, the transmitter, minus snake, was recovered from a rock ledge half way down the face of the cliff. The rock ledge was littered with the remains of countless animals, including a partial rosy boa skeleton. WAP-3, from the Wild Animal Park, showed a similarly large, uncharacteristic move well into the project. In a short time period, it traversed a paved parking lot, a moderately busy, two lane road, and a 50 meter wide agricultural field. With permission of the landowner, the body of the snake was recovered, body and transmitter intact. Examination of the remains provided evidence that a raptor had killed it, there were several penetrating claw marks along the length of the snake. Opening the snake revealed that one of the puncture wounds had penetrated the heart. Strangely, the body of the snake had not been opened by the predator; and no portion of the snake had been removed. Both San Pasqual Valley and the Santa Margarita Gorge are known to be home to many red-tailed hawks (*Buteo jamaicensis*), and many other predatory birds.

The fate of MT-2 is unknown. On September 9, 1999, the transmitter was found, by itself, lying on the ground. There was no sign of the snake. The antenna had three separate knots in it, one tied around a small twig. Possible explanations include

predation, human interference, or complications with the surgery site. If MT-2 had complications similar to SMER-3 above, it may be possible that the protruding antenna became entangled and resulted in the transmitter being pulled out through the incision. As with SMER-2, a predator may have consumed the snake, leaving the transmitter. Lastly, MT-2 was in an area which receives heavy traffic from hikers. Someone may have encountered the snake and intentionally removed the transmitter.

Further Research

The San Diego Zoological Society and the Center for the Reproduction of Endangered Species (CRES) have picked up this project and are continuing the research past the data presented in this report. They have continued to collect data on the spatial and thermal patterns of the eight rosy boas at the San Diego Wild Animal Park. Their collaboration on this project with the United States Geological Survey will greatly help in the long term monitoring and increased understanding of this species. Future papers to be written include an analysis of the thermal patterns displayed by the rosy boa and how this changes over the course of the year.

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