British Herptelogical Society Bulletin, No. 10, 1984

SNAKE HIBERNATION: IN AND OUT OF THE ZOO

BERN W. TRYON

Department of Herpetology, Knoxville Zoological Park, P.O. Box 6040, Knoxville, Tennessee 37914

Visitors to the zoo reptile facility during recent winter months were often surprised to see a number of empty exhibit cages. Instead of the snakes that are residents of these enclosures during the warm season, the visitor is greeted with signs which state "These animals are temporarily in hibernation". Though the text of the signs gives brief explanation that some reptiles require a several month hibernation period in order to successfully reproduce, the details of this phenomenon have, through space restrictions, been omitted.

One purpose of this article is to delve a bit deeper into the intricacies of snake hibernation both in Nature and in the captive collection and to relate how this program is of major importance to the overall goals of animal breeding and conservation. Foremost, however, this article attempts to show that in any collection of captive snakes, whether large or small, zoo or private, hibernation or cooling can be instrumental in establishing not only a self-generating source of specimens, but a potential base for scientific study.

Too often, zoologists tend to disregard data generated from studies on captive specimens, indicating that observations are invalid or not applicable to studies in Nature based upon behaviour brought out through captive restraints. It seems, however, particularly in an animal species that reacts primarily to instinctive devices for survival, that these restraints are lessened by subjecting the animal to as close to natural conditions as possible. In rare forms of animals where little or no work has been done on natural populations, data from captive specimens can provide this base for future study.

In temperate climates, response to the approach of winter can be readily observed throughout the animal kingdom; birds will be seen in large flocks heading south, squirrels spend much of their time gathering and storing nuts, certain hoofed mammals such as caribou move down the mountainside to their winter feeding grounds, domestic dogs and cats begin to develop their "winter coats", and even human beings go through a variety of ritualistic though not necessarily instinctive procedures. Hibernating mammals, such as bears, must not only grow a protective coat, but at the same time develop an insulating layer of fat from which the body feeds during their winter dormancy.

But what about snakes? Consider for a moment the example of a Western Diamondback Rattlesnake (*Crotalus atrox*) somewhere in Texas. Temperate Zone to be sure, with plenty of seasonal temperature extremes and a hard winter in the forecast for the months ahead. The snake coils basking in the midday sun under a blue, late September sky. During mid-afternoon, the wind picks up, clouds roll in and a chill is in the air. The first hint of a "blue norther" (as typical fall cold fronts are termed in Texas) has reached the region! As night-time temperatures fall into the 40s for the first time since spring, certain instincts, going back perhaps many thousands of years, begin to go to work. Responding to the overnight chill and shortened days, our snake begins a journey of up to ten miles, through several meadows, across a number of streams, up and back down a few low hills, and perhaps transversing a road or two. The destination is a series of well-worn rock crevices halfway up the southeast facing slope of a distant mountain. Barring tragedy along the way, our snake will join others of its species, possibly numbering into the hundreds, that have also obeyed their instincts in this annual migration to this specific den site.

These snakes will spend what time is available to bask during the sunny days, and retreat into the crevices at night until the cold settles in. At this time, they are deep within the mountainside where they will remain until springtime finally arrives. The inner crevices will hold the temperature somewhere between 40 and 50 degrees, and since snakes are cold-blooded (as are other reptiles), their body temperatures will also remain close to this temperature. Unlucky are those that for some reason cannot make it to the security of the den site, for as temperatures plummet to the below freezing mark, so must their body temperatures! Freezing temperatures for any length of time are usually fatal to all reptilian species.

The first few days of spring in early March are usually not enough to bring the snakes out of dormancy. A week or two of strong sun brings about a slow increase in inner den temperatures, and it is at this point that basking at the den entrance begins with retreat at night, as was the case back in the fall. This delayed response to early spring temperatures is most probably an instinctive protective mechanism, for a premature dispersal could have the same disasterous effects as would late arrival to the den in fall! After another week of daily temperature increases, dispersal begins *in mass,* and the snakes move out once again to their summer feeding grounds. Visitors to den sites during the summer are hard pressed to even recognize them as such, and few if any snakes are ever seen. It is not known if instinct takes the snakes to the same summer living quarters each year, but this is interesting, for certainly a single feeding area couldn't support the entire den population!

And so it goes, season after season, for our group of Diamondback rattlesnakes. It is thought by some that gravid females instinctively return to the proximity of the den site a month or so before all others in order to give birth. Supposedly, through this process, the newborn snakes will in turn instinctively know where they must travel with the approach of each future winter. Accumulating scientific evidence, however, points to the probability that young are born mostly a short distance from the den and spend their first or second winter in local available mammal holes or other retreats, eventually locating "family" den sites through olfactory trailing sometime at a later time.

Needless to say, the couple of weeks spent in fall and spring basking around a den site (called the "lying out period") can be most critical for survival. Studies of various dens have shown entire populations wiped-out from one season to the next by snake-hating "sportsmen" or over-zealous collectors who happen upon the dens during these times of congregation.

My first experience with a snake den occurred in the fall of 1975. It was a beautiful late October day with bright skies and temperatures in the high 70s when Steve Dobbs, former Director of the Atlanta Zoo, and I set out to locate a den just south of Dallas in the Cedar Hill community. Years earlier, while Steve was a Reptile Keeper at the Fort Worth Zoo, he had found this den which housed large numbers of Diamondbacks, along with an occasional Copperhead and Coachwhip. The Cedar Hill area, incidently, is the furthest East the Western Diamondback is known to range in north-central Texas.

We parked the car, and after gaining permission from the land owner, walked about a mile through wooded cow pastures until we reached a bluff several hundred feet above a large meadow. From this prominence, the skyline of the city of Dallas could easily be seen in the distance. The edge of the bluff contained horizontal limestone fissures, and as we began descending the 45 degree slope, Steve instantly pointed out an adult Diamondback, then another, coiled among the dried brown leaves and chips of limestone rock. Their coloration was so cryptic that I had trouble spotting them! Steve suggested that I look for anything reminiscent of a "cow-pie", and soon the analogy was complete, as a number of others were located and identified as Diamondbacks coiled basking in the afternoon sun. Fortunately, our presence had not been immediately detected by the snakes, and as we sat watching for a few moments, two individuals crawled leisurely from the crevices to assume the characteristic, coiled basking position, totally unaware that their potential, mortal enemy sat observing not 15 feet away!

Soon our movement was noted, and one specimen made a beeline for the sanctuary of the limestone fissures, rattling briefly as he went. Others remained still until they determined we were too close for comfort. One very large, probably very old individual had apparently just eaten a huge meal, most likely a rabbit judging from the size of the lump at midbody. This snake appeared to be asleep as we approached to within a few feet. After taking several photos, we touched him with our snake hooks, and after a few gentle prods, his head swung around in apparent confusion. Once realizing the situation at hand, he made a rather awkward and undignified retreat toward the rock crevices and directly between two narrow saplings ... too narrow, in fact, to allow passage of the section of body containing the food item! So there he struggled helplessly for a moment or two until we finally assisted him on his way.

In all we spotted about 25 snakes, mostly adults ranging in size from two to slightly over six feet in length. Steve was overjoyed to see that his den was still an active one with plenty of snakes twelve or so years after its initial discovery. Though neither of us has revisited the site since that

Fall day in 1975, we both hope it continues to survive regardless to its close proximity to the rapidly expanding Dallas-Fort Worth area ("Metroplex", as the area is locally termed). To Steve and myself as herpetologists, the re-discovery of this active den site was an exciting and rewarding experience. The average citizen of Dallas, on the other hand, would no doubt be mortified to learn that such a large aggregation of venomous snakes survives but a few miles from his home!

It was at this point that I began to see first hand that hibernation was in fact a very normal and perhaps very necessary part of the life cycle of a reptile living in the Temperate Zone, but I wondered how it related to my specimens in captivity. I began to search through the scientific literature for articles which dealt with reptile hibernation and found them few and far between. Most early papers were concerned mainly with snakes discovered here and there during the winter months, but a few were more thorough, such as the Prairie Rattlesnake (*Crotalus viridis*) den studies expounded upon by the late Lawrence Klauber in his monumental, two-volume set of books on the life histories of rattlesnakes, and other papers. Another thoroughly studied den site for Red-Sided Garter Snakes (*Thamnophis sirtalis parietalis*) in Manitoba, Canada was made famous by herpetologists Michael Aleksuik, Patrick Gregory and others through numerous technical papers and one article which appeared in the November 1975 issue of *National Geographic* entitled "Manitoba's Fantastic Snake Pits".

Although Aleksuik and Gregory's studies dealt primarily with snakes in Nature, several points relevant to our captive animals were noted. First, because the warm season was so short in Manitoba, timing for breeding was fixed within a period of a few days, and this had to occur immediately upon emergence from hibernation in order for there to be sufficient time for gestation and birth prior to cool (and sometimes downright cold!) Fall temperatures. Secondly, through a series of experiments, they determined that for these Garter Snakes, temperature fluctuation alone was the key triggering mechanism which induced breeding behaviour. Finally, the female snake, after giving birth, had to have sufficient time to obtain enough food to allow her body weight to return to normal if she was to produce another brood the following season.

From available evidence accumulated to date, reproductive success (or failure) in most species of snakes is of course multifaceted but is most likely a result, directly or indirectly, of temperature and its effects. Subsequent to the above mentioned studies and my own work, two recent technical papers, one by Bill Garstka, Brian Camazine and David Crews in 1982, the other by Antonella Bona-Gallo and Paul Licht in 1983, both appearing in the journal *Herpetologica* and both dealing with the Red-Sided Garter Snake, showed that factors of temperature were not only responsible for reproductive cycling *per se* but also influenced reproductive behaviour in these snakes.

In a nutshell, Gartska and his colleagues showed through various experiments that male snakes must experience an extended period of low temperature dormancy in order to become sexually active. In fact, even castrated males showed courtship behaviour after at least seven weeks of hibernation, and in all males, courtship was directly proportional to the duration of the cooling period. Bona-Gallo and Licht experimented with females and reported that with few exceptions, only snakes kept in simulated hibernation for sixteen weeks or more were sexually receptive to male courtship attempts and permitted copulation. Further, they showed that only those females that actually hibernated completed the reproductive cycle. Well-fed females maintained at about 85 degrees and not hibernated, although sexually attracted to males, possessed completely regressed ovaries and remained in this state for over a year. In summary, these papers show that physiologically and behaviourally, the reproductive cycles of Red-Sided Garter Snakes are strongly dependent upon climatic or environmental conditions, as could be expected in the most northerly occurring reptile in the western hemisphere.

Summing it all up, I felt that artificially hibernating captive specimens could be the key to successful reproduction, particularly with the "difficult" forms, but there could be drawbacks. I began in 1975 with my own personal collection, comprised primarily of various species of kingsnakes (*Lampropeltis*), ratsnakes (*Elaphe*) and a few varieties of small, mountain-dwelling rattlesnakes (*Crotalus*), all of which in Nature experience a natural period of dormancy. Admittedly, I was concerned that losses would occur, particularly after reading of the death rates of as much as ten percent and more for various natural populations which had been studied, and up to thirty-four percent for one group of snakes placed in a man-made hibernaculum! After all, many of my twenty-five or so specimens had been in captivity for years under more or less constant thermal conditions, and most could not be easily replaced, if at all! But, on the other hand, I had not been successful in breeding any of them, so I had to take the chance.

Feeding in my collection was discontinued in early November, 1975, and on December 1, I sealed off the heat duct in my snake room, closed the door in stages, and slowly over a period of about one week, the temperature fell from a comfortable (to me!) 80 degrees to about fifty-five. Each specimen in its appropriately sized aquarium had access to water and a darkened hiding area in which most spent the majority of the winter months. I checked the animals as often as possible, expecting, I guess, to find some of my choice specimens turned "belly-up". Surprisingly, (but not really) it didn't happen, though most movement ceased whenever the temperature fell much below 55 degrees. I attempted to keep temperatures somewhere between 50 and 60 degrees until the first of April, a good time for warming, I assumed, since temperate snake activity in Nature begins to occur with regularity about then. Temperatures were recorded twice daily, and though on several occasions it fell to about 45 degrees and rose to slightly above 70, the snakes appeared in good condition.

In an article appearing in 1980 in *Animal Kingdom*, Bronx Zoo herpetologist Peter Brazaitis reported that hibernating temperatures for a New York population of Timber Rattlesnakes (*Crotalus horridus*) under observation fluctuated at about 52-54 degrees for most of the winter. Even in the harshest of environmental conditions such as those in Manitoba, Canada where surface temperature may reach —40 degrees or lower, it is doubtful that temperatures within snake hibernacula fall much below 38 degrees.

Warming in my collection began slowly in mid-March, and feeding was initiated in mid-April. About two weeks later, breeding behaviour was seen in my Gray-Banded Kingsnakes (*Lampropeltis alterna*), a secretive west Texas and Mexican variety, and in late June of 1976, both females presented me with fine, fertile clutches of eggs! This was followed (after a second hibernation period) in 1977 by three more clutches of eggs from these kingsnakes and one brood of live young from an Arizona Ridgenose Rattlesnake (*Crotalus willardi willardi*), the second ever to be reported from a captive-breeding. In later years, due to a number of these captive-bred babies maturing and producing young of their own, well over 100 Gray-Banded Kingsnakes and five more Rattlesnake broods have been the result of chances taken, I thought, back in 1975.

So encouraged was I by the success in breeding Gray-Banded Kingsnakes that I gradually acquired hatchlings of a number of other varieties of Mexican kingsnakes, mostly offspring hatched in the collections of friends and zoos. These were raised to maturity and in 1983, fifteen of sixteen mature females of six varieties produced eggs, along with an additional brood of six Ridgenose Rattlesnakes. The identical thermal regime has been used on all of these adult specimens. Though a few offspring are retained from year to year to enhance breeding potential in my own collection, most have been transferred to zoos and other individuals interested in establishing breeding groups or conducting behavioural research on these interesting species.

In 1977 I began to record the weights of my specimens. From all I had read, hibernating snakes were prone to a weight loss of up to and exceeding ten percent in adults and as much as twenty percent in juveniles, and one would assume that any animal that goes without food for five months out of each twelve would have to lose weight! Right? Well, not necessarily, as I was about to discover. I weighed each of my specimens on December 1 after they had fasted for two to three weeks and immediately prior to cooling, and then again on April 1, a week or two before their first Spring feeding. When I compared the figures, I was amazed to learn that contrary to what I had fully expected, only a very few animals lost any weight whatsoever. In fact, a number showed slight increases of a few grams or so! I attributed these gains to water consumption as temperatures, and subsequent animal activity increased. It was felt that this weight stabilization, and the fact that I experienced a zero death rate was most significant, for it showed that, among other things, the temperature range chosen for hibernation seemed ideal.

Compilation of these weight data over the years has also pointed out other interesting information. For example, growth can be calculated over an active season by comparing April with December weights for individual specimens. From my figures on Gray-Banded Kingsnakes, it takes about four to five times more food in order for reproductively active females to maintain their weight from one season to another than for males in the same age brackets. As a result, in Nature, annual egg production may not occur, particularly during lean seasons. The cost of annually producing that clutch of eggs (much less two clutches, as has been seen in a number of kingsnakes and other colubrid species) is enormous, and most probably, some snakes lead much more productive lives in captivity. One of my females has produced a total of nine clutches in a six year period of time, and considering that clutch size for this species is usually eight to ten eggs with a maximum of thirteen, this has resulted in a pile of baby kingsnakes!

Also, for these kingsnakes, size rather than age seems to be the critical determining factor for initial reproduction. Generally, snakes hatched in late Summer or Fall will not be hibernated until their second Winter in order for them to achieve maximum growth. In these Gray-Banded Kingsnakes, females achieving a weight of about eighty-five grams prior to their first hibernation will produce eggs the following Spring; those much under this weight will not, though all are approximately the same age. Current studies by myself and others are beginning to show this to be true for other varieties of colubrid snakes as well, including the Mexican forms mentioned above.

An additional experiment involved actually hibernating a number of kingsnakes in their first winter after hatching. In this case, seventeen babies were each fed (or not fed) from zero to five meals between hatching in early September to cooling on December 1st. The results were not surprising as three or four entering hibernation without feeding died prior to April 1 (the fourth died shortly thereafter), two of four with one meal consumed died, and all those which had taken three or more meals survived in good condition. Unfortunately, the weights of the above kingsnakes were not recorded, but those of two Ridgenose Rattlesnakes were. From birth in August at weights of about 6.5 grams to December 1 with average weights of about 16 grams after ten meals each, these specimens were cooled and weighed again on April 1st. Comparisons revealed almost no significant change over a four month period of time. Undoubtedly, these results are duplicated in Nature.

Just as the Red-Sided Garter Snake can be considered one of the most thoroughly studied of all snakes both in Nature and under controlled captive conditions, the Ridgenose Rattlesnake represents one of many species known primarily from observations on captive specimens. Since the nominate form was described to science in 1905, four other subspecies have been recognized, all occuring in Mexico. Two enter slightly into the United States, one in southwestern New Mexico, the other in southeastern Arizona. All are found in forested, montane habitat mostly at elevations of from 6,000 to 10,000 feet where true wintertime, and thus an extended hibernation period are the rule. Summer temperatures may vary considerably, particularly during rainy periods, and occasional daily temperature fluctuations of 30 degrees (and more) are not altogether uncommon. As may be expected, more is known about the Arizona subspecies, the nominate form, than probably all others combined.

My interest in this unique species dates back to the very first time I read a book entitled "Snakes and Snake Hunting" by the late Carl Kauffeld, longtime Curator of Reptiles at the Staten Island Zoo. Published in 1957, this book is now commonly referred to as "The Bible" by a small army of snake enthusiasts, professional and otherwise. Kauffeld's obsession with field collecting, and rattlesnakes in particular, combined with his vivid written descriptions of collecting adventures gave the zoo worldwide notoriety. Chapter six, aptly called "Huachuca heaven" relates how in 1941 Kauffeld secured two *willardi* there, at that time the thirteenth and fourteenth specimens known from the United States.

Through repeated readings of Kauffeld's book, interest became obsession. Then in March of 1972, during a collecting trip in South Carolina, I was fortunate to meet Brent Martin, then a student at the University of Arizona in Tucson, who, as it turned out, shared my obsession with this snake. But there was a big difference ... Brent had actually collected *Crotalus willardi*! Brent extended an invitation which could hardly be turned down, and in July of 1973, armed with an Arizona scientific collecting permit, I made my first trip west. On 15 July 1973, I found my first *willardi*, a beautiful female, and the obsession became reality ... a long story short to be sure! Not long thereafter I acquired a young male, and another trip to Arizona in 1974 netted an additional female.

Much discussion ensued during these trips as to the best way to maintain *willardi* in captivity... certainly, one had to look at natural conditions and go from there, we figured. Brent was one of the first individuals I know to actually attempt artificial hibernation with his captive snakes. In the Fall of 1975 Brent found a gravid female which gave birth shortly after capture (the first record of viviparity in this species), and in late 1975 he published the results of the first documented captive-breeding from his own collection. In 1976, another publication (all in the *Bulletin of the Maryland Herpetological Society*) described the birth, again resulting from captive-breeding, of *Crotalus willardi obscurus,* the subspecies occuring in New Mexico.

In 1976 after a first hibernation period, a pair of my specimens bred which resulted in the 1977 brood spoken of earlier. I published the results of this breeding in 1978 (once again in the *Maryland Bulletin*). From all that was known from combined observations at that time, *willardi* apparently mates one season and produces young the next. I thought that this type of reproductive strategy was based upon climate and food availability in Nature, and this coincided with studies on a few other varieties of rattlesnakes which in Nature produce broods of young only every other year or two based upon the above factors.

As it turned out, my conclusions, although perhaps applicable to some *willardi* in Nature, are not an indication of the potential for this species. Brent was kind enough to give me a newborn female from his captive-bred brood of 1975, and a newborn male from an additional wild-caught gravid female was secured in 1976. This pair of snakes was placed together for the first time on 6 August 1978 when breeding occurred almost immediately. From this one breeding and after a hibernation period, birth took place almost exactly twelve months later. At that time I assumed it would be another two seasons before I could expect an additional brood, but breeding again took place in October of 1979 which produced a brood in August of 1980. From other pre-hibernation copulations, this pair has been successful in 1981 and 1983 in producing broods of healthy offspring!

From interest, to observation, to a combination of both, relating these years and experiences with *Crotalus willardi* are included to point out that the results of longterm observation on captive animals, particularly the little known forms, can become a baseline from which an understanding of the animal's entire natural history can be drawn.

Prior to the last decade, reptile reproduction in zoo facilities was not only minimal but largely by chance. Indeed, temperature was an important factor in maintaining these animals, but it was usually kept at a high level the year around. It was determined that a temperature range of between 80 to 90 degrees was optimal for most reptilian species, and this was what was instituted in most facilities. Specimens began establishing noteworthy longevity records, but still little reproduction occurred. Then, in the early 1970s, biologist Paul Licht of the University of California at Berkeley, through his work with reproductive patterns in lizards, concluded that, unbelievably, certain lizard species maintained at what was considered to be their "optimum" temperature year around not only failed to cycle reproductively, but often turned out to be sterile! Though it is not known with certainty if other reptilian forms suffer the same consquences, available evidence points quite clearly to the fact that constant conditions under "optimum" temperatures can create a reproductive malfunction in some temperate species.

In the late 1970s, a number of progressive zoo reptile departments began experimenting with hibernation. Slowly but surely, more varieties were exposed to a hibernation or at least a cooling period, and in the winter of 1983-1984, approximately one third of the Knoxville Zoo's reptile inventory underwent this procedure. This was comprised of mostly North American forms, including various species of kingsnakes (*Lampropeltis*), ratsnakes (*Elaphe*), moccasins (*Agkistrodon*) and a variety of rattlesnakes (*Crotalus*). Since it has become apparent that even tropical species undergo some seasonal temperature fluctuations in Nature, certain of the boas, pythons, tropical kingsnakes and rattlesnakes are cooled to a temperature of about 68 to 70 degrees for approximately two months with feeding discontinued or infrequent. Through the use of spotlights and heating plates, some specimens receive a significant daily thermal fluctuation. Cooling tropical forms was unheard of just ten years ago.

Plate 1. *Crotalus willardi willardi.* Captive bred 1985. B.W. Tryon.

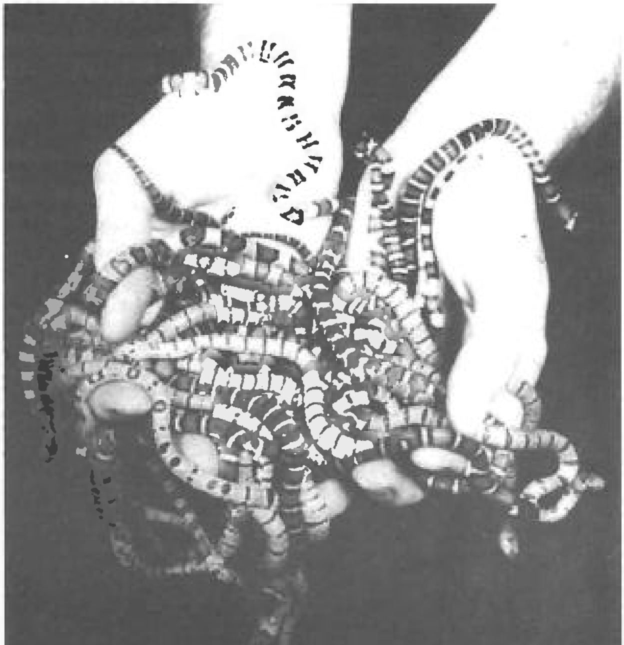

Plate 2. *Lampropeltis* hatchlings, 1983. B.W. Tryon collection.

Though thermal manipulation has proven effective time and again, a classic example of success involved a trio of Angolan Pythons (*Python anchietae*). Two Knoxville Zoo males were sent to the Houston Zoo to pair up a single adult female in 1971. Every effort, including artificial insemination, was made to breed these rare snakes, for these were the only zoo specimens in this country, and the species is extremely uncommon even in African collections, with no breedings having been recorded elsewhere to date. Attempts were unsuccessful, though the specimens were observed to copulate annually, until 1981, after they were placed in a thermally fluctuating environment in a cool room with a base temperature of about 70 degrees. The five eggs and hatchlings in 1981, followed by seven additional hatchlings in 1983, may for a long time be the most significant reptile breedings achieved through thermal manipulation.

Thus, the hibernation or cooling of most snakes appears to be as important in captivity as it undoubtedly is in Nature. A primary goal of most major zoo and personal collections today is the conservation of rare and endangered species through captive-breeding, and thermal manipulation of these captive animals is becoming an increasingly important management tool utilized to help achieve this goal. In addition to stimulating the incentive for breeding in some species, to assuring successful reproduction in many, and to establishing a fixed time of the year for reproductive cycling in most, hibernation may actually be shown to extend captive longevities. As opposed to just ten years ago, an examination of the makeup of reptile collections both in and out of the zoo shows an ever increasing percentage comprised of captive-bred specimens.

It would seem a reasonable prediction that after another five to ten years down the road, few if any specimens will ever have to be removed from that den site in Nature for zoological exhibition and breeding purposes.