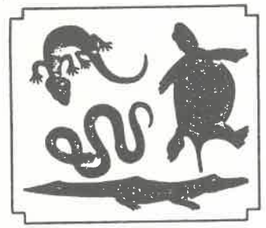

9th International Herpetological Symposium On Captive Propagation and Husbandry

San Diego, California
June 26-30, 1985

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The color photographs on the following pages and the front and back covers are of captive reptiles and amphibians photographed in natural settings. Although not necessarily discussed in this volume these uncommon species are none-the-less included as a bonus for our readers.

Cover photo: Sungazer (Cordylus giganteus).
Rock outcroppings of South Africa. Photo by Sean McKeown.

Back Cover: Amazonian Horned Frog (Ceratophrys cornuta).
Rain Forests of South America. Photo by R. Andrew Odum.

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ACKNOWLEDGMENTS

The Ninth International Herpetological Symposium on Captive Propagation and Husbandry, which was held in San Diego, California, was not the product of a few individuals but the collective talents and efforts of many. A few words of acknowledgment are hardly adequate appreciation to all of those who helped make this a successful event. We want to emphasize here that these conferences are the result of volunteer labor that largely goes unnoticed. The main reward for the many hours devoted to the conference organization is found in the enjoyment of having participated in the building of a successful contribution to the knowledge of herpetology.

California was selected by those of us on the west coast who wanted to make this annual event accessible to Californians who had not previously been able to travel to the other symposiums. Considerable thought was given by the host committee to select a location that would give those not familiar with California a real feel of what "California Dreaming" is all about.

Susan Schafer and Vince Scheidt were instrumental in making many of the local arrangements. The effort and time they devoted to the conference was appreciated by us as well as all those that attended. Susan and Vince also secured free entry into the San Diego Zoo and use of the Zoo's auditorium. Susan arranged a most memorable tour/banquet at the Wild Animal Park. Vince was in charge of arranging the "name that (obscure) herp (or other life form) contest." The winner must have trained with Raymond Ditmars and James Oliver. His herp menu at the banquet will be savored long into the future. Vince and Robert Fischer, along with members of the San Diego Herpetological Society, displayed most of the reptiles and amphibians of southern California. This was enjoyed by new visitors to California as well as those that have spent the many hours in the field it takes to see such a large sample.

James Bacon, Curator of Reptiles at the San Diego Zoo, and Charles Schultz, Senior Keeper, deserve mention for providing

registrants and their families behind the scenes tours of the herpetarium. James Bacon was also supportive in allowing Susan Schafer to utilize Zoo time in making conference arrangements.

Paul S. Chaffee, Fresno Zoo Director, was actively supportive of the Symposium. Appreciation is also extended to the Fresno Zoo reptile staff for behind the scene tours of the zoo's unique fully computerized facilities.

Chuck Greghosky deserves recognition for the photography competition that he organized.

Marty Rosenberg helped to produce the printed conference agenda and acquired the assistance of Case Western Reserve University in it's printing. We were disappointed that Marty could not join us this year in San Diego.

Appreciation is expressed for the following non-papered presentations: (1) "Effects of Dietary Regimen on Growth and Development of the Leopard Gecko (Eublepharis macularius)" by Bela Demeter, National Zoo, Washington, D.C., (2) "Reptile and Amphibian Reproduction at the San Diego Zoo for the Last Two Years" by Susan Schafer, Zoological Society of San Diego and (3) "Some Insights into Captive Propagation of Turtles" by Christopher H. Dodge, Library of Congress, Washington, D.C.

John Tashjian deserves special recognition for his superlative color slide presentation "A Pictorial Review of the Venomous Snakes of the World" which culminates over thirty years of photographic work with these taxa.

Ron Tremper's unique satirical publication "Journal of Perverted Herpetology" clearly demonstrates that living one's entire life in the San Joaquin Valley of California can do strange things to one's brain, but it was appreciated none the less.

Harvey Fischer, Bruce Hiler, and Richard Ross were of considerable logistical support and attended to many details that helped make the symposium a pleasurable event. Harvey provided entry into the Los Angeles Zoo and obtained access into Sea World and Bruce arranged free admission into Steinhart Aquarium. Dick's "herper" slide show was enjoyed by all, along with his

dubious awards in herpetology.

One of Richard Ross's herpetology awards went to a well deserving pair. Richard and Mary Anne Hahn were awarded special recognition through the presentation of a plaque that denotes their long dedication and contributions to the International Herpetological Symposia. We look forward to their support in many more conferences to come.

The assistance of John Brode, Howard Lawler, Karl Peterson, Vince Scheidt, and Ron Tremper in the introduction of the speakers is also acknowledged here as are the contributions of each of the panel moderators.

Once the conference ended, the work did not. The editors put in a large block of time to insure that the proceedings would be produced in such a way to compliment the equal amount of time donated by the authors.

We also want to recognize our wives, Anna Gray and Jinny McKeown, for their support and encouragement during the year leading up to the conference.

A heartfelt thanks to all of the above. To all other contributors, we extend our sincere gratitude to you collectively for your efforts on behalf of the Symposium.

Sean McKeown
Program Chairman

Randall L. Gray
Symposium Coordinator

INTRODUCTORY REMARKS

Sean McKeown

The majority of captive management and breeding techniques for reptiles and amphibians in use in the most widely respected zoos and private collections have been developed during the past ten (10) years. Many of these advances can be directly attributed to the exchange of information presented at captive breeding symposia. Further, these advances reflect a desire to properly manage and display a representative cross section of reptiles and amphibians, not just large and/or venomous snakes.

Another positive trend within the past decade is the maintenance of some species of reptiles and amphibians in enclosures both indoors and outdoors, which are designed to duplicate their natural environments as closely as possible.

While these strides are significant, we must not lose sight of the larger issues. Natural areas throughout the world are disappearing at an alarming and unprecedented rate. By the beginning of the next century thousands of plant and animal species that exist today, will be extinct (Pawley, 1983). Reptiles and amphibians, especially those from tropical areas and islands, will lose not only their habitats, but in some cases their temperature and humidity gradients as well (McKeown, 1985).

All of us in attendance at the 9th International Herpetological Symposium on Captive Propagation and Husbandry - zoological park and museum personnel, private breeders, university staff and students, hobbyists, suppliers, state and federal wildlife officials - should realize that despite our very different backgrounds, we share a common goal. Simply stated, that goal is the desire to see reptiles and amphibians continue to exist and, where possible, flourish. Let us not forget that captive management and breeding is just one tool to reach that goal.

The program committee has specifically scheduled talks that address several of the larger issues vital to reptile and amphibian populations, both in captivity and in the wild. Please

note the papers offered on field conservation through zoos that utilize some non-zoo staff members to achieve their goals. Please pay special attention to papers that encompass field studies where the key components of the captive enclosures and diets are based on the findings of documented field work. This work is not only exciting and timely, but clearly reflects what quality wildlife management is all about.

It is my hope that <u>this</u> conference and the proceedings will serve as a catalyst for all of us to reflect on such topics. I encourage each of you to interact with colleagues in attendance with mutual interests and the common interest of appreciating living herpetofauna.

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McKeown, S. 1985. The ecosystem approach - New survival strategies for managing and displaying reptiles and amphibians in zoos. In Gray, R.L. (ed.) Proceedings of the Northern California Herpetological Society and Bay Area Amphibian and Reptile Society 1985 Conference on Captive Propagation and Husbandry of Reptiles and Amphibians, pp. 1-5.

Pawley, R. 1983. Domesticated alligators and vanishing crocodiles. In Proceedings of the 6th Annual Reptile Symposium on Captive Propagation and Husbandry, pp. 1-7. Zoological Consortium, Inc., Thurmont, MD.

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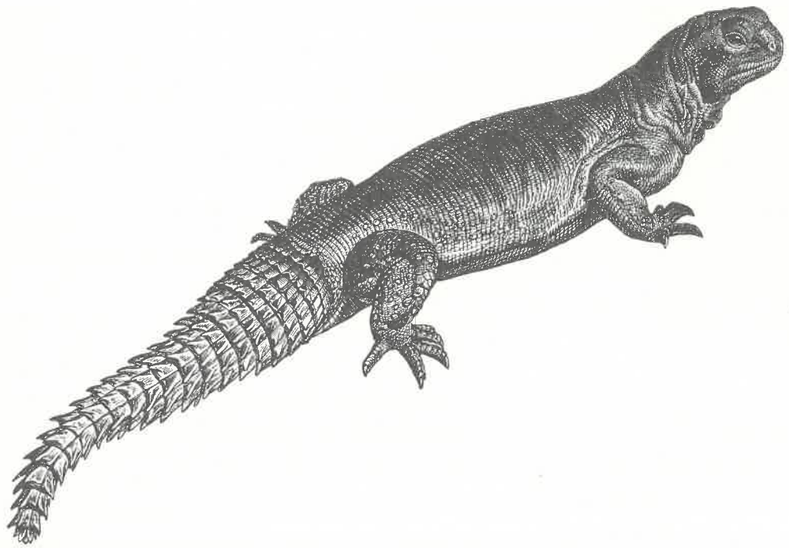

Dispersed throughout the proceedings are copyright-free drawings of herptiles for the readers enjoyment. Please note that these drawings are not products of the authors nor necessarily species described in the text.

FORGOTTEN AND VANISHING: AMPHIBIANS AND REPTILES IN THE NEOTROPICS

William W. Lamar

ABSTRACT

Techniques for maintenance and breeding of captive amphibians and reptiles have evolved rapidly during the past 15 years, and much data have been published. It is time for the herpetological community to expand its sphere of interest in order to work with important but overlooked taxa. Also, it is necessary to strive towards effective and accurate documentation of captive observations so that the community at large can benefit. Such information can be of critical utility in community studies, an important adjunct to conservation efforts. The Neotropics are a veritable wonderworld of herpetological diversity, and their habitat is being rapidly altered to meet short-sighted economic demands. The following is a text from a slide presentation designed to heighten awareness about the extent and rapidity of forest destruction in the tropics, as well as make others aware of the diverse possibilities for making useful observations on captive Neotropical herpetofauna.

In my lifetime, which I am fond of calling brief, there has been marked progress in the area of herpetological husbandry. Techniques for feeding have benefitted greatly from our increased understanding of natural history and behavior; indeed, captive amphibians and reptiles can now be manipulated extensively, and forms previously considered to be intractable maintained. Also, exhibit techniques have evolved concurrent with increasing technology and aesthetic awareness.

In his exhaustive 1970 compendium, Fitch presented reproductive data for 824 species of lizards and snakes, the overwhelming majority of which were from temperate regions. He cited only six references dealing with reproduction in Lampropeltis triangulum, five for the genus Python, two each for Corallus and Epicrates, zero for Chondropython, and one for Phelsuma. Information was available for but three species of Bothrops and ten species of Crotalus. In considering the extensive amount of published reproductive data extant for the groups just mentioned, it should be borne in mind that Fitch's references included simple information which in many cases was fragmentary.

To those of us gathered here for the Ninth Herpetological Symposium on Captive Propagation and Husbandry, it should be obvious that we have advanced admirably in the 15 years that have

elapsed since Fitch's summary, although I might add that efforts with regard to amphibian propagation lag far behind those for reptiles, in terms of diversity. In fact, of the 29 presentations slated for this symposium, only five include amphibians, and just one of these deals exclusively with them.

Many of you have become remarkably proficient at inducing amphibians and reptiles, to cooperate as captives and your reasons and methods for doing so are as varied as your results. I daresay all of you have benefitted from the publication of data, whether as consumers gleaning new ideas and techniques, or as producers, adding to our accumulated knowledge. Still, we regularly ignore a motherlode of observational opportunities which, if documented, would greatly benefit the field.

But much of this information has value beyond our immediate needs. We still know so little about the amphibians and reptiles with which we share this planet. Breeders of amphibians and reptiles can provide useful, basic natural history and behavioral data which touch upon many aspects of a species' biology, and this in spite of the ever-present artifacts of captivity which modify our interpretations. "Natural history focuses attention on organisms, on where they are and what they do in their environments. (Natural historians document) things like the chronology of reproductive events, clutch size, ecdysis (and behavioral repertoires)" (Greene, 1985). They analyze feces and stomach contents and parasites; in short, they are like worker ants laboring with minutiae to accomplish larger goals, and astute observers of captive herps can add much to what we know.

At a recent symposium on predator-prey relationships in lower vertebrates most speakers called for more of this "basic natural history data", and this with full knowledge of the disdain of such efforts that has accompanied the rise of molecular biology (Greene, 1985). Such information can provide the critical building blocks not only for theoretical work but also for community studies, which are crucial to habitat conservation.

I want to tell you a little about tropical forests and their predicament, and while I emphasize the Neotropics, a similar

situation prevails in the world's other tropical regions. Collectively, they comprise an area only the size of the USA. Southern Mexico, Central- and South America - the Neotropics - contain the majority of our dwindling rainforest reserves.

"Tropical forests form the most diverse and complex ecosystem on earth - a virtual powerhouse of evolution - containing 40% of all living species" (Myers, 1984). Indeed, the Neotropics aptly have been termed the most glorious celebration of biological diversity the world has ever known.

Consider the La Selva Forest Reserve in Costa Rica; an area 25 acres larger than the San Diego Zoo harbors: 320 tree species, 394 kinds of birds, 104 mammals, 76 reptiles, 46 amphibians, 42 species of fish, and 143 butterflies (Myers, 1984)! In rough terms that is half again as large as the flora and fauna of the state of California, which has an area of 410,000 sq. km. There are about 850 bird species in the U.S. and Canada combined. In Tambopata, a single locality in Amazonian Peru, there are 530 (Myers, 1984)! A recent and only partial botanical inventory was carried out at Cerro Tacarcuna, a 1900m mountain in the Darien region of Colombia and Panama. Only the upper 500m were inventoried (where species richness is lowest) yet still, 239 kinds of plants, of which one in five were new, were found.

I want to really bring this home to you, so let's look at a herpetological comparison. Texas is our most species-rich state in terms of herps. With an area of 267,339 sq. mi., it boasts 203 species: 41 anurans, 20 salamanders, 26 turtles, 1 crocodilian, 47 lizards, and 68 snakes. From a systematic standpoint, Texas' herpetofauna is relatively well-known. Ecuador is a country on the Pacific coast of South America. It has an area of 104,506 sq. mi., which is only 39% that of Texas. Far from adequately known, Ecuadorian herpetofauna comprises at least 667 species, including 317 anurans, 5 salamanders, 21 caecilians, 18 turtles, 5 crocodilians, 120 lizards, 1 amphisbaenian, and 180 snakes! In snakes alone that works out to a species per 580 square miles. Computing a similar coefficient

for Texas, one finds a snake species per 3,931 square miles! As for amphibians, with a world total of approximately 3,140 species, Ecuador has 11%, while Texas has slightly under 2%.

"It is entirely too easy to think of tropical forests as vast, impregnable, and immutable features of our planet, but such is not the case...they are only too vulnerable to modern technology and an insatiable demand for chipboard, toilet paper, and hamburgers. The world has become a very small place. Each of us is involved in the depletion of tropical forests - we participate every time we use a deodorant, an aftershave lotion, a lipstick, each time we read a glossy magazine, apply varnish to furniture or fingernails, wield a squash racquet, or pull on our jogging shoes" (Myers, 1984).

We also depend upon tropical forests for the basics. In 1960 a child suffering from leukemia faced only one chance in five of remission. Now that child enjoys four chances in five, thanks to two powerful drugs prepared from biocompounds found in a tropical forest plant. At least another 1400 kinds of plants from tropical forests contain principles active against cancer. Still more plants reveal the potential to help with another pressing health need: effective and safe birth-control (Myers, 1984).

Our dependency upon tropical forests is not confined simply to its products. "Birds abound in tropical forests. Looking only at those birds whose existence is so severely restricted to forest habitats that elimination of the forests would cause elimination of the birds, we find that they total some 2,600 species, or 30% of all the birds on the planet. A recent one to four percent annual decline in numbers of U.S. songbirds is believed to be related to disappearing habitat in their Latin American wintering grounds, due primarily to clear-cutting for pasture to provide hamburgers at a cheap price for our fast food industry. At precisely the time of the songbirds' return to the U.S., a number of insect species are at a vulnerable larval stage. It is at this point speculative, but the loss of the feeding activity of millions of songbirds in early spring could

result in an annual insect explosion which would spell bad news for America's agriculture. If we leave the situation to unfold beyond doubt, it could be too late to solve" (Myers, 1984). Sadly, those of you who find this news anxiety-producing will probably satiate yourselves with a hamburger at lunch today.

Much, if not most, of the forests of Central America are being levelled due to forest farming, cattle raising, and timber exploitation...there may be little left by 1990. Likewise, extensive tracts in southeastern Colombia, and most of Ecuador's Pacific coast forests are being rapidly converted. The list goes on... At the same time both subsistence and luxury hunting take their toll. People need protein, and the cost of a bullet is far less than that of a kilo of beef in the market.

A persistent sector of the world's population continues to labor under the notion that women are more attractive draped in cat skins. Additionally, a recent fashion trend in the U.S. which eschews cowhide boots in favor of a bewildering array of tasteless substitutes made from dwindling populations of tropical animals has had a serious impact. Would you believe 12,000,000 Tegu (Tupinambis) hides from Argentina were imported by leather manufacturers in 1983 alone? That same year we used 150,000 Boa constrictor hides.

Direct faunal loss is even more difficult to document than loss of forest. A conservative estimate for the latter, using available data, is that we are losing an area of tropical forest equal to 205,000 sq. km., or half the size of California, on an annual basis (Myers, 1984). Thus, during our week of meetings here at the Symposium, roughly 3,942 sq. km. of this precious resource will disappear forever.

We have established that we have a region of unparalleled herpetological diversity right beneath our noses, and that it is disappearing rapidly. I have said all of this not so much to depress you, for there is still cause for optimism, but to alarm you, for there is much need for urgency. You also need to be curious, and perhaps this curiosity will be stimulated by considering some of the amphibians and reptiles of the

Neotropics, the challenges they pose to the herpetologist, and the kinds of information we can hope to gain from working with them.

A very primitive and unusual snake, Anilius scytale, remains poorly known. There is controversy over its method of prey capture, and evolutionary hypotheses have been extended based upon this. Chance observations are inconclusive, but it may be a constrictor. Captive behavior offers the opportunity to clarify the situation, providing information possibly vital to our understanding of the affinities of this genus. Blind snakes represent another group traditionally overlooked due to secretive habits and inconvenient prey specializations. Some blind snakes are surprisingly sizeable, and there is no reason some taxa couldn't be induced to feed and perhaps be displayed.

Colubrid snakes, unless they are brightly ringed, aberrant, or both, tend not to be overly popular among U.S. herpetologists. This is partly due to the difficulties many of them pose as captives. However, the problems they pose are no more formidable than those faced by Ditmars in his day. The level of tenacity and inventiveness you have shown in order to reach your present levels of expertise should never be underestimated...applied to new taxa, it will produce positive results, both in breeding and display.

Many of the commonly-kept species of snakes are lie-and-wait predators, but it can be decidedly different to work with visually oriented species such as vine snakes of the genus Oxybelis and parrot snakes (Leptophis). Those who long for carefully arranged and planted displays will find that the possibilities are endless with these lightweight, arboreal forms. Still larger arboreal or semi-arboreal species about which we know little include the seven- to nine-foot Pseustes sulphureus with a spectacular defense display, and its congener Pseustes poecilonotus, which exists in a wide array of patterns.

The genus Pseudoboa, like its closely allied genera Clelia and Oxyrhopus, is in a state of taxonomic confusion. We know little about variations among the species of these genera, but

the pattern polymorphisms could be largely resolved with access to entire litters. Equally poorly known is the genus Erythrolamprus. A broad range of variation exists and these represent one population! There is evidence that snakes of this genus take a directional cue from scale overlap when ingesting snake prey (Greene, 1976b). Captive reproduction and feeding observations would expand our knowledge of these interesting "false coral snakes".

The rear-fanged Philodryas viridissimus boasts quite a potent bite. In both color and defensive posture it is mimicked by juvenile Chironius scurrulus, which carry no venom. However, it appears that size alone becomes a sufficient defense for the russet six- to eight-foot adults as they race about the forest floor searching for frogs. Prior to the discovery of their unusual green-to-red ontogeny, they were thought to represent two species. Many Neotropical snakes show marked ontogenetic changes in color and pattern, and until more is known about the life history of these forms, their relationships will remain confused.

Equally perplexing are forms like Xenodon severus, which exists in at least six different colors and patterns at one locality! A little-known congener of the familiar false water cobra, Hydrodynastes gigas, is H. bicinctus, a large brightly-colored aquatic form with an obscure life history. A common and fairly conspicuous faunal element in some localities, its food habits are still unknown. Other aquatic colubrids of the genera Helicops and Hydrops feed quite readily in captivity, but little is known about their reproduction, Helicops in particular merits scrutiny, as more than one reproductive mode may be employed in this genus.

A number of monotypic genera in the Neotropics contain interesting species about which we know virtually nothing. Tripanurgos compressus has a wide range in Central- and South America, but appears to be locally common only. The first significant information on its natural history has just been published (Riley and Winch, 1985). Cryophis hallbergi is a

Mexican form somewhat reminiscent of the preceding species. It has a much more limited range and is also locally common; nonetheless it remains a mystery to us. The well-known genus Thamnophis is widely represented throughout Mexico and northern Central America. It has proven to be an exceptionally good subject for captive behavioral studies.

Dipsadine snakes, the snail and slug eaters, have been traditionally avoided due to the high degree of prey specificity they display. Recent successes with Farancia indicate that such specificity may in fact be advantageous in inducing captives to accept non-traditional prey items (Lamar, pers. observ.). Coral snakes, with 50+ species, comprise a difficult group to maintain in captivity. Many of them are primarily ophiophagus and seem to have elevated metabolisms. Their reproductive behavior has been little studied, and a number of the larger varieties are good candidates for captive programs.

Iguanid radiation in the Neotropics is spectacular. There are over 60 taxa of Anolis in Colombia alone (S.F. Ayala, pers. comm.) and over 200 taxa of lizards there. A published hypothesis regarding relationships among the genus Uracentron depended in part upon supposed ontogenetic change which was borne out subsequently through a captive hatching (Greene, 1976b).

Just as Anolis has diversified in South America, so have the spiny lizards of the genus Sceloporus in northern Central America. A largely unappreciated group with impressive male breeding colorations and behavioral displays, spiny lizards offer excellent exhibit possibilities. The large anoline Polychrus, phlegmatic and abundant, has proven difficult as a captive. It remains for someone to establish the proper light cycle, caging, and diet for this spectacular lizard. Another colorful genus is Enyalioides, a group of primarily terrestrial lizards that retreat into burrows on the forest floor. Stomach contents and scat have revealed no dietary specialization, so it would seem that cage surroundings might hold the secret to its success in captivity.

Among the semiaquatic teiids, Crocodilurus lacertinus has

remained an enigma. I know of only one captive in a U.S. zoo, yet thousands of its hides are processed by the leather industry annually. Its near relatives in the genus Neusticurus are prehensile-tailed stream dwellers that swim well and feed upon grasshoppers and beetles they capture on undergrowth overhanging the water (Dixon and Lamar, 1981). Dramatic male combat occurs in some species. Microteiids like Ptychoglossus are abundant, especially in the Andean foothills. Many are communal egglayers, while others leave their eggs exposed on logs or debris. One form supposedly is bioluminescent, although the evidence is not convincing.

Anguid lizards of the genus Abronia are closely related to alligator lizards. Found at high and low elevations, some are terrestrial, while others are adapted for life in trees. They are among the most beautiful New World lizards. The Xenosaurs are surely among the world's strangest lizards. Some are found in running water, while others climb trees by day but live beneath rocks in silt. To date only two short comments have been published about Xenosaurus reproduction, yet there are common and hardy species within the genus.

Sphaerodactyline geckos include some of the world's most diminutive reptiles, especially the genera Lepidoblepharis and Sphaerodactylus. They do quite well in captivity, sallying forth from their hiding spots to do battle with Drosophila. Stalking behavior parallels that of Eublepharis, including tail twitching.

Tropical wood turtles are as endearing and interesting as North American Clemmys and breed very readily in captivity. Forms common in South America, but seldom maintained in U.S. collections, include Rhinoclemmys diademata, R. melanosterna, and R. annulata of the Pacific coasts of Colombia and Ecuador. The monotypic chelid genus Peltocephalus is in many ways similar to the Madagascan Erymnochelys. It reaches a very large size, has an enormous head, and feeds upon meat and palm nuts. It has been reproduced only once in captivity and is rarely seen in the U.S.

Chelid turtles of the genus Podocnemis have suffered greatly at the hands of man, and several species currently receive at least nominal protection. P. sextuberculata is an Amazonian form not commonly seen in U.S. collections. Its shell structure has not been explained, and little is known about its habits. The genus Phrynops includes several commonly-imported species and several rare ones. Phrynops rufipes was long thought to be among the latter group but seems to be simply secretive. Many Phrynops are nocturnal, and thus may live in close proximity to man without being detected.

The emydid turtle Trachemys scripta as presently recognized has an enormous range, including much of North America and the Neotropics. However, populations can be very different from one another, and further knowledge will likely result in the recognition of other species. One of the most distinctive is Trachemys scripta venusta from the Colombia-Panama border.

Most neotropical crocodilians are in some sort of trouble due to intensive hunting or habitat destruction. This, coupled with their size places them out of reach for most individuals but really offers possibilities for some of our more established zoological parks. Dwarf caimans of the genus Paleosuchus are among the world's smallest crocodilians, however, and in many ways perfect for zoos without a lot of exhibit space. The Orinoco crocodile (Crocodylus intermedius) is one of the most critically endangered of the South American crocodilians. Miami's Metrozoo has a strong commitment to working with this species, and one can only hope that other programs will follow. It may already be too late for the distinctive Apaporis river caiman (Caiman crocodilus apaporiensis); it has nearly succumbed to hunting pressures along its limited range.

Amphibians exist in a bewildering array in the Neotropics. Often beautifully colored, they are proving in many cases to be easily bred as well. The recently described Hyla hutchinsi (Pyburn and Hall, 1984), while quite distinct in life from its relative Hyla geographica, closely resembles the latter species in preservative. Thus, until its tadpoles were examined,

Hyla hutchinsi was not recognized. Until recently, Phrynohyas resinifictrix was considered to be synonymous with P. venulosa, a well-known hylid. However, as we have come to know more of the life history of P. resinifictrix, it has proven to be a remarkably distinctive and highly arboreal form that lays its eggs in pools of water high in hollow trees. Its tadpole is also very different from that of P. venulosa.

Centrolenids are aptly known as "glass frogs" due to the translucent quality of their skin. These frogs lay adhesive clusters of eggs on leaves high above running water. The emergent tadpoles fall through the air into the water to complete their life cycle. Another group of frogs that leave their eggs on leaves above water are the phyllomedusines. Recent research (Pyburn, 1980a) has revealed that eggless capsules are included with the mass in order to provide moisture during development. The waxy texture of the skin in Phyllomedusa bicolor is the result of glands which seal the skin and impede dessication.

For years there have been four universally recognized morphotypes into which all anuran larvae can be partitioned (Orton, 1953). However, the unusual microhylid Otophryne robusta from the Amazon basin has been shown to have larvae of a fifth type (Pyburn, 1980b). The scientific community was so skeptical of this news that it was difficult to publish the report. Equally strange is the ability of Otophryne to capture insect prey by extruding its tongue sideways.

Among the Neotropical bufonids, Blomberg's toad is one of the most familiar. Interestingly, it cannot easily be distinguished from Bufo gutata, from which it is separated by three mountain ranges and 1500 kilometers. Almost all Bufo have a trill-like call, but B. guttata and its relatives emit a note. Neotropical toads are anything but mundane, as evidenced by Bufo ceratophrys. Long known from a few small specimens, this palm-sized bufonid has recently been found to be a food specialist, feeding upon ants and termites. The genus Atelopus includes a multitude of slow-moving, brightly-colored species, some of which have involved male combat, and some of which are

explosive breeders, with as many as several dozen males competing for a single female.

Like Atelopus, the poison dart frogs of the genera Phyllobates and Dendrobates have received more attention in Europe than the U.S. Many taxa are recognized, and there remain many to be described. Captive propagation has shed new light on several of these polymorphic species. The familiar genus Rana is represented in South America by only one form, Rana palmipes, but there are abundant and very beautiful species to be found in Central America; some are exclusively aquatic. Caecilians are another tropical group with Neotropical representatives. Seldom seen due to their fossorial habits, caecilians range from the diminutive Minascaecilia, a genus just described recently (Wake and Campbell, 1983) to species of the genus Caecilia, which can approach four feet in length. There is much need for observations on captive behavior and reproduction in caecilians.

I hope that this brief review of some of the amphibians and reptiles of the Neotropics will stimulate your interest and encourage you to take a closer look at the herpetological wonderland which lies to our south. The party isn't over, as we have the intelligence and the resources to stave off total destruction of tropical forests. But it requires immediate attention and concern. The demonstrated ability of practitioners in the field of herpetological husbandry can be of assistance. If we broaden our scope and increase our efforts to document and share our observations, the entire field will benefit and so, ultimately, will wild populations of amphibians and reptiles from which we draw our pleasure.

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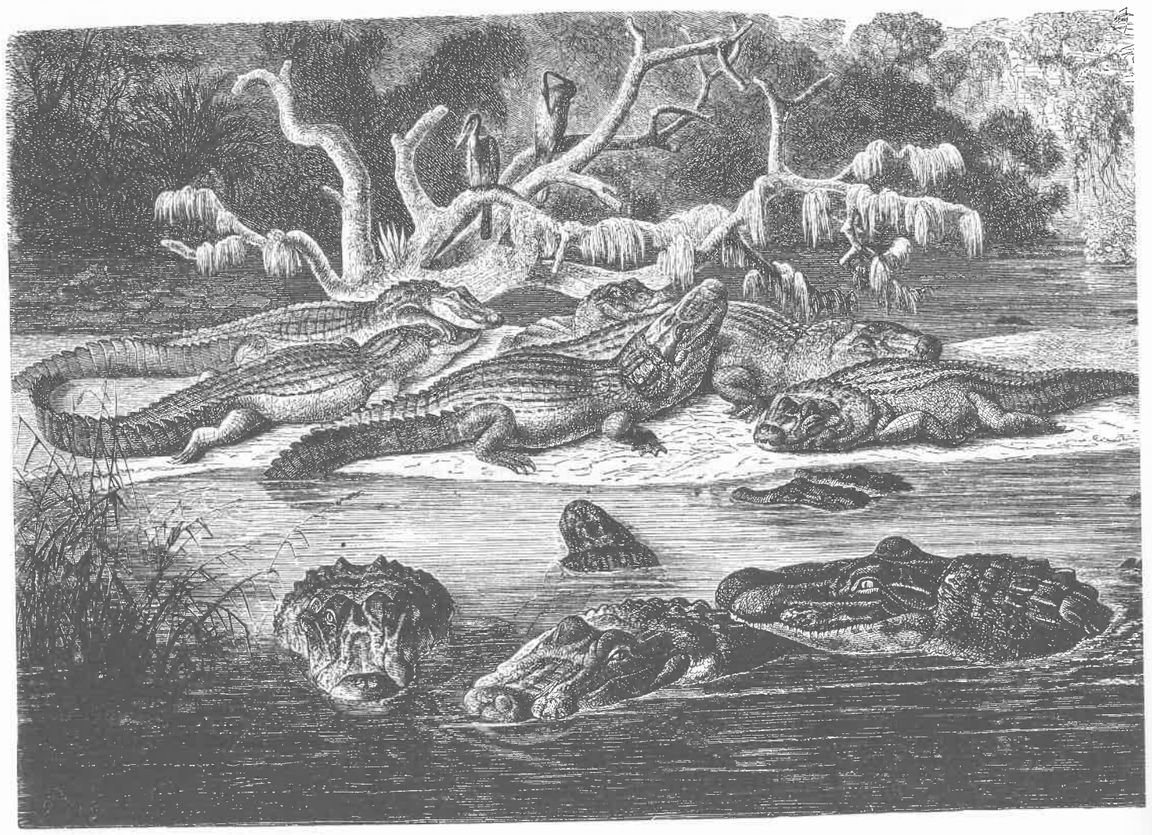


REPTILES AND AMPHIBIANS OF MADAGASCAR

Quentin Bloxam

Jersey Wildlife Preservation Trust has a Scientific Accord with Madagascar, binding the Trust to a program of cooperation which will develop joint field research and captive breeding of that country's endangered species. As a result, two staff members of Tsimbazaza Park were sent to Jersey in 1984 to join our student training program. I visited Madagascar at the end of the same year, to provide back-up instruction to their training, and to carry out field work, particularly at Morondava on the West Coast.

The field work involved investigation of selected species that might benefit from a captive breeding program. The species included mammals, birds, and reptiles. However, for the nature of this meeting I have concentrated on the reptiles, with some of the amphibians included.

The first part of my trip was spent at the Tsimbazaza Park, where I advised keepers on basic reptile husbandry. The problems at their zoo are similar to many of those of other collections in developing countries. The paramount one is, of course, the lack of finance. The Tsimbazaza Park was originally built by the French when Madagascar was a colony of France; at that time sufficient funds were available. However, after the French left, the situation deteriorated dramatically.

The vivarium at the Park consists of fourteen cages of varying size suitable mainly for exhibition purposes. All these cages are inside the building; light is provided by windows at roof level. There is no direct sunlight or supplementary heat provided for the reptiles. My time was spent relandscaping every display and instructing one keeper on basic management techniques which could be used within the restrictions of this building.

Two species of Boas were maintained: Acrantophis dumerilii and Sanzinia madagascariensis. Once the specimens started to feed regularly on a suitable diet they settled well, and should eventually breed providing the management regime is

adhered to.

The two Lizard species the Park maintains, Zonosaurus madagascariensis and Z. laticaudatus, were less suited to this accommodation as they were not given an artificial sun substitute, and did not have access to natural sunlight. The small colubrids, Ithycyphus miniatus and Liopholidophis lateralis, were ideal species for this vivarium. They feed on frogs and should do well.

During my time there, I managed to organize two outside areas; one for Chamaeleo brevicornis and the other for baby Geochelone radiata, all of which had been confiscated. Three days after being moved outside, the Chameleons were seen mating. Finally, there is a group of adult G. gigantea, a now extinct native species. These were not breeding, possibly because of their inadequate diet.

Hopefully, the future of the collection will improve, finance will be provided by outside organizations, and I will be returning to give further on-site guidance.

After the work at the Park, I was able to indulge in a short tour of Madagascar, my prime motivation being to photograph as many species as possible.

I travelled first to Berenty, a semi-arid area in the south; then to Antsirabe, just south of Antananarivo; then to Perinet in the east and, finally, to Nosy Be, an island off the north coast.

BERENTY

This reserve is famous for its Lemurs. However, there are many interesting reptiles, particularly to boa enthusiasts, as both A. dumerilii and S. madagascariensis occur in this forest. I was fortunate enough to find both species. Phelsuma mutabilis are also found here; this species is seldom seen in captivity, perhaps because it is not so colorful as the other members of the genus. The most attractive gecko that I found was Paroedura pictus, a species similar to the gekkonid genus Coleonyx.

ANTSIRABE

This region is famous in Madagascar for its fruit and

vegetable products, and the climate is almost temperate. There are many rice paddies that abound with Ptychadena mascareniensis and Rana tigerina. These and the common Chamaeleo lateralis are a main prey item for another colubrid, Dromicodryas bernieri.

PERINET

Perinet is on the edge of the rain forest which runs along the east coast. There are many interesting species here, including a variety of chameleons, two of which were photographed: C. o'shaugnessyi and C. parsoni. Perhaps the best known lizard species found here is the bizarre Uroplatus fimbriatus. It was a very damp day when I was there, and a number of frogs were seen. Regrettably, Madagascan frogs are very difficult to identify out of the laboratory, with some exceptions, and I could not identify many of those I photographed.

NOSY BE

I spent just one day on this island, but I was lucky to see Pelomedusa subrufa, Phelsuma laticauda, and the introduced Kinixys belliana.

MORONDAVA

This is an area of deciduous forest, and I was working in an 80 sq. kilometer Forestry Reserve. The Reserve is worked by the Swiss government, and is an experiment in exploiting timber without destroying the forest. A nursery for the endemic trees is part of this program, and the felled trees are replaced. So far, the experiment appears to be working. Far more worrying, perhaps, is that outside this area intensive oil exploration is being carried out.

Should oil be discovered, it is not difficult to envisage what might happen to this unique area.

Of particular interest to the herpetologist is the little-known Pyxis planicauda, and I was fortunate to find twenty specimens including a beautifully marked infant. This is an interesting species of tortoise, reputed to aestivate for up to six months. It is found only in the Morondava area and lives

in the leaf litter in dense forest. As a result, it is very difficult to find. This is potentially a vulnerable species, and may benefit from a captive breeding program.

Morondava is an area of great variety, and for the first few days it was intensely hot (40°C). Many basking lizards were observed, including Chalarodon madagascariensis, Oplurus cuvieri, Z. ornatus, Mabuya gravenhorsti, and M. elegans. Snakes were also easily found, particularly Lioheterodon madagascariensis and L. geayi. Less easy to find were Dromicodryas quadrilineatus and Mimophis mahafalensis, and only one A. dumerili was seen. P. madagascariensis were found and another Paroadura, P. pictus. Of the chameleons, C. labordi and C. verrucosus were relatively common, but Brookesia ebenaui proved to be most elusive. Over the last two days of my visit, it rained heavily at night and in the afternoon, which resulted in an abundance of frog species, including Tomopternia labrosa and Pseudohemisus granulosus. Unfortunately, I could not identify the other species I saw.

I am sure that there were many more species of frogs that were not seen. Unfortunately, because my time was restricted, further study was impossible.

CONCLUSION

Madagascar is a naturalist's paradise. Anyone privileged to visit the island will have an unforgettable experience. However, Madagascar shares the problems common to all developing countries, and there will always be a threat to the natural areas. The Jersey Wildlife Preservation Trust's involvement in Madagascar is two-fold. First, we are assisting in the training of Madagascan personnel in captive management, and helping them develop a better understanding and appreciation of their unique wildlife. Second, we are offering the facilities and expertise of the Trust's headquarters in Jersey for captive breeding and study program of species that may be in danger of extinction.

A full list of the species photographed is included with this report.

Acknowledgments:

To Wildlife Preservation Trust International for funding the trip.

To all the many people in Madagascar who helped me in my work and made the visit so enjoyable.

To Mr. Gerald Durrell and Dr. Lee Durrell who gave me the opportunity to spend this time in Madagascar.

To my assistant, Mr. Simon Tonge, who helped me with this report, and whom I wish could have been with me to share in the beauty of Madagascan wildlife.

Jersey Wildlife Preservation Trust

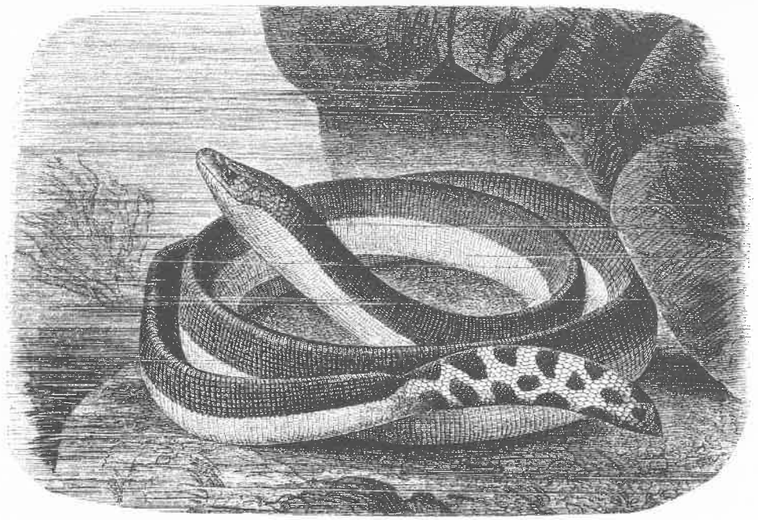
SPECIES PHOTOGRAPHED IN MADAGASCAR DURING JERSEY WILDLIFE PRESERVATION TRUST VISIT, 1984

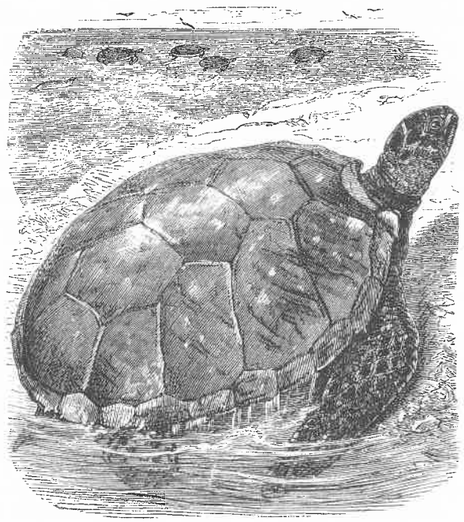
	M	B	A	T	P	N
Chelonia						
Geochelone radiata	-	X*	-	X*	-	-
Geochelone gigantea	-	-	-	X**	-	-
Pyxis arachnoides	-	X*	-	-	-	-
Pyxis planicauda	X	-	-	-	-	-
Kinixys belliana	-	-	-	-	-	X
Pelomedusa subrufa	X	-	-	-	-	X
Sauria						
Hemidactylus mabouia	-	X	-	X	X	X
Hemidactylus frenatus	-	-	-	-	X	-
Homopholis sakalava	X	-	-	-	-	-
Lygodactylus miops	-	-	-	-	X	-
Lygodactylus ?decaryi	-	X	-	-	-	-
Phelsuma mutabilis	X	X	-	-	-	-
Phelsuma madagascariensis kochi	X	-	-	-	-	-
Phelsuma lineata	X	X	X	X	X	-
Phelsuma laticauda	-	-	-	-	-	X
Paroedura bastardi	X	-	-	-	-	-
Paroedura pictus	X	X	-	-	-	-
Uroplatus fimbriatus	-	-	-	-	X	-
Mabuya gravenhorsti	X	X	X	X	X	-
Mabuya elegans	X	X	-	-	-	-
Oplurus quadrimaculatus	-	X	-	-	-	-
Oplurus cuvieri	X	-	-	-	-	-
Chalarodon madagascariensis	X	X	-	-	-	-

	M	B	A	T	P	N
Zonosaurus ornatus	X	-	-	-	-	-
Zonosaurus madagascariensis	-	-	-	X*	X	-
Zonosaurus laticaudatus	X	-	-	X*	-	-
Chamaeleo lateralis	X	X	X	X	X	X
Chamaeleo verrucosus	X	X	-	X*	-	-
Chamaeleo parsoni	-	-	-	X*	X	-
Chamaeleo labordi	X	-	-	-	-	-
Chamaeleo o'shaughnessyi	-	-	-	-	X	-
Chamaeleo balteatus	-	-	-	X*	-	-
Chamaeleo brevicornis	-	-	-	X*	-	-
Brookesia ebenaui	X	-	-	-	-	-
Serpentes						
Acrantophis dumerili	X	X	-	X*	-	-
Acrantophis madagascariensis	-	-	-	X*	-	-
Sanzinia madagascariensis	-	X	-	X*	X	-
Ithycyphus miniatus	-	-	-	X*	-	-
Liopholidophis lateralis	-	-	-	X*	-	-
Mimophis mahafelensis	X	-	-	-	-	-
Lioheterodon madagascariensis	X	X	-	-	-	-
Lioheterodon geayi	X	-	-	-	-	-
Madagascarophis colubrina	X	-	-	-	-	-
Dromicodryas bernieri	-	X	X	-	-	-
Dromicodryas quadrilineatus	X	-	-	-	-	-

KEY

M = Amborompotsy Forest near Morondava (SW)
B = Berenty Reserve and environs (SE)
A = Antsirabe, central highlands
T = Tsimbazaza Park, Antananarivo
P = Perinet (E)
N = Nosy Be (NW)
** Native to Madagascar but now extinct except for captive specimens
* Captive specimens





REPTILES AND AMPHIBIANS IN NEW ZEALAND: THEIR CONSERVATION AND CURRENT STATUS

Vincent N. Scheidt and Robert N. Fisher

INTRODUCTION

New Zealand is approximately the same size and shape of California. It consists of two main islands and numerous small ones. The approximately three million residents live primarily in the major metropolitan centers. About 1900 kilometers south and east of Australia across the Tasman Sea, New Zealand is geographically remote and biologically fascinating because of the large degree of endemism.

THE HERPETOFAUNA

Seven genera of endemic reptiles and amphibians occur in New Zealand (Table 1). The number of species accepted varies somewhat, but is thought to be forty-two according to Newman (1982).

The amphibian fauna consists of one frog genus, Leiopelma, which has three species. This genus is the sole member of the family Leiopelmatidae. The terrestrial reptile fauna includes the Tuatara (Sphenodon punctatus) and the lizards. Five genera of lizards comprise the bulk of New Zealand's herpetofauna. Two skink genera occur: Leiolopisma has seventeen species, and Cyclodina has six species. Eighteen species of geckos from three genera - Hoplodactylus, Naultinus and Heteropholis - represent the remaining lizard fauna. These three genera are endemic to New Zealand, and some are quite colorful.

THE HERPETOLOGISTS

The number of professional and amateur herpetologists in New Zealand is small. No professional herpetological association (like the Herpetologist League or the Society for the Study of Reptiles and Amphibians) exists there, although there is an "amateur" group, the New Zealand Herpetological Society, Inc. (NZHS), which is a member of the Australasian Affiliation of Herpetological Societies. This organization links a number of regional groups in the South Pacific together by conducting a

biyearly meeting and regularly publishing the journal Herpetofauna. The New Zealand Herpetological Society, Inc. is "amateur" only in the sense that it principally attracts persons not exclusively employed as full-time herpetologists (Rowlands, 1982). Indeed, a society accepting only full-time New Zealand herpetologists would be an extremely small group! "Amateur" is a word with generally negative connotations when used in herpetology, and in this case it does not fairly reflect the scientific and conscientious interest in research and conservation activities conducted by many of the society's members.

Unique to New Zealand is its Department of Scientific and Industrial Research (DSIR). This essentially autonomous organization conducts independent investigations on topics of scientific and industrial interest. Employees work directly for DSIR and are not formally affiliated with the National Wildlife Agency (NWS), museums, or universities. Limited reptile and amphibian research has recently been conducted by the Ecology Division DSIR biologists. Most projects, however, essentially remain in the realm of ornithology, mammalogy, or entomology. Recent legislative charges which have afforded new fully-protected status to the herps of New Zealand will hopefully continue to gradually shift some emphasis to research on New Zealand herpetofauna.

The New Zealand Wildlife Service, a division of the Department of Internal Affairs, currently employs two full-time herpetologists. Mr. Donald G. Newman has conducted extensive studies on the biology of the Tuatara and Hamilton's frog (Leiopelma hamiltoni). He is the department authority as well as a respected authority on these species. Dr. David R. Towns researches the biology of New Zealand's lizards. Most of the emphasis of the NWS research involves wild population management, conservation, and basic ecology.

Two major public and several smaller public and private zoological parks maintain and exhibit New Zealand herpetofauna. The emphasis is placed on entertainment, education, and

aesthetics. No zoo exhibits a comprehensive collection of New Zealand reptiles and amphibians and instead prefer to exhibit larger non-native species including crocodilians, Australian agamids, and turtles (Rowlands, 1982). The New Zealand Wildlife Service recently began assembling native reptiles and amphibians with an emphasis on rare and endangered species at its Mount Bruce National Wildlife Centre (previously known as Mount Bruce Native Bird Reserve) near Wellington. Specimens are held for public display and captive propagation purposes (Underhill, 1984). Efforts are being made to establish self-sustaining populations of the held species.

Limited research on captive propagation and conservation occurs at the National Museum and other natural history centers in New Zealand. Museum studies are more oriented toward topics such as systematics. University studies are not usually related to captive or wild reptile and amphibian management.

One of the most enviable characteristics of this particular insular community is the amount of communication that occurs. Most people in New Zealand's herpetological community know one another, often quite well. Herpetologists within the NWS, DSIR, the private sector, NZHS, at universities, zoos, and museums all keep in touch with one another regarding research priorities, successes, failures, and other herpetologically related subjects. Rather than oppress through a myriad of complicated legal trappings, the NWS is "only too happy to support all research contributions, from any individual from any organization, now and in the future" (Newman, 1982). An example of the sort of camaraderie and cooperation shared by nearly all New Zealand's herpetologists is illustrated by the joint field trips conducted by the NZHS and NWS to remote and/or interesting areas of the country. Any given field trip might have a NWS herpetologist, several NZHS members, a university instructor or a few students, and possibly even a few interested guests from the scientific community at large. The implementation of joint and cooperative projects is a major goal of the Wildlife Services (Imboden, 1982).

CURRENT RESEARCH

Current areas of research concerning conservation and captive propagation in New Zealand include a variety of subjects.

The effects of introduced reptiles and amphibians on the endemic herpetofauna is presently receiving attention. Litoria ewingi, a small Australian treefrog, has become well established on the South Island following its introduction in 1875 (Robb, 1978). In 1946, this species was successfully introduced on the North Island, and specimens have recently been collected in areas close to native Leiopelma habitat (Bell, 1982). It is expected that the ecological niches of these different anurans will not overlap extensively, and that Litoria ewingi is simply occupying a "vacant" niche. A small, oviparous Australian Skink Lampropholis delicata has also become established and its role in the habitat is being studied. Other introduced and established herps include L. aurea and L. raniformes. Both species are medium-sized Rana-like frogs, and will probably have little affect on the native herpetofauna.

The impact of introduced mammals has been devastating to the native herpetofauna. The absence of native terrestrial mammals has allowed for the evolution of highly vulnerable forms. The country's endemic avifauna has been severely affected by introducing weasels, ferrets, and rats, predators that become well-established following generally deliberate introductions (Lockley, 1982). Substantial research investigating the relationship between the Tuatara and the Polynesian Rat Rattus exulans has been conducted (Crook, 1973a; 1973b; Whitaker, 1978; Newman, 1982) and future projects are planned to determine the effects of introducing mammalian predators on New Zealand's lizards.

There is on-going research on the ecology of the Great Barrier Island Skink L. homalonotum. A joint effort by the NWS and the NZHS, this research has enhanced the working relationship between these two groups (Newman, 1982).

Captive propagation of rare and endangered species is thought of as an "insurance policy" (Rowlands, 1982), and is

strongly encouraged by the NWS. For this reason, the process to obtain permits by responsible hobbyists in New Zealand is generally a straight-forward one.

Limited research is being attempted outside New Zealand on its reptiles. At present several institutions are working with the Tuatara and breeding has taken place in Carl Gans' lab at the University of Michigan at Ann Arbor. Also, several species of Hoplodactylus, Naultinus,and Heteropholis geckos have produced offspring in two U.S. zoos during the past six years.

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TABLE 1

Endemic Amphibians and Reptiles of New Zealand
(Based on Newman, 1982)

Scientific Name	Common Name
Leiopelma archeyi	Archey's Frog
Leiopelma hamiltoni	Hamilton's Frog
Leiopelma hochstetteri	Hochstetter's Frog
Sphenodon punctatus	Tuatara
Cyclodina aenea	Copper Skink
Cyclodina alani	Robust Skink
Cyclodina macgregori	-
Cyclodina oliveri	Marbled Skink
Cyclodina ornata	Ornate SKink
Cyclodina whitakeri	-
Heteropholis gemmeus	Jewelled Gecko
Heteropholis manukanus	Marlborough Green Gecko
Heteropholis poecilochlorus	Lewis Pass Green Gecko
Heteropholis rudis	Rough Gecko
Heteropholis stellatus	Nelson Green Gecko
Heteropholis tuberculatus	-
Hoplodactylus chrysosireticus	Goldstripe Gecko
Hoplodactylus duvauceli	Duvaucel's Gecko
Hoplodactylus granulatus	Forest Gecko
Hoplodactylus kahutarae	-
Hoplodactylus maculatus	Common Gecko
Hoplodactylus nebulosus	-
Hoplodactylus pacificus	Pacific Gecko
Hoplodactylus rakiurae	Harlequin or Stewart Island Gecko
Hoplodactylus stephensi	Stephens Island Gecko
Leiolopisma acrinasum	-
Leiolopisma chloronoton	Green Skink
Leiolopisma fallai	Three Kings' Skink
Leiolopisma gracilicorpus	-
Leiolopisma grande	Grand Skink
Leiolopisma homalonotum	Great Barrier or Chevron Skink
Leiolopisma infrapunctatum	Speckled Skink
Leiolopisma lineoocellatum	Spotted Skink
Leiolopisma moco	Moko Skink
Leiolopisma nigriplantare nigriplantare	Chathams' Skink
Leiolopisma nigriplantare maccanni	Common or McCann's Skink
Leiolopisma otagense otagense	Otago Skink
Leiolopisma otagense waimatense	Scree Skink
Leiolopisma smithi	Shore Skink
Leiolopisma striatum	Striped Skink
Leiolopisma suteri	New Zealand Oviparous Skink
Leiolopisma zelandicum	Brown Skink
Naultinus elegans elegans	Auckland Green Gecko
Naultinus elegans punctatus	Wellington Green Gecko
Naultinus grayi	Northalnd Green Gecko

TAGGING THE GREEN TURTLE (Chelonia mydas) IN COSTA RICA, WITH SIDE NOTES ON FLORA AND FAUNA OBSERVED

Charles Beck

The gathering of data on the nesting of the Green Turtle is the ongoing project of Dr. Archie Carr of the University of Florida at Gainesville. Beginning this work some thirty years ago, he has authored numerous technical papers and publicized the plight of the Green Turtle to the public in several books. Under the auspices of the Caribbean Conservation Corporation, personnel, facilities, and equipment are made available for the project each summer. Located on Costa Rica's northeastern coast, the research area is near the tiny village of Tortuguero, and the five mile stretch of beach under research is the largest nesting site in the Caribbean of the Green Turtle. The nesting season runs from early July through mid-September. In 1984 a total of 2,422 nesting emergences were recorded on the five miles of study beach!

Funding for the research during the 1984 season was organized by the New York Zoological Society's travel department. Four teams, which averaged nine people each, were scheduled. All briefing concerning the project, transportation, lodging, food, etc. was handled expertly by the New York Zoological Society. Each team was headed by a Bronx Zoo employee. I was fortunate to be in the fourth and last group, which was headed by John Behler, Curator of Herpetology at the Bronx Zoo.

We arrived at the peak of the nesting season. Dr. Jeanne Mortimer, an assistant professor under Dr. Carr, was project coordinator at Tortuguero for the entire season. She also is well known for her work with Green and Hawksbill Turtles. Numbers of turtles tagged by each team during the 1984 season are as follows:

Group A	442
Group B	552
Group C	544

The major portion of the work was at night, when the turtles emerged from the sea to nest. The study beach ran from the mouth, or Boca, of the Tortuguero River, to a point five miles south. This area was marked in 1/8 mile increments. The station, affectionately referred to as "Casa Verde", was located on the north end, at the 6/8 mile mark, and the village of Tortuguero was farther south at approximately mile 3. Three shifts were scheduled and posted for each night: 8:00 p.m. to midnight, midnight to 4:00 a.m., and the morning shift. The morning shift was interesting. We had to depart at 4:00 a.m. and transportation to the village up the river was provided by boat. Villagers from Tortuguero were paid to "flip" turtles along the beach the previous night. They were instructed to observe the turtles, determine whether or not they were going to lay eggs, and turn them only after egg deposition had occurred, to avoid interfering with egg laying. Often, the morning shift proved to be the most difficult; one morning we had forty-eight turtles to record. With that number of turtles, time is a factor as the sun rises and the heat increases. The "taggers" were usually sent out in groups of two or three. One carried a belt pouch containing tags, tagging pliers, data book, tape measure, and a flashlight. The others carried a pair of large calipers and a tape for recording carapace masurements. When possible, the eggs were counted by collecting them by hand under the female as she was laying. The ritualized nesting sequence was exciting to watch. "Body pitting" involved making a large, shallow depression with her front flippers and sideways movements of her body. Then "chambering" began. Using her hind flippers alternately, the female would remove scoops of sand. After twenty to thirty minutes, a perfectly fashioned, flask-shaped hole or chamber was dug. Nest building was followed by the actual egg laying, with up to three hundred eggs deposited. After egg laying, the female filled the chamber with sand, smoothed it over, and then returned to the sea. Incubation of the eggs takes approximately sixty days. The bulk of the nesting

turtles are Green Turtles, but occasionally Hawksbills Eretmochelys imbricata and Leatherbacks Dermochelys coriacea are observed. The nesting period coincides with the rainy season.

When weather permitted, excursions were made into the forests or on the nearby rivers. Many interesting plants and animals were observed, including monkeys, fishing bats, and many tropical butterflies. A number of reptiles and amphibians were brought in to the station by local inhabitants or collected by team members. They included common boas, eyelash vipers, false coral snakes, strawberry poison-dart frogs, brown basilisk lizards, and caiman. The observations made in the wild will no doubt enhance our captive husbandry and display techniques. The trip was a memorable adventure and provided an opportunity to partake in a worthwhile conservation effort.

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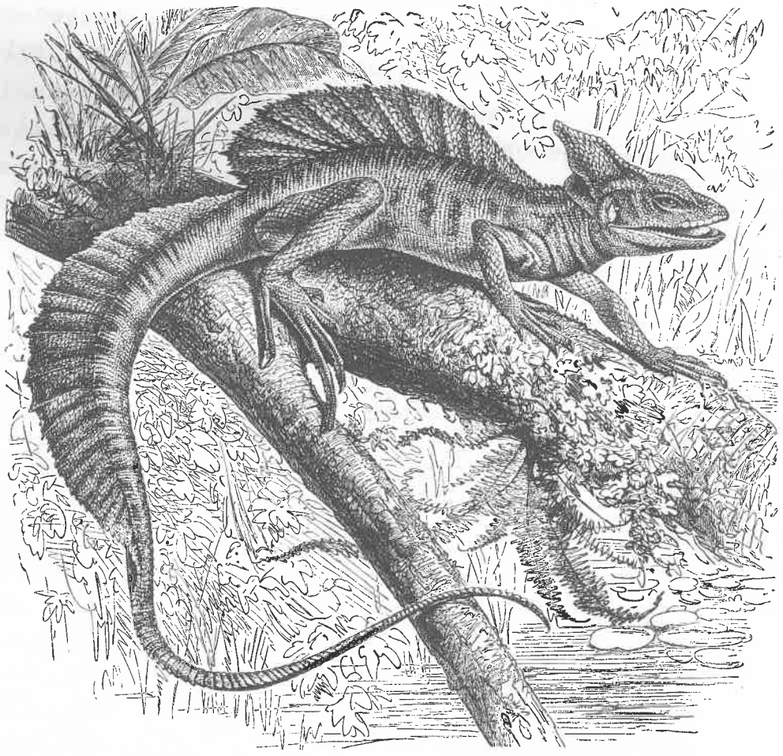

THE ENDANGERED EGYPTIAN TORTOISE *TESTUDO KLEINMANNI*: STATUS IN EGYPT AND ISRAEL

James R. Buskirk

BACKGROUND

The Egyptian tortoise *Testudo kleinmanni* (or *Testudo leithii*) is the smallest and least-known tortoise species inhabiting the Mediterranean basin. Its range is also more restricted than that of any other Mediterranean tortoise. Specimens are rare in both public and private collections in Europe and North America. The rather scant literature on *T. kleinmanni* is fraught with inaccuracy and contradiction. Its status in the wild appears to be in decline.

Mystery surrounds the origin of the type specimen of this tortoise, which was presented to Gunther in 1869 and described as *Testudo leithii*. The specimen allegedly was collected in "Sindh, Baluchistan" (now Pakistan), an area from which no subsequent specimen has ever been taken (Loveridge and Williams, 1957). Lortet's type specimen was sent to him in 1875 from Alexandria, Egypt, near which it had been collected by a French banker, Edouard Kleinmann. Although the Egyptian tortoise is still called *Testudo leithii* by some authors, this taxonomic designation was previously allocated to a fossil chelonian from India found in 1852 by Carter, and now assigned to the pelomedusid genus *Carteremys* (Loveridge and Williams, 1957).

Louis Lortet wrote his description of *T. kleinmanni* in 1883, and four years later wrote of an acquaintance's experience keeping live specimens of this species with members of the other three Mediterranean tortoises in southern France. The gist of these observations was that the *T. kleinmanni* is less cold-tolerant than its relatives, but that it remained active during the mild Egyptian winter--at least in northern Sinai, where the specimens in question had been collected (Lortet, 1887).

DESCRIPTION

In appearance, the Egyptian tortoise recalls a small Mediterranean spur-thighed tortoise, Testudo graeca, the species to which it appears most closely related. The largest specimen on record measures only 127mm (Flower, 1933). The carapace is domed and exhibits a posterior marginal flare in some adult specimens, notably males. Females attain the greatest size, and full-grown males with worn scutes measuring only 91mm CL have been seen by the author. Indeed, the most outstanding secondary sexual characteristic of male T. kleinmanni, the thickened, long tail with distally located vent, was seen in a specimen only 73mm CL. The largest female seen by the author in Egypt in 1984 measured 123mm CL, while the largest male was 116mm. In both sexes and in juveniles, the nuchal shield is posteriorly broadened, forming a triangle. Most T. kleinmanni have a single supracaudal scute--an exception is the female in the photograph on page 20 of Obst-Meusel, 1974.

In coloration, the Egyptian tortoise usually has much less dark pigment on the carapace than any other Testudo. The basic color is dull yellow to yellowish-green; dark markings are usually restricted to a narrow smudge along the anterior and lateral margins of the vertebral scutes, and the anterior and external-lateral edges of the costals. The centers of the carapacial scutes bear no dark pigment. Those tortoises with the greatest amount of dark pigment seen by the author were females. The plastron of all specimens save the very young exhibits two unique features: a movable posterior lobe, and a symmetrical dark triangular figure in each abdominal scute, the base being along the abdomino-pectoral seam and the apex toward the tail. Faint smudges of dark pigment are sometimes present in the pectoral scutes, but the rest of the plastron is uniformly yellowish. The soft parts show this same pale color, sometimes with a hint of pink. The black spot seen on the top of the head of only one tortoise (of a few hundred) examined by Flower was seen on several Egyptian tortoises by me. There is no terminal claw on the tail or thigh tubercle(s) in this species. The most

remarkable feature of the soft parts of T. kleinmanni are the large, overlapping scales on the forelimbs, arranged in three rows. The following table distinguishes this tortoise from T. graeca, the species with which it is most likely to be confused (also see Figures 1 and 2):

T. kleinmanni	T. graeca
Maximum CL approx. 13cm	Maximum CL approx. 30cm
Carapace pale, areolae immaculate	Carapace pale, mottled, or dark, depending on race. Areolae almost always spotted
Plastron with dark triangular blotch in abdominal scutes only	Plastral shields with random blotches
No thigh tubercles	One to three tubercles on each thigh
Three longitudinal rows of large scales on forelimbs	Four or more longitudinal rows of small scales on forelimbs
Posterior lobe of plastron kinetic in all specimens	Posterior lobe of plastron mobile only in adult females

For a more detailed description of the Egyptian tortoise, consult Anderson (1898) or Loveridge and Williams (1957). It should be noted that the anatomical peculiarities of the skull, which have prompted some writers to place this tortoise in its own genus, Pseudotestudo, are shared with five other endemic African genera, three of them (Pyxis, Psammobates, and Homopus) consisting of diminutive species (Loveridge ad Williams, 1957). Testudo kleinmanni is the only dwarf tortoise occurring in the northern hemisphere.

RANGE

The geographic distribution of the Egyptian tortoise has been inaccurately described and is not completely known today. Aside from the type specimen from "Sindh", this tortoise has been reported from coastal Syria and Arabia by Werner (1925), and from Syria by Noel-Hume and Noel-Hume (1958). Museum records and current Israeli field work plot the outlying west and east poles of the range at Qaminis, Libya, on the eastern shore of the Gulf of Sirte, and in the central Negev Desert about 90 km east-southeast of Gaza (Geffen, pers. comm.). Between these points, the range is highly discontinuous, in part because of

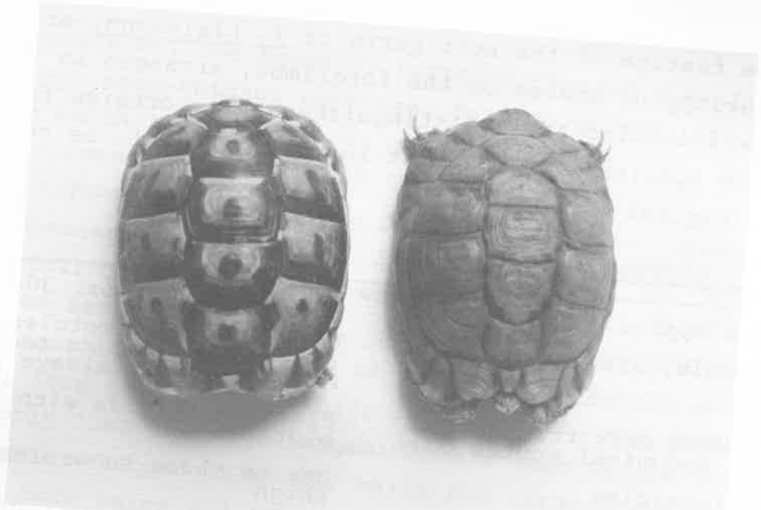

Figure 1. Testudo g. graeca (left) and T. kleinmanni (right).

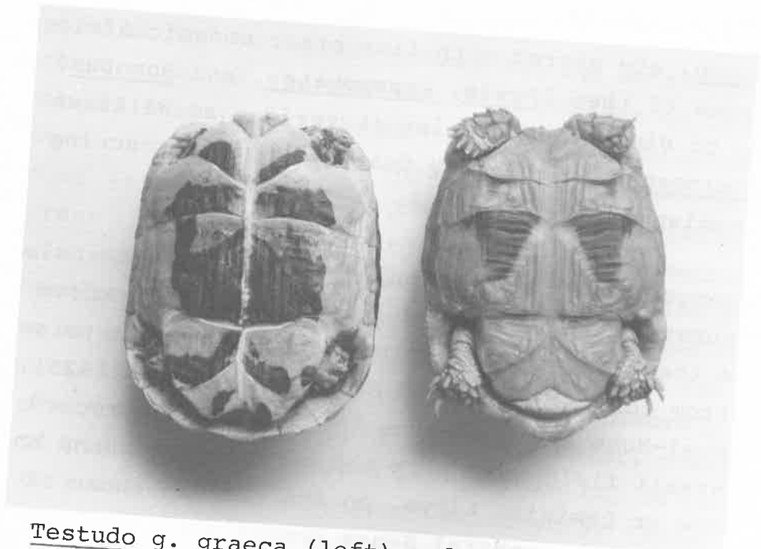

Figure 2. Testudo g. graeca (left) and T. kleinmanni (right).

human impact on habitat, and in part due to natural factors. Throughout this portion of coastal northeast Africa and extreme southwest Asia, annual precipitation is only 100-200mm, increasing in coastal Cyrenaica (Libya) to as much as 400mm.

The Libyan distribution of T. kleinmanni is least known. Alan Resetar, at the time employed by the Field Museum of Natural History, did not find any Egyptian tortoises in Kouf National Park in Cyrenaica in 1981 (pers. comm.). However, he found T. graeca graeca abundantly in several habitats, from coastal dunes to the top of a wooded escarpment a few hundred meters above sea level. Records for both species from Barca (Barce; Al Marj) exist, but as the precise origin of the specimens is unknown, it is unwise to challenge Loveridge and Williams' assertion (1957) that the two species are allopatric. They listed four Libyan localities, one of which (Wadi Tessina) was found to be that of a misidentified juvenile T. graeca, almost certainly an introduction (Calabresi, 1924). The single locality (Derna) given by the latter for T. kleinmanni is surrounded by known localities for T. graeca. It is possible that each species is soil type-specific, as is the case with T. kleinmanni and T. graeca in the northern Negev (see Israel status report).

In Egypt, T. kleinmanni is known from 21 known locales, largely fringing the Mediterranean coast, from the Libyan border (Salum) nearly to the Gaza Strip (Flower, 1933; Loveridge and Williams, 1957; Marx, 1968). Some of these records are suspect, notably Damietta (Lortet, 1887), Bir Gindali (Marx, 1968), and Giza (Loveridge and Williams, 1957). The latter two cases were probably introduced specimens, since a single tortoise was found in each instance, and these areas are geographically remote from known areas where the tortoise occurs in numbers. The case of Damietta is more perplexing: Lortet implies that he personally collected several here, but the species is otherwise unknown from the alluvial soil of the Nile delta. Most of the records are from northeast Sinai and the northwest coast of Egypt, with some of the first records centered around Alexandria. Loveridge and

Williams (1957) also reported the tortoise from along the Suez Canal, consistent with Lortet's (1887) report from near Port Said. While I was in Egypt in 1984, professional reptile collectors told me that they had found tortoises at Siwa Oasis (some 350 km south of the Mediterranean coast near Libya) and at an unnamed location in southern Sinai. Mendelssohn (in Groombridge, 1982) felt that this species doe not occur naturally more than 60 km inland from the Mediterranean; more recent research by his student Eli Geffen places this distance at 90 km. Following this guideline, if the newly reported localities (above) and the records from Bir Gindali and Giza are valid, they lie well outside the natural range of T. kleinmanni, and would represent introductions.

For a description of the easternmost range of this tortoise in Israel, refer to the final section of this paper.

HABITAT

The few accounts of the natural habitat of T. kleinmanni present two different pictures. Lortet (1887) described both, beginning with the environs of Alexandria, where it was said to occur abundantly "in shoreline grasses and at the edges of salt lakes or salt marshes . . . It also rather often invades cultivated fields and gardens." In the same work Lortet, quoted a friend who had found a specimen of T. kleinmanni "in the sand of the Egypto-Syrian Desert near El Arish." Without specifying the type of habitat, he also reported the T. kleinmanni from the vicinity of Port Said. Interestingly, in more than a decade of occupation of the Sinai by Israelis, who scoured the peninsula seeking biological rarities, the few specimens that were found, were in the north. Werner (1982) assigned T. kleinmanni to the community of psammophile reptiles of the northern Sinai sand dunes. A professional Egyptian reptile collector told me that the tortoise was most abundant to the east of El Arish, towards Khan Yunis (in the Gaza Strip); he did not specify the habitat (Nasr Tolba, pers. comm.). This tortoise has not been found in the coastal dunes of the Gaza Strip itself (Geffen, pers. comm.).

No published information concerning the habitat of T.

kleinmanni in Libya exists. Dr. Henry W. Setzer, a mammologist working for the Smithsonian Institution, collected a trio of Egyptian tortoises (USNM 139092-94) in July or August, 1955, on the sparsely vegetated coastal plain near Qaminis, Cyrenaica (pers. comm.). The substrate was described as sandy loam. It is interesting that the animals were found active in midsummer, as they are known to estivate elsewhere in their range (Groombridge, 1982; Geffen, pers. comm.).

In Israel, the Egyptian tortoise occupies areas of high, semi-stable sand dunes separated by deep troughs of more compact sand. The vegetation is mostly of Saharo-Arabian origin, with most plants belonging to the Artemisia monosperma association (Geffen, pers. comm.).

THE STATUS OF Testudo kleinmanni IN EGYPT

I visited one known Egyptian coastal site, El Daba, in April, 1984 in an attempt to locate a population of T. kleinmanni. This site, about 130 km west of Alexandria, was selected for being as close to Libya as was possible to travel, and because it represented the only site in Egypt where T. graeca has been recorded (almost certainly an introduction, Lambert, 1983). Along the inland dune rising from a salt marsh, which in turn was separated from the sea by a higher primary dune, was sparse vegetation typical of such areas. Among the notable plants present were Zygophyllum, Salvia, and Limonium, the latter being a species on which the Egyptian tortoise is said to feed (Lortet, 1887). Rodent burrows were present; Groombridge (1982) reported that tortoises in the Negev used rodent burrows for cover sites. However, no tortoises were found, and only one local inhabitant (of nearly a dozen questioned) evinced familiarity with the animal. On the day of the survey, the air temperature was about 15°C, and strong winds were probably responsible for the fact that no reptiles were seen. Later, in the company of British herpetologist Stephen Spawls, I also visited Wadi Gindali (the exact site of Bir Gindali not being found on any map consulted). The only reptile encountered in this inland site was a female Cerastes

cerastes; Spawls had seen no tortoises on prior visits, nor anywhere in Sinai. I did not have time to visit northeastern Sinai, and Egypt west of El Daba was off-limits for security reasons. My inquiries about tortoises to residents of Alexandria, the type locality, led nowhere. The roadside vegetation westward from this city had largely been supplanted by fig orchards and other crops for a distance of about 80 km. Tortoises might have once occurred in these disturbed areas and possibly still do, despite the elimination of most of the natural vegetation. The brackish lagoon near Alexandria were not investigated; Nasr Tolba, who is familiar with them, assured me that there were no tortoises in the vicinity.

The evidence presented so far in this section would suggest that the Egyptian tortoise has disappeared or nearly disappeared from at least some of the areas where it was commonly found a century ago. In 1982, Mendelssohn estimated the world population of the species at 10,000 or fewer (Groombridge, 1982). If this number is accurate, then the Egyptian pet trade will soon bring about the extinction of this tortoise.

The month of peak activity of T. kleinmanni is reported to be April, and in April, 1984 the pet shops near Talaat el Harb in downtown Cairo had large numbers of specimens. Close examination showed that virtually all specimens offered for sale were males. The asking price ranged from $8.00-25.00. The proprietors of three shops all said that the specimens were brought from Sinai. Approximately 200 specimens were seen in these three shops; they were crowded two or three deep into narrow glass terrariums or crates, and most appeared listless.

The other place in Cairo I saw large numbers of T. kleinmanni was the Giza Zoological Gardens. This zoo was established in the mid-nineteenth century and first exhibited this species in 1899. By 1910, 21 T. kleinmanni had been hatched at the Giza Zoological Gardens, and the total number hatched in 1929 was 77 (Flower, 1933). In 1984, I saw 40 T. kleinmanni housed in two glass-fronted enclosures about 1.5m square. No cover sites were provided, a single steep-sided water

dish--too high for the tortoises to reach--occupied the center, and the bottom was lightly covered with fine sand. The animals appeared to be segregated by size, and I did not see any juveniles. The animals were fed lettuce and other chopped vegetables daily.

The curator of reptiles at the Giza Zoological Gardens is a very affable veterinarian, Dr. Ali Kamal el-Din Nagaty. He expressed dismay that the tortoises seemed to die from a "wasting disease" manifested by inanition and anorexia. The tortoises sometimes bred, but he said the young never survived more than a year. Dr. Nagaty plied me with questions concerning tortoise maintenance in subsequent visits. He told me that the zoo regularly replenished its collection of T. kleinmanni with fresh specimens brought in by collector Nasr Tolba and his brothers. When I asked why he continued to acquire more probably doomed tortoises, he replied that the price offered was favorable. Dr. Nagaty also asked me whether there were books dealing with diseases in reptiles, and seemed unaware of the captive breeding record of T. kleinmanni during the early part of the century, when Stanley Flower was director of the zoological gardens. In spite of the mysterious ailment causing high mortality, Dr. Nagaty said that some of the tortoises had been in the zoo for over 20 years. However, he admitted there were no systematic records kept of accessions, nor were deceased animals necropsied or retained as museum specimens. I suggested the zoo keep at least some of the tortoises outdoors in a larger and more natural enclosure, which appealed to him, and I showed him how to distinguish the sexes of the Egyptian tortoise. I eventually sent several papers dealing with this species to Dr. Nagaty, as well as papers on captive maintenance, reproduction, and illnesses of tortoises.

Dr. Mervat Morcos presides over the welfare of Egyptian wildlife and has an office on the grounds of the Giza Zoological Gardens. She told me that the Egyptian tortoise is one of five reptiles protected by Egyptian legislation under Law 102. She said that in essence, this law prohibits the export of these

species for any purpose. Other protected reptiles include the Egyptian cobra, chameleon, desert monitor, and the spiny-tailed lizards. She also said the domestic trade in tortoises was not legal, but that the pet shop owners did not know about the law. Dr. Morcos added that a series of nature reserves had been recently set aside, and the tortoises were guaranteed protection in the reserves containing them. However, Dr. Nagaty told me that the warden of the El Hammam Reserve (between Alexandria and El Daba) had offered to sell him T. kleinmanni tortoises at a stiff price. Because the price was higher than what he paid his usual source, he refused the offer. Theoretically, most of the northern Sinai is incorporated into a nature reserve, according to Dr. Morcos. My request for a permit to export a single T. kleinmanni, alive or dead, was denied.

I also visited the zoology department at Cairo University. Dr. Kamal Al-Badry graciously allowed me to interview him and provided me with reprints of recent papers dealing with the hematology of T. kleinmanni. When I asked him about the methods used in the hemotological research on tortoises, Dr. Al-Badry replied that the animals were decapitated--200 in a single experiment. All other tissues were discarded, and no records were kept of the origin of the tortoises. He had not even inquired where the subjects of his research had originated, and he was unfamiliar with T. kleinmanni in the field. I also learned that there were no preserved specimens of this species at Cairo University.

The focus of some of Dr. Al-Badry's experiments was seasonal variation of certain blood components. An assumption, not developed or attributed to any reference, is that T. kleinmanni hibernates, as do most temperate zone chelonians. This assumption is contradicted by Lortet's early account (1887), by present field work carried out in Israel, and by the reports of the Tolba clan who probably supplied Dr. Al-Badry with his tortoises. An interesting finding of the hematological research is that T. kleinmanni, regardless of season, has higher blood concentrations of creatinine than the well-studied desert

tortoise, Scaptochelys (Gopherus) agassizii, another arid-adapted species (Rosskopf-Woerpel, 1982).

Non-invasive research done on Egyptian tortoises at the Giza Zoological Gardens by Khalil and Haggag (1955) showed that this T. kleinmanni can excrete either urea or uric acid, favoring the latter as a water conservation measure. Such a property would seem vital to a tortoise which has adapted to perhaps the driest environment on earth inhabited by any chelonian. Unfortunately, its kidneys may not permit T. kleinmanni to outpace the rapacious whims of its human predators.

I attempted to convey to both Dr. Nagaty and Dr. Morcos the urgency of protecting T. kleinmanni from the domestic pet trade, but I received no assurances that Cairene pet shops would be notified that it was illegal to sell tortoises. Until this practice is stopped, the logic behind the ban on export is compromised. Dr. Al-Badry was unaware of the protected status of T. kleinmanni, and had not heard of the Director of Wildlife, Dr. Mervat Morcos. Fortunately, Dr. Al-Badry's peers in the United States have informed him of a less drastic means of obtaining chelonian blood for his research.

THE STATUS OF Testudo kleinmanni IN ISRAEL

One hundred years ago the British naturalist H. B. Tristram reported T. kleinmanni from southern Palestine. Specifically, he wrote that this small tortoise inhabited "the region between Hebron and Beersheba and of the Arabah, south of the Dead Sea." Today it is known that no tortoises inhabit the latter region, while the tortoise occurring around Hebron is Testudo graeca terrestris. Fifty years later, the pioneer Jewish biologist F. S. Bodenheimer mentioned a population of dwarf tortoises inhabiting the Negev Desert, and proposed that these be called Testudo floweri. No further description of this tortoise was given, and in the following sentence the author maintained that T. kleinmanni (as T. leithii) "replaced" floweri at El Arish in northern Sinai. He modestly concluded his section on Palestinian tortoises by admonishing that the status of T. kleinmanni in Palestine "still requires special study"

(Bodenheimer, 1935). Testudo floweri is now recognized as the southernmost race of T. graeca inhabiting the eastern Mediterranean region. It is found in the dusty loess of the northwestern Negev, in a triangle from north of Beersheba to the Gaza Strip. The generally pallid coloration of this race distinguishes it from all other Israeli T. graeca (subspecies terrestris), and makes it superficially very similar to T. kleinmanni, although it attains a considerably larger size than the latter. Nonetheless, the constant characteristics which separate the two species (see Introduction: Description) are present on close examination of even a young T. floweri when compared to T. kleinmanni. All the more interesting is that the ranges of these two species lie very close to one another--a situation mirrored by the apparent overlap of the distribution of T. graeca graeca and T. kleinmanni at the opposite extreme of the latter's range in Cyrenaica (Libya). The two species in Israel appear to be allopatric, the determining factor being soil type (sand dunes and plains for T. kleinmanni, eroded limestone loess for T. floweri) rather than temperature or rainfall (Geffen, pers. comm.).

Barash and Hoofien (1956) did not list T. kleinmanni as occurring in Israel. The first definite population of T. kleinmanni in Israel was discovered in 1963 during a zoology field trip led by the late Dr. Georg Haas of the Hebrew University of Jerusalem (Werner, 1982). Since that time, T. kleinmanni has been found in a 100 km^2 area in the western and central Negev. Most of the habitat is composed of semi-stable sand dunes. Density is very low (about 5 specimens per km^2), and may have been lowered as a result of overgrazing by goats (Groombridge, 1982). According to Mendelssohn, plant cover may comprise as little as 5% of the habitat, but in areas less degraded by goats the plant cover may comprise ca. 40% of the habitat. In areas with vegetation loss, tortoises have to travel greater distances in search of food, which renders them more vulnerable to predation (Groombridge, 1982). As in other parts of the range, annual precipitation

rarely exceeds 200mm, and is often barely adequate to sustain the annual vegetation the tortoises eat, and for which they must often compete with goats.

Another negative impact on the small Israeli population of the T. kleinmanni arises from military maneuvers (Perry, 1984). Fragile desert environments show the scars of tank maneuvers, in real or simulated combat, for generations. Habitat destruction by agriculture, settlement, and industry also poses a threat to the T. kleinmanni. In addition, Bedouin goatherds have been known to wantonly smash tortoises with a club (Mendelssohn, pers. comm.).

The major non-human predators of the T. kleinmanni, in order of importance, include the brown-necked raven, the hooded crow, and the desert monitor. Adult tortoises are largely safe from predation by monitor lizards, and young tortoises are somewhat protected from being preyed upon because the monitors do not emerge from hibernation until spring, when the tortoises cease their winter activity and begin to estivate (Groombridge, 1982).

Protection of T. kleinmanni in Israel takes the form of a legislated ban on exportation; stringent conditions are imposed concerning scientific research and maintenance in zoological institutions (Mendelssohn, pers. comm.). A proposed nature reserve at Holot Agur in the western Negev would further safeguard about one-fifth of the known Israeli population of T. kleinmanni, but has yet to gain the full approval of the Israeli government. At present, the ecology of the T. kleinmanni at Holot Agur and elsewhere is being intensively studied by Eli Geffen, a zoology student at Tel Aviv University. This institution maintains a captive colony of T. kleinmanni at its Wildlife Research Center, where a few pairs are active the year round in outdoor enclosures. Reproduction has occurred at the University, and the young grow rapidly, with sexual maturity reached by five years (Groombridge, 1982). The rapid growth of captives is accompanied by frequent shell deformities (Geffen, pers. comm.). Clutch size is very small--a maximum of four

eggs--and although there is no published information on reproduction of T. kleinmanni in the wild, Dr. Mendelssohn believes reproduction ceases during drought years. In the small enclosures at Tel Aviv University, eggs are laid in May or June, and the eggs hatch in the fall or winter months (Perry, 1984). Preliminary evidence suggests that T. kleinmanni is a short-lived species in the wild, rarely reaching the third decade (Groombridge, 1982). Unless diligent conservation measures are taken with regard to this small tortoise, it is likely that Stanley Flower's grim prediction in 1933 will indeed come to pass.

Acknowledgments:

I would like to thank the following individuals in Egypt for their assistance in obtaining information about T. kleinmanni: Dr. Al Kamal el-Din Nagaty of the Giza Zoological Gardens, Dr. Mervat Morcos, Director of Wildlife, and Dr. Kamal S. Al-Badry of Cairo University. Aktham Mohammed Abu Illa, a geologist stationed in El Daba, was very helpful and hospitable during my stay there. Stephen and Laura Spawls shared their knowledge of Egyptian highways and by-ways, and provided transportation and company to one of the sites visited.

In Israel, I am indebted to Professor Heinrich Mendelssohn of Tel Aviv University for his informative correspondence. It should be noted that virtually all of the information contained in the IUCN Red Data Book article on T. kleinmanni (Groombridge, 1982) had been prepared by Dr. Mendelssohn. His student Eli Geffen has given invaluable assistance by reviewing the manuscript on Israeli T. kleinmanni, sending slides of habitat and tortoises in Israel, and providing much information regarding T. kleinmanni and T. g. floweri not yet published. His colleague Dr. Fridlander kindly identified the plants seen at El Daba. Dr. Yehuda L. Werner of the Hebrew University of Jerusalem was my first Israeli correspondent on this project, and put me in touch with the aforementioned individuals. My friends Janet Ewing and Bob Hoffman (who were hosted by Eli Geffen) photographed living tortoises of both species mentioned at the Institute for Nature Conservation Research near Tel Aviv, and I thank them warmly.

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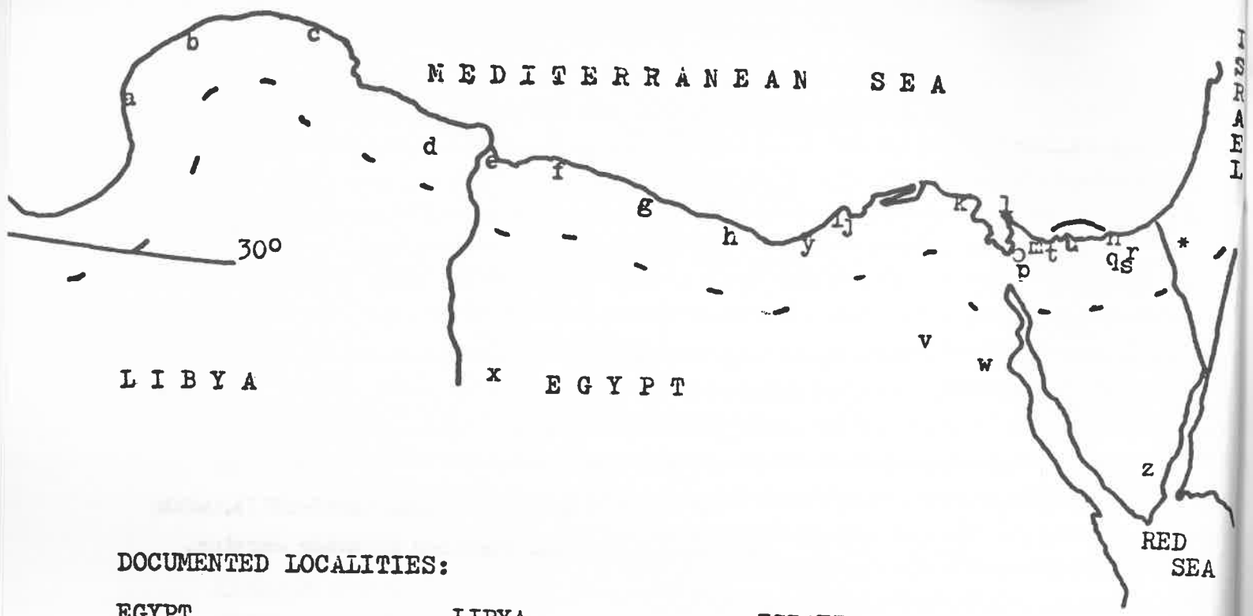

DOCUMENTED LOCALITIES:

EGYPT	LIBYA	ISRAEL
e Salum	a Qaminis	* Holot Agur
f 1.6 km S Sidi Barrani	b Barca	
g Mersa Matruh	c Derna	
h El Daba	d between Giarabub and Tobruk	
i ALEXANDRIA (type)		
j Maryut		
k Damietta		
l Port Said		
m Romani		
n El Arish		
o Kantareh		
p Ismailia		
q Lahfan		
r Wadi Hareidhin		
s Wadi el Amr		
t Katia		
u Bir el Abd		
v Giza (extralimital)		
w Bir Gindali (extralimital)		

UNDOCUMENTED LOCALITIES IN EGYPT:

x Siwa Oasis (extralimital)
y El Hammam
z S Sinai, E Mt. Sinai (extralimital)

PUBLISHED LOCALITIES, NOT FOUND IN GAZETTEER:

Salmana (Egypt)
Khabra Abu Guzoar (Egypt)
Sirtica (Libya)

FURTHER DISTRIBUTION IN ISRAEL:

Out of courtesy to Israeli researchers who have not yet published their findings, the author refrains from listing four additional sites in the NW and NC Negev where populations of Testudo kleinmanni have been identified.

FIG. 3

GEOGRAPHIC DISTRIBUTION OF TESTUDO KLEINMANNI

Scale 1:7,920,000 - - - 90 km S Mediterranean coast

UTILIZATION OF CALIFORNIA'S HERPETOFAUNA

John M. Brode

Regulations restricting the capture of California's reptiles and amphibians were first enacted in the early 1970's in an effort to reduce the number of animals collected for the pet trade. At that time, thousands of reptiles and amphibians were being collected for commercial export and sale within the state. The mortality rate of these animals in the pet trade was estimated to be at least 50%. In May, 1979, the California Fish and Game Commission determined that the collection of California reptiles and amphibians for the pet trade was not an appropriate use of the resource, and subsequently promulgated regulations prohibiting such use, except for sale to scientific and educational institutions. In July, 1980, three collectors and one wholesale reptile dealer obtained a court injunction permitting them to continue their commercial activities. In October, 1981, the courts voided the injunction, upholding the Commission's regulation.

Presently, reptiles and amphibians are protected in California under several categories: Endangered, Threatened, Fully Protected, and Protected. Fully Protected is a special category established by the state Legislature prior to the state Endangered Species Act and now includes only certain threatened and endangered species. Protected status is given to species that warrant protection but are not necessarily threatened or endangered. The remaining "nonprotected" species are regulated through limits and methods of capture.

Highest priority for use of California's herpetofauna is for scientific and educational use. Next is recreational (sport/hobby) use and last is commercial use. Scientific and educational use is regulated via Scientific Collecting Permits, Memorandums of Understanding, and limited term Commercial Field Collecting Permits. Capture from the wild for recreational (private) use requires a sport fishing license, and is regulated through bag and possession limits and methods of capture.

Capture from the wild for use in the pet trade is prohibited.

Scientific use is usually associated with college, university, and medical research. Results of this research are published in scientific and medical journals or presented at symposia and other professional meetings. Educational use includes teaching aids, museum displays, zoo and public aquaria displays, and occasionally private reptile farms. Information is disseminated through direct communication, self-teaching displays, and display of live animals. The Department of Fish and Game issues about 200 scientific collecting permits and about 100 commercial field collecting permits annually. Animals collected commercially are used primarily by out-of-state universities, zoos, and medical research facilities. Although the number of permits issued is fairly high, the number of animals collected is relatively low compared to previous levels of commercial collecting. For instance, during 1980, three commercial collectors captured 24,349 animals while 86 scientific collectors captured 4,009 animals.

The number of recreational collectors is unknown. Recreational collectors can be divided into two basic types, casual collectors and hobbyists. Casual collectors capture reptiles and amphibians because of curiosity, ego gratification, or to be macho. Usually, no useful information results from this activity.

Hobbyists either maintain collections of a number of species or concentrate on one or two species at a time for captive breeding purposes. Hobbyists provide information through care sheets, papers published in herpetological journals, and papers presented at symposia.

The total collecting pressure on California's herpetofauna is unknown. Based on scientific collecting records (commercial and noncommercial), the desert areas of southern California receive the most pressure. During 1980, for example, four southern California counties had more than 10 scientific collectors per county, two counties had 6-10 collectors, and the remainder of the state had five or less collectors per county.

There appears to be a trend among reptile hobbyists in California to utilize captive born reptiles rather than wild caught specimens. There also appears to be a trend towards captive breeding and away from consumptive collecting. If these trends continue, consumptive use of California's herpetofauna may be drastically reduced in the future.

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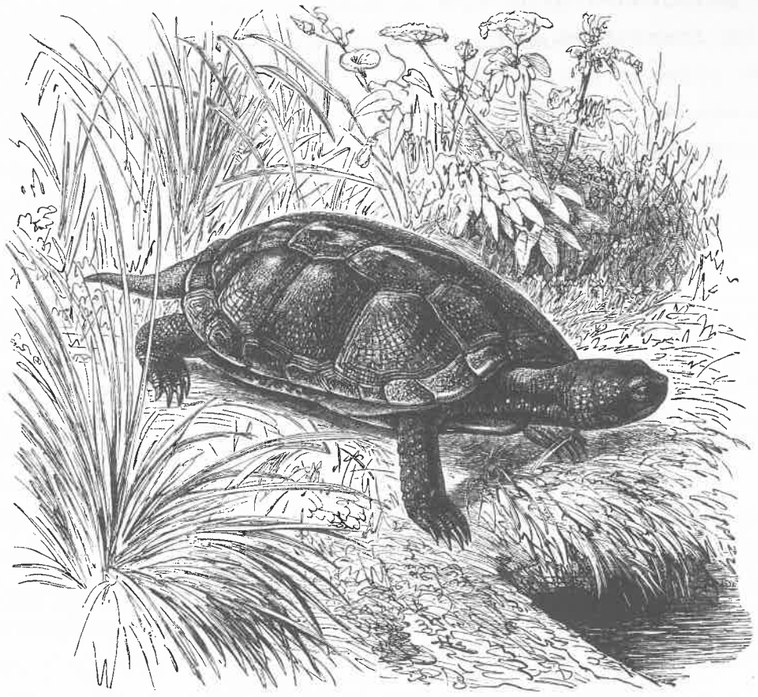

REPTILE BREEDING RECORDS AT THE MELBOURNE ZOO

Chris B. Banks

INTRODUCTION

The value and necessity of good records requires no elaboration. The statement is either accepted or refuted. What matters is the establishment and maintenance of such a system and how it is utilized. It is all very well to record every observation and statistic possible, but if such information is not used to check long-term trends or provide supportive data for articles or reports, then it has been a waste of a great deal of time and effort.

The Reptile Department at the Melbourne Zoo operates a number of record systems. The starting points for much of the data are a daily diary and weekly feeding chart. From there, information is transposed onto individual specimen cards, post-mortem charts and breeding charts. The last two systems were commenced in 1975 and the breeding charts, in particular, have proved to be of enormous benefit.

MATERIALS & METHODS

The establishment of the breeding charts was prompted by the need to present all data relating to reproduction in a particular species in a concise but readable form. The paucity of such basic information as dates of mating and oviposition, incubation lengths and growth of the young, for many species, highlighted the need for the recording of this data. The system finally chosen consists of three parts:

Sheet A: relevant data on parent animals; dates of parental separation; mating and birth/oviposition; egg dimensions; and incubation temperature/humidity/length.

Sheet B: clutch size; number of eggs fertile and number of young born/hatched; survivorship of young over 12 months; and weight/length of young at birth and 1,3,6 and 12 months.

Sheet C: data in note form extracted from the daily diary;

in a few instances there is a small degree of duplication between Sheet C and Sheets A/B. However, the duplication is minimal. Entries on Sheet C are concise and often abbreviated, with reference to the daily diary where a fuller account of a particular event is recorded. Figures 1-7 show how the data is recorded. On those occasions where a breeding is of special significance, a first breeding for Australia, growth data is recorded at monthly intervals for the first year. The reverse of Sheet B is usually used for these data.

When these data were first entered on the sheets it was found that much of the information recorded in the daily diary prior to 1975 contained very little detail, and none at all in relation to growth of the young. However, the available data were still transferred to the sheets where it was considered meaningful. The growth data for a particular group are usually only recorded as the average for that group at that time. In many cases time does not allow for the weighing and measuring of every individual, and in these instances about half the group is selected. Care is taken to ensure that different sized sub-groups, if present, are represented. Where the data so recorded have been checked against that for the whole group, the difference has been insignificant. A separate small chart is maintained on the Reptile House notice-board to advise staff of when recordings are due.

DISCUSSION

As of 1 May, 1985, the full range of data has been recorded for 33 species of reptiles and amphibians bred at Melbourne Zoo. This includes 22 instances where a species has reproduced more than once and seven cases where a species has bred in four or more years. Reproductive data have been gathered on a further 35 species on Sheet C only. For these species actual birth or hatching has not occurred but observation of matings, egg-layings (fertile and non-fertile), courtship and intraspecific aggression

are still recorded.

Allowing for the variation in growth rates, both between and within litters, it is now possible to easily check on a young reptile's progress. Where at one time data were recorded on every group of growing young, regardless of species, it is necessary now to only carry out spot checks of weight and length increase and compare these with previous data, for those species which reproduce regularly. This decreases the amount of time necessarily spent on obtaining the basic information.

EXAMPLES

Krefft's Tortoise - Emydura krefftii - Figures 1 & 2. This species was first recorded as breeding at Melbourne in 1978. Subsequent breedings have provided material for three papers: that from 1978/79 for a paper on captive reproduction (Banks, 1983); from 1979 for a paper on pigmentation (Dunn, 1982); and also from 1979 for a contribution relating to possible oviductal development (Banks, in press). All the data may be combined and published in a future paper, as very little reproductive information is available on this species. We have not observed breeding in this species since 1982; this may be explained by the sole breeding female being injured on two occasions, necessitating her removal from the exhibit tank. We expect breeding activity to resume in the coming season (late 1985).

Inland Bearded Dragon - Amphibolurus vitticeps - Figures 3-5. A. vitticeps has been the collection's most prolific species with 14 breedings being recorded in the past 14 years. The parent lizards involved in breeding No. 9 were part of the clutch of young resulting from breeding No. 5, five years earlier. The lack of particular growth data in the earlier years is clearly evident from Sheet B. This prompted the monthly recording of weight, snout-vent and total lengths for three clutches at the present time. Two are from the same female but were incubated at different temperatures.

Arafuran File Snake - Acrochordus arafurae - Figures 6 & 7. One of the collection's more valuable species, A. arafurae is not a widely-kept snake. The 1983 breeding is thought to be

the first for the species in captivity from a captive mating, and is the subject of a paper to be published in the International Zoo Yearbook (Dunn et. al., in press). Intriguing observations are continually being made on the Melbourne specimens and these will undoubtedly be incorporated in a further article.

The species for which the full range of reproductive data have been recorded at Melbourne is as follows:

Red-eared Slider	- Pseudemys scripta elegans
Malayan Box Turtle	- Cuora amboinensis
Gulf Coast Box Turtle	- Terrapene carolina major
Star Tortoise	- Geochelone elegans
Elongated Tortoise	- G. elongata
Broad-shelled Tortoise	- Chelodina expansa
Eastern Long-necked Tortoise	- C. longicollis
Krefft's Tortoise	- Emydura krefftii
Macquarie Tortoise	- E. macquarii
Freshwater Crocodile	- Crocodylus johnstoni
Estuarine Crocodile	- C. porosus
Eastern Bearded Dragon	- Amphibolurus barbatus
Inland Bearded Dragon	- A. vitticeps
Thorny Devil	- Moloch horridus
Crested Basilisk	- Basiliscus plumifrons
Cunningham's Skink	- Egernia cunninghamii
Major Skink	- E. frerei
Hosmer's Skink	- E. hosmeri
Blotched Blue-tongued Lizard	- Tiliqua nigrolutea
Eastern Blue-tongued Lizard	- T. s. scincoides
Northern Blue-tongued Lizard	- T. s. intermedia
Shingleback	- Trachydosaurus rugosus
Boa Constrictor	- Boa constrictor
Childrens Python	- Bothrochilus childreni
Carpet Python	- Morelia spilota variegata
African Rock Python	- Python sebae
Carpet Python x Amethystine Python	- M. s. variegata x Morelia amyethystina
Carpet Python x Water Python	- M. s. variegata x Bothrochilus fuscus
Arafuran File Snake	- Acrochordus arafurae
Corn Snake	- Elaphe guttata
Taipan	- Oxyuranus scutellatus
Western Brown Snake	- Pseudonaja nuchalis
Mexican Mocassin	- Agkistrodon bilineatus
Western Massasauga	- Sistrurus catenatus tergeminus
Giant Tree Frog	- Litoria infrafrenata

These data are freely available and enquiries are welcomed. Relevant information will be included in Frank Slavens Inventory of Reptiles and Amphibians in Captivity commencing with the 1986 edition.

The record system has now been in operation for 10 years and will be reviewed in the near future to determine if it can be streamlined in any way. While it is too early to make valid comparisons with data obtained for wild specimens, informal discussions with workers studying reptiles in the field indicate that captive data such as that obtained at Melbourne Zoo may be relevant. It is interesting to note the similarities in the data obtained on Melbourne's Taipans to that found by Shine on Wild Taipans (Banks, 1983; Shine and Covacevich, 1983).

Much of what has been presented here may seem obvious and rather basic. While this may be so, the fact remains that the lack of such data in the literature indicates that it is not being recorded. It is my intention to reverse this situation whenever possible, and a system such as that described here will be the vehicle to achieve that end.

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Figure 1. Breeding Chart for Emydura krefftii (Sheet A).

A SPECIES.....Krefft's Tortoise — Emydura krefftii

Breeding No.	Specimen No. 1:0	Specimen No. 0:1	Period In Collection 1:0	Period In Collection 0:1	Wild/Captive Bred 1:0	Wild/Captive Bred 0:1	Age 1:0	Age 0:1	Length 1:0	Length 0:1	Kept Together/ Separated and When Introduced	Mated Captive/Wild	Date/Egg-Laying	Ave Egg Length and Weight At Laying	Incubation Temperature °C	Incubation Humidity %	Incubation Length (days)
1	3	1	5Y.	5Y.	W	W	A.	A.			K.T.	CAPTIVE	3-10-78	35 x 20---; 7g	30	95	49
2. A	?	1	6Y	6Y	W	W	A.	A.			K.T.	CAPTIVE	16-8-79	36 x 20---; 8g	30	/	50-55
B	?	2	6Y	6Y	W	W	A.	A.			K.T.	CAPTIVE	16-9-79	35 x 18---; 7.5g	30	/	20
C	3	1	6Y	6Y	W	W	A.	A.			K.T.	CAPTIVE	6-10-79	34 x 20---; 7.8g	30-31		45
D	?	2	6Y	6Y	W	W	A.	A.			K.T.	CAPTIVE	29-10-79	36 x 20---; 7.8g	30		50
3.	?	?	7Y	7Y	W	W	A.	A.			K.T.	CAPTIVE	28-9-80	35 x 20---; 8g	31		45
4. A	?	?	8Y	8Y	W	W	A	A			K.T.	"	29-6-81 Eggs found	34 x 19---; 7.5g	/		13-17
B	?	2	8Y	8Y	W	W/A	A.	A			K.T.	"	26-6-81	35 x 19---; 8.5g	28		57
5.	?	2	9Y.	9Y	W	W	A.	A			K.T.	"	11-6-82	35 x 20---; 8.2g	27.5-30		58-62

Figure 1. Breeding Chart for Emydura krefftii (Sheet B).

B SPECIES.... KREFFT'S TORTOISE – Emydura krefftii.

Breeding No.	No. Eggs / ~~Young~~	No. Fertile	No. Hatched	Young At Birth: Ave Length mm	Young At Birth: Ave Weight g	Survival Rate: 1 mth	3 mth	6 mth	1 yr	Length Gain (mm): 1 mth	3 mth	6 mth	1 yr	Weight Gain (g): 1 mth	3 mth	6 mth	1 yr	Comments: (Behaviour, Colour, Pattern Change Etc
1.	16	16	15	28	3·6	16	12	12	6	♂ 39 ♀ 35	38 42	50 58	83 96	5·6 6·6	7·4 10·9	15·1 27·7	70·9 103·6	
2. A	20	A	18	28 x25	4·4	18	18	18	10	32	41	56	75	6·0	11·7	29·7	59·7	4 RETURNED FOR EXPERIMENT 1974-19
B	15	13	4	27x24	3·3	4	4	4	4	30	39	50	68	4·6	8·3	17	51	
C	15	12	8	28x24	3·7	4	3	3	/	29	40	54*	/	4·3	10·4	27·5	/	FEEDING COMMENCED AT 3 WKS.
D	14	14	1	TORTOISE LACKED REAR LEGS + WAS DESTROYED														
3.	19	18	16	33	5·9	8	3	3	3	37	44	46	65	8·8	11·7	12·8	39·4	EARLY INFECTION
4. A	14	13	9	30x27	4·2	9	6	5	5	30x27	39	47	63	4·3	9·9	14·9	38·3	
B	17	15 ~~dead~~	14	NOT RECORDED.														
5.	19	19	13	28x25.	3·9	11	9	8	6	32x29	39 x 35 [41 – 34 x 37 – 32]	95x93 [50 – 40 x 48 – 37]	53x51 [62 – 44 x 60 – 44 n=4	5·8	8·2 [6·9 – 9·0]	16·4 [21·2 – 11·8]	26 [37·4 – 14·4 n=4	

Figure 2. Breeding Chart for Emydura krefftii (Reverse of Sheet B).

		Length Gain (mm)								Weight Gain (g).							
Clutch 1.		2	4	5	7	8	9	10	11	2	4	5	7	8	9	10	11
	A.	34	40	45	53	54	54	60	75	6·2	13·0	14·2	23·2	24·3	22·4	34·6	56·8
	B.	43	52	55	59	64	65	72	86		23·8	25·9	30·9	33·4	42·6	56·2	80·6
Clutch 2. (Room 1)	A	35	46	50	61	61	63	69	69	7·3	15·3	19·5	37	38	37	47·1	49·6
	B	35	43	47		58	60·5	64	65	6·9	11·0	15·5		28	31	36·3	40·1
Experimentals	DARK		39·5			61		64	65·5		10·6			30·7		38·3	42·8
	LIGHT		35·5			58		63	65		8·9			29·1		37·4	42·3
			6 { 47·5 / 44			61·0 / 58·0					6 { 20·1 / 15·8			30·7 / 29·1			
Clutch 5.	MEAN	39·7 x 31·2	40·8 x 37·4	44·9 x 42	45·3 x 43·9	47·4 x 46	48·6 x 47·6	49·9 x 48·3	50·6 x 49·6	6·6	9·8	12·8	14·9	16·7	24·7	19·4	21·2
	RANGE	37 x 32·5 / 33 – 29·5	43 – 37 x 39 – 32·5	48·1 – 37 x 45·5 – 35	53 – 40 x 52 – 37	55·5 – 43 x 54 – 39·5	57 – 44 x 58 – 43	58·5 – 44 x 58 – 43	61 – 44 x 59 – 43	4·8 – 7·4	7·5 – 10·9	8·8 – 16·3	8·8 – 23·5	11·3 – 25·7	17·8 – 35·6	12·4 – 32·3	13·3 – 34·4

Figure 3. Breeding Chart for Amphibolurus vitticeps (Sheet A).

SPECIES... INLAND BEARDED DRAGON – Amphibolurus vitticeps

Breeding No.	Specimen No. 1:0	Specimen No. 0:1	Period In Collection 1:0	Period In Collection 0:1	Wild/Captive Bred 1:0	Wild/Captive Bred 0:1	Age 1:0	Age 0:1	Length 1:0	Length 0:1	Kept Together/ Separated and When Introduced	Mated Captive/Wild	Birth/Egg-Laying	Ave Egg Length and Weight At Laying	Incubation Temperature °C.	Incubation Humidity %	Incubation Length DAYS
1.	/	2			W	W	A	A			/	CAPTIVE	27-11-72	/	/	/	80
2.	/	2	/	/	W	W	A	A			K.T.	"	6-11-73	/	/	/	62
3.	/	2	/	/	W	W	A	A			K.T.	"	5-11-74	/	/	/	60
4.	/	2	/	/	W	W	A	A			K.T.	"	21-11-74	/	/	/	62
5	/	2	/	/	W	W	A	A			K.T.	"	30-11-75	/	/	/	61
6	/	2	/	/	W	W	A	A			K.T.	" A	29-10-76	/	/	/	57
												" B	7-12-76	/	/	/	59
7	/	2	/	/	W	W	A	A			K.T.	" A	23-10-77	/	30.5	/	58
												B	30-11-77	/	30.5	/	59
8	/	2	/	/	W	W	A	A			K.T.	"	1-12-78	33 x 18mm; 5.3g	30-33	/	61
9	/	/	5Y – HATCHED 30-1-76		C.	C.	5Y.	5Y.			K.T.	"	9-11-80	/	26-30	/	63
10. A	/	/	/	1M.	/	W	/	A			/	WILD.	15-10-84	31 x 18mm; 5.1g	27	/	72
B.	/	/	3Y.	8Y	C	C	3Y.	8Y.			K.T.	CAPTIVE	8-11-84	27 x 16mm; 3.7g	28	/	79
C.	/	/	3Y.	3M.	C	W	3Y.	8Y.			K.T.	CAPTIVE	1-1-85	29 x 15mm; 4.0g	25-31.5	/	103-107

Figure 4. Breeding Chart for Amphibolurus vitticeps (Sheet B).

B SPECIES.... INLAND BEARDED DRAGON – Amphibolurus vitticeps

Breeding No.	No. Eggs /Young	No. Fertile	No. Hatched	Young At Birth Ave Length (mm)	Young At Birth Ave Weight (g)	Survival Rate 1 mth	Survival Rate 3 mth	Survival Rate 6 mth	Survival Rate 1 yr	Length Gain (mm) 1 mth	Length Gain (mm) 3 mth	Length Gain (mm) 6 mth	Length Gain (mm) 1 yr	Weight Gain (g) 1 mth	Weight Gain (g) 3 mth	Weight Gain (g) 6 mth	Weight Gain (g) 1 yr	Comments: (Behaviour, Colour, Pattern Change Etc
1	11	10	7			7	5	5	4									
2	15	14	14			12	10	9	8									EGGS INCUBATED IN 'CATS PRIDE'.
3	17	17	17			17	15	12										
4	17	17	17			15	14	11										
5	14	14	14			13	13	11	10				340				71	
6 A.	18	18	18	113	3.2													
B.	15	15	15															
7 A	19	19	19	111	3.1	19	7	6	6	114	142	153	276	3.5	2.4	7.6	44.2	2 INCUBATION METHODS. CLUTCHES PLACED TOGETHER 17/2. HIGH MORTALITY FEBRUARY + MARCH.
B	18	18	17	107	3.1	16												
8	15	15	15	99	3.6	15	13	12	4 (DEPARTED)	138	177	180	281	6.5	13.2	15.8	59.2	
9	19	19	18	116	3.1	18	2	2	1	124	131	162	239	3.6	4.3	7.5	28.1	HIGH MORTALITY AGAIN.
10. A. HATCHED 26-12. SEE OVER.	26	22	17	99.7 (89-108) S.V. 41.2 (40-43.5) n=6	2.3 (1.8-2.5) n=6	15	14			118 S.V. 47.6	166 S.V. 62.5			3.3	7.4			
B HATCHED 27-1.	6	6	6	90.7 (85-94) S.V. 39.8 (38.5-41.5) n=6.	2.1 (1.8-2.2) n=6 -	6	6			111.8 (102-107) S.V. 47.2 (45-49) n=6	155 (131-164) S.V. 63 (55-69) n=6.			3.4 n=6.	7.8 (4.7-9.2) n=6			
C. HATCHED 16-4	18	15	11.	102 (90-112) S.V. 43 (42-46) n=6.	2.2 (1.9-2.5) n=6.	11.				118 (108-128) S.V. 47.7 (45-50) n=6.				3.4 (2.6-4.2) n=6.				

Figure 5. Breeding Chart for Amphibolurus vitticeps (Reverse of Sheet B).

1ST FIGURE IN EACH CATEGORY (NOT EACH MONTH) IS SAME LIZARD. ie: 48·5/ 122/3·2 etc.

MONTHS

	1	2	3	4	5	6	7	8	9	10	11	12
	48·5	54	65	77								
	46·0	52	59	64								
	51·0	58	68	62								
	42·0	52	58	67								
	48·0	53	57	63								
	50·0	60	68	65								
				65								
				79								
				77								
				74								
	M. 97·6	54·8	62·5	69								
TOTAL LENGTH	122	143	171	192								
	119	133	156	161								
	127	146	187	151								
	94	136	158	180								
	122	138	153	172								
	124	156	171	175								
				170								
				216								
				189								
				191								
	M. 118	142	166	180								
WEIGHT.	3·2	5·5	9·0	13·6								
	2·9	3·7	5·4	8·3								
	4·2	5·8	9·3	7·1								
	2·2	4·1	6·3	9·5								
	3·5	4·3	5·7	7·2								
	3·7	6·5	9·0	7·4								
				7·9								
				14·7								
				12·7								
	M. 3·3	4·9	7·4	11·3								
	n=6	n=6	n=6	10·0								
				n=11								

WHOLE GROUP. from n=11 M. 3·3

Figure 6. Breeding Chart for Acrochordus arafurae (Sheet A).

A SPECIES... ARAFURAN FILE SNAKE – Acrochordus arafurae

Breeding No.	Specimen No. 1:0	Specimen No. 0:1	Period In Collection 1:0	Period In Collection 0:1	Wild/Captive Bred 1:0	Wild/Captive Bred 0:1	Age 1:0	Age 0:1	Length 1:0	Length 0:1	Kept Together/ Separated and When Introduced	Mated Captive/Wild	Birth/Egg-Laying	Ave Egg Length and Weight At Laying	Incubation Temperature	Incubation Humidity	Incubat'n Length
1.	4		YOUNG RECEIVED FROM B. GARNETT ON 1/3/78.									WILD WILD.	25-2-78		♀ GRAVID ON	AUGUST 1977	
2	1	2	3Y	3Y	W	W	♂6Y	♀6Y				C (SHEET C)	10-3-83				
3	1	2	5Y	5Y	W	W	♂8Y	♀8Y				C(-)	12-3-85				

Figure 6. Breeding Chart for Acrochordus arafurae (Sheet B).

B. SPECIES... ARAFURAN FILE SNAKE – Acrochordus arafurae

Breeding No.	No. Eggs/Young	No. Fertile	No. Hatched	Young At Birth Ave Length mm	Young At Birth Ave Weight g	Survival Rate 1 mth	Survival Rate 3 mth	Survival Rate 6 mth	Survival Rate 1 yr	Length Gain 1 mth	Length Gain 3 mth	Length Gain 6 mth	Length Gain 1 yr	Weight Gain 1 mth	Weight Gain 3 mth	Weight Gain 6 mth	Weight Gain 1 yr	Comments: (Behaviour, Colour, Pattern Change Etc
1	18	18	17 (1 autolysed)	380	27.8	2				395				24.4				Eggs fertile on candling 2/4. 1 egg opened 21/4 - embryo 3 cm long. 1 dead 1/5.
2	11	9	9	346 (305–381) n=11	25.9 (23.1–27.3) n=11	9	9	7	7	370 (310–381) n=9	390 (310–416) n=8	451 (408–491) n=7	570 (511–652) n=7	25.4 (22.7–26.9) n=9	34.8 (28.5–45.5) n=8	59.2 (47.6–71.2) n=7	122.6 (112.6–131.4) n=7	
3	19	18	16	375 (323–404) n=11	28.4 (22.5–29.8) n=11	15	8	7		378 (357–404) n=10				27.1 (21.9–28.9) n=10				

Figure 7. Breeding Chart for Acrochordus arafurae (Sheet C).

SHEET C

ARAFURAN FILE SNAKE - Acrochordus arafurae.

1982.

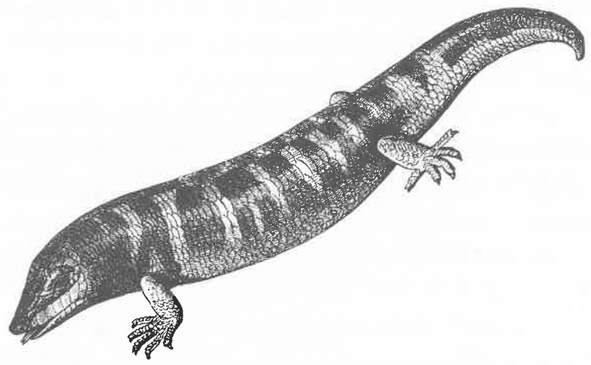
Attempted mating 7/5. (No. 1 acting as male), 12/5, 18/5, 28/5, 31/5, 3/6, 3/7. 20/7 - placed on display. Attempted mating 29/7, 5/8, 10/8 (semen noted in water see diary),
No. 2 looking very full - 21/8.

1983. Male stimulating female on 20/1 (see diary). 9 young born 10/3 (+2 unfertilised eggs). Refused to eat live Gambusia but started taking larger (approximately 5 cm.) live goldfish almost as soon as placed in tank (24/3). Noted that immediately on putting young snake back in the water, they seemingly try to bite themselves; this only lasts for 3 or 4 seconds.

4 Gambusia eaten by young 30/3, plus all fed on goldfish 2/4. Male courting female on 7/4. Length of young is very difficult to measure accurately as they are so elastic. Young starting to slough 5/9, 4/10, 17/10, 6/11. 28/11, 13/12, 24/12.

1984. Adults mating 8/2. 3/5, 30/5, 31/5, 1/6, 7/6, 15/6, 17/6, 19/6, 24/6, 26/6, 1/7, 14-20/7, 25/7, 28-31/7, 3/8, 4/8, 6-11/8, 15/8.

1985. Female produced 16 live young, 2 dead plus 1 unfertilised egg 12/3. Young began feeding 21/3. 1983 specimens weighed/measured 12/4 (probing attempted). The group of 3 or 4 which are not feeding as well as main group starting to 'bite side-ways' as per first group in early 1983. Young starting to take fish from forceps on 1/5 and also developing 'fungus'. Treated 2/5.



HIGH TECH HERPETOLOGY: AN UPDATE ON THE FRESNO ZOO'S COMPUTERIZED ENVIRONMENTAL CHAMBERS

Alan G. Baker

In the early 1970's, a master plan was developed for the Fresno Zoo that included a new reptile facility. Dr. Paul Chaffee, zoo director, and Ron Tremper, who was then herpetologist, developed a reptile house concept that utilized environmentally controlled chambers as exhibits. The system was initially designed to use a cam system to run the heating and cooling units, similar to ones used in timed watering systems. However, the company that manufactured the cams went out of business. The contract for the facility went to a local Fresno firm called Energy Systems. They modified the chamber concept, and most importantly, added a computer to control the system instead of depending on cams. The building itself was designed around the computerized environmental chamber concept. The exterior walls of the building are thick adobe brick without windows. This helps reduce rapid temperature fluctuations within the building. If the facility loses power, the internal building temperature will not reach a critical point for at least 24 to 36 hours.

Inside the building, the comfort of both the staff and the public is attended to. The work areas and public viewing areas are both separately air conditioned. The public area also is carpeted, and the lights are dimmed by rheostat controls, which helps reduce glare on the display windows. The display area is a large oval, with the work area in the center of the oval, behind the displays. The work area contains an office, a rodent colony room, two quarantine or holding areas, a cold room kept at approximately 64^{o}F, a storage area, and restrooms. A large work island contains a dishwasher and a small refrigerator for antivenin storage.

The chambers roll up to openings in the wall dividing the public from the work areas. This wall is removable, which allows for different configurations of the chambers. A separate

deionized water system circles the work area and allows easy hookup to each chamber.

The computerized environmental chambers are the heart of the reptile house system. There are three sizes of chambers: 20, 32, and 66 cubic feet. The internal mechanical components and computers are the same for all three sizes of chamber.

The chambers draw in fresh air from the work areas of the building. The air passes through ultra-violet sterilizers and flows through a fiberglass paper filter. The air is then heated or cooled according to the requirements of the species maintained in the chamber. The temperature is under control of the computer temperature sensors. The air flow then moves upward through ducts in the hollow walls of the chambers and enters the top of the animal display area through a two piece plastic grid system. The exhaust ports are located on the side of the display area approximately five inches from the floor of the animal area. The air leaves the unit after passing through a viral filter. Cooling of the chambers is done when the air passes a chilled water refrigeration unit. Other than the water and electric hook-ups, the chambers are self-contained and rest on casters for mobility.

The computer controls all the necessary functions in each chamber, and the required information is programmed in by the reptile house staff. The front control panel contains a keyboard through which program information is entered. The temperature inside the chamber shows the temperature on a digital display to one-tenth of a degree. The control panel also contains a hibernation control switch, a manual light override, and visual and auditory alarms. The computer can be programmed to vary the light cycles daily if needed. Different temperature and humidity settings for day and night periods can also be programmed. The dual lighting systems allow for a "daybreak and sunset" period using only BL black lights before and after the daylight periods. The hibernation control allows us to hibernate the animals without removing them from public display. The opportunity to maintain separate temperature and humidity settings during the

night makes it possible to house and breed several rare species of animals, including New Zealand geckos Naultinus sp..

Over the course of the last six years we have uncovered several problem areas with our systems. The units were originally equipped with motorcycle batteries to maintain the computer program in case of a power failure. After several years the batteries were no longer functional. Following each power outage we were forced to reprogram all 31 chambers, which could take over an hour. To eliminate this problem we installed lithium batteries with a ten year life span.

The humidity system also proved to be ineffective. After a problem with overheating, which caused one chamber to catch fire, the system was disconnected. In addition, we have recently been having problems with our water system. Deionized water is used in the chamber cooling systems. Poor water quality caused the steel components to rust, with subsequent build-up in the cooling coils. Several became totally blocked. The coils are not replaceable parts, so the entire refrigeration unit must be replaced at considerable expense. In addition to problems with the chilling units, we have experienced problems with the heating units. The heating units are connected to a failsafe system linked to the duct fans in the unit. If the fans are not running, the heater unit will not engage. The bearings and motors in these fans ran 24 hours per day for six years. This is well above the expected performance levels of the fan units, and replacement of the fan units and bearings is now becoming common. The "down time" on the chambers while these systems are repaired affects our display ability and is also detrimental to animal health. With only thirty-one displays, even one chamber "down" presents a problem.

We are in the process of finalizing plans for converting our units to a system with centralized heating and cooling that will pipe water to each unit. The individual computers will control water flow to maintain temperature set points in each unit. This system will not allow overheating of the units because the hot water temperature will be maintained below dangerous levels.

Overall, the computers have been reliable. However, computer problems often must be handled by the designer, since specialized testing equipment and training are needed for diagnosis or repair. Bevens' Systems, the computer designers, have been extremely helpful, but they are located 250 miles away from Fresno.

During the past six years, our reptile house and computerized chambers have proven to work well and are valuable tools for herpetologists. Problems have developed, but our units are prototypes for further advances in this area, and problems were expected. The Fresno Zoo plans to keep improving our system and will continue to be a source of information and research in the area of "High Tech Herpetology".

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THE PROPAGATION AND REARING OF CERTAIN ANURAN SPECIES

Bob Bader

INTRODUCTION

Until a few years ago breeding of anurans in captivity had been done by only a few zoos (International Zoo Yearbook, 1972-1981), usually by chance. Few private collectors ever kept frogs or toads, and those that did usually had a few specimens in an aquarium. Today it is quite common for zoos and private collectors to routinely breed several species of anurans in successive years. Although a few species are bred naturally (National Zoo, pers. comm.; St. Louis Zoo, pers. comm.) most anuran breeding is done in conjunction with the use of a synthetic hormone, GnRH (Odum et al., 1983; Ernie Wagner, pers. comm.).

This paper deals with the natural breeding of several species of anurans, including Litoria caerulea, Hyla versicolor, H. cinera, and Bufo americanus.

HOUSING

Proper housing (i.e. size of enclosure, temperature and humidity control, adequate water for breeding adults and rearing tadpoles, and natural vegetation) is an important criterion for the natural breeding of anurans. Quite often these requirements cannot be met in a public display. My anuran cage is a 10' x 26' greenhouse attached to my house. It is foliated with several species of plants including bromeliads, philodendrons, palms, ferns, cacti, and succulents. At one end of the greenhouse is a 100 gal. pond. At its deepest point the water depth is 28 inches, but there are three shallow ledges 8 inches in depth. The pond contains water lilies, lotus plants, pickerel weed, and dwarf papyrus; the surface of the water is covered with duckweed and water lettuce. At the other end of the greenhouse is a large hot tub that serves as an observation area.

A 50-foot sprinkler hose encircles the floor of the greenhouse to provide "rain" inside whenever necessary. Supplemental heat is needed only at night during the winter

months, and I use a Kero-Sun heater (LR-350 by Toyotomi America, Inc., Brookfield, CT.). For the past two winters I have noticed no adverse effects from using kerosene heat. The frogs are not segregated, and are kept in the greenhouse twelve months a year.

FEEDING THE ADULTS

Feeding is accomplished by the provision of a feeding station. The feeding station consists of a box 30 inches long x 16 inches wide x 24 inches high. The inside top 3 inches is lined with glass, which prevents the crickets from climbing out, but gives the frogs easy access to them. The frogs seem to have no trouble finding the crickets. They apparently cue in on the sound the crickets make or learn (through conditioned response) where to expect food.

Pinkie mice are offered to the large frogs on a semi-regular basis.

During the spring and summer, large numbers of grasshoppers, moths, and other wild insects are released in the greenhouse.

BREEDING

The frogs remain dormant throughout most of January and February. By March they become active again, and depending on the species, the males begin calling. Continuous steady calling by a particular species usually indicates that they will soon breed, and I have noticed several species will call throughout the summer. When it rains outside I turn on the sprinkler hose for 3-6 hours at night.

During the spring of 1984 Bufo americanus was the first species to breed. They bred in April, the same breeding season as wild B. americanus. Hyla versicolor bred in May; Litoria caerulea bred 17 June; and Hyla cinera bred in early July.

During the spring of 1985, Litoria caerulea bred 26 April and 1 May (2nd generation); two other species have tadpoles in the pond as of 10 June, 1985.

CARE OF TADPOLES

The tadpoles remain in the pond until they metamorphose. Because of the large number of aquatic plants there is no need to

aerate or filter the water.

Besides the algae and duckweed that they eat, I feed the tadpoles daily on Purina Trout Chow (Purina Feed Co., St. Louis, MO.). I feel that this is an adequately balanced diet and no other supplement is necessary. All the tadpoles have grown quite rapidly and they are very healthy when they metamorphose. Because over-feeding can be more dangerous than under-feeding (Odum, et al., 1983), I feed only once a day, and then I limit the amount of food to what can be eaten within 3 hours.

CARE OF NEONATE Litoria caerulea

Metamorphosis in L. caerulea begins ca. 3-5 days after the development of front legs. The froglets will climb out of the pond onto the various plants. Over 99% of the metamorphosis occurs after dark.

As the froglets emerge from the pond I collect them and place them in 20 gal. aquaria with newspaper for substrate and two water bowls on the bottom. I house ca. 50 in each aquarium. Within two or three days of metamorphosis I begin feeding pin-head crickets. I dust the crickets first with Pervinal multi-vitamin powder (St. Aubrey/Division of 8 in 1 Pet Products, Inc. N.Y., N.Y.). Pervinal is essential if you are feeding farm-raised crickets.

I found that the froglets can be overfed, and now I try not to feed more than they will eat in a day. I feed every other day. As the frogs grow their food items must also be correspondingly larger. Within several weeks L. caerulea can grow large enough to take pinkies.

Care must be taken in feeding small frogs too large a cricket. Even though they may easily eat it, sometimes the cricket is swallowed alive and could possibly chew through the stomach wall.

GENERAL COMMENTS

Most of the Hylas kept in the greenhouse were nocturnal, particularly L. caerulea. For the last 18 months I have never seen one during the daylight hours. Even at dusk they are not active.

The Hylas do not appear to be cannibalistic. I have observed L. caerula grabbing frogs much smaller than the mice they eat but they always spit them out.

Usually if just one male is calling it does not elicit much response from females, but when more than one male calls females are present around the pond.

A personal observation on female response to males is that when the females can voluntarily travel to the males, amplexus and egg laying are more likely than when males and females are confined in a small area, i.e. an aquarium or a small cage.

Although the use of GnRH allows one to readily and easily breed many anuran species, there is no evidence available as to whether there are any long term effects on an individual that has had an "extra dose" of hormones.

Amphibians set up in large naturally planted exhibits can be bred without the use of these hormones. We can learn more about an amphibian's normal life cycle if we can house them in a more natural environment.

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PREVENTION OF GAS BUBBLE TRAUMA IN CAPTIVE AMPHIBIANS

Kris Orwicz and John Colt

ABSTRACT

Gas supersaturation of water has been identified as a serious problem in the culture and holding of amphibians. Gas supersaturation causes a non-infectious disease called gas bubble trauma or gas bubble disease. The most common clinical sign of gas bubble trauma is the formation of small, gas-filled bubbles on the webbing of the hind legs and body surfaces. In the advanced stages, the clinical signs of gas bubble trauma are similar to "red leg," a serious disease of captive and wild amphibians.

Well waters typically have higher dissolved gas levels than surface waters. The use of well waters may increase the chances of producing gas bubble trauma in captive amphibians. The highest dissolved gas levels in surface water will commonly occur in the spring and summer. Increases in water temperature or entrainment of air into the water system may result in lethal dissolved gas levels, even if the dissolved gases are initially near equilibrium. Gas bubble trauma can be prevented by removal of the excess gas, which can be removed by several simple and inexpensive devices.

INTRODUCTION

Disease is a serious problem in the rearing and holding of amphibians. Gas supersaturation produces gas bubble trauma (GBT) in aquatic animals due to the formation of bubbles in the blood and tissue. In amphibians, the clinical signs of GBT are similar to "red leg" disease, commonly caused by Aeromonas hydrophila and gas supersaturation may be responsible for many incidents of "red leg" in both laboratory and natural conditions. This paper will discuss measurement of gas supersaturation, production of supersaturation and prevention of GBT in captive amphibians.

WHAT IS GAS SUPERSATURATION AND HOW DOES IT EFFECT AMPHIBIANS?

Gas bubble trauma is a result of hyperbaric dissolved gas pressure and therefore gas supersaturation must be expressed in terms of pressure rather than mass or molar units. Four commonly used pressure parameters are defined as:

Partial Pressure: Pressure (mm Hg) that a single gas would exert by itself if it occupied the entire volume of a mixture.

Total Gas Pressure (TGP): The sum of the partial pressures and vapor pressure of water (mm Hg).

Differential Pressure ($\triangle P$): The difference between total gas

pressure and the barometric pressure (mm Hg).

Gas Supersaturation: The partial pressure of the gas in the liquid is greater than the partial pressure of the gas in the gas phase.

If the total gas pressure is less than the barometric pressure, gas bubble trauma cannot develop, even though individual gases may be highly supersaturated. Since $\triangle P$ is equal to barometric pressure minus total gas pressure, positive $\triangle P$'s represent supersaturated conditions. Additional information on the computation and reporting of gas supersaturation can be found in Colt (1983, 1984).

There are many methods and instruments available for measuring gas supersaturation. The most commonly used instrument is the "Weiss Saturometer" and uses a membrane-diffusion method to measure gas supersaturation. This instrument is simple to operate, portable, and requires no power. The instrument consists of 200 feet of silicone rubber tubing connected to a pressure gauge. The silicone rubber is permeable to dissolved gases. At equilibrium, the pressure inside the tubing is equal to the total gas pressure in the water (Fickeisen et al., 1975). Typically, pressure is measured with a "gauge pressure" device and therefore reads out directly in terms of $\triangle P$.

Other types of instruments using the membrane-diffusion method are available and vary in capabilities and costs. Commercial sources of membrane-diffusion instruments are listed in Appendix A. Prices of these instruments range from $700-$3000. Bouck (1982) describes an inexpensive "gasometer" that is simple to build. This instrument also can be installed inline (inside a pipe) and can continuously monitor $\triangle P$.

When the $\triangle P$ inside an aquatic animal is greater than zero (i.e. supersaturated), there is a tendency for bubbles to form. Bubbles that form in the blood are called emboli, and bubbles formed in the tissues are called emphysema. The quantity, size, and location of emboli and emphysema is related to the degree of supersaturation, exposure time, and tissue type.

At extremely high levels of gas supersaturation (P =

200-250mm Hg), a high mortality is observed within 1-3 days. This is due to large emboli occluding critical portions of the circulatory system (Beyer et al., 1976; Colt et al., 1984b). In the bullfrog (Rana catesbeina) external clinical signs are rarely observed, but internally bubbles may be present under the skin and in the vascular system, along with a large degree of internal hemorrhaging (Colt et al., 1985). In the Eastern Newt (Notophthalmus viridescens) bubbles in the eye or a swollen abdomen have been observed occasionally.

As the $\triangle P$ is decreased (115-185mm Hg), internal effects are less severe. However, external effects become more prominent and death may result from a secondary bacteremia. Some clinical signs are quite obvious while others are subtle. Abnormal behavior may be observed. This may include the inability to locate or ingest food, loss of equilibrium, and floating (due to the accumulation of gas under the skin or in the gastrointestinal tract).

In bullfrog tadpoles (Rana catesbeiana), exposure to gas supersaturation results in the inflation of the gastrointestinal tract. Affected tadpoles floated on the surface, either with their left sides elevated or on their backs. Tadpoles exposed for ten days to a $\triangle P$ of 160-170mm Hg showed increased levels of systemic Aeromonas hydrophila bacteria (Colt et al., 1984a).

Clinical signs in frogs (Rana catesbeiana, Xenopus laevis) begin with the formation of gas bubbles in the interdigital webbing, occurring within 24 to 48 hours. The bubbles then expand in size and number throughout the webbing. An ascending hyperemia progresses up the legs and abdominal surfaces due to the rupturing of small capillaries. The forelegs follow the pathogenesis of the hind legs. External bubbles disappear, leaving petechial and ecchymotic hemorrhages which enlarge and progress into eroded areas of necrotic skin. At this point, the frogs typically lose their ability to stay submerged. Death may result due to accumulation of gas in the vascular system, or from a secondary bacterial infection (usually

Aeromonas hydrophila). The development of these clinical signs occur within 3-4 days for Xenopus held at a ΔP of 180mm Hg (Colt et al., 1984b). These signs may be reversed within a few days by reducing the TGP to equilibrium. Failure to observe the emboli may be due to their small size, ease of rupturing, and the rapid development of hemorrhaging which obscure the bubbles.

Amphibians appear to be able to withstand a higher degree of gas supersaturation than fish. In fish, a ΔP in the range of 120-140mm Hg will kill 50% of the animals in four days. In amphibians, no clinical signs are seen below a ΔP of 100mm Hg when held for two weeks or more. Long term "safe level" for amphibians are poorly defined at this time. A provisional criteria of 20mm Hg may be used for amphibians until further information is available (Colt et al., 1984a, b, ms).

OCCURRENCE OF GAS SUPERSATURATION

Gas supersaturation can be produced by a variety of processes. The major mechanisms are heating, bacterial action, air entrainment and photosynthesis. The occurrence of gas supersaturation in the hatchery may be a result of a supersaturated water source, or due to production of supersaturated conditions within the hatchery system.

Natural supersaturation commonly occurs in ground water, springs, streams, lakes, and bays at some time of the year (Bouck, 1976; Harvey, 1967; Lindroth, 1957). The usual mechanism in these situations is heating of the water, since the solubility of gases decreases with increasing temperature. In large bodies of water such as lakes and reservoirs, heating occurs to a significant depth. Spring or well water is commonly supersaturated due to the water temperature being higher at discharge than at the time the water went underground.

This mechanism may be coupled with bacterial action, which may modify dissolved gas levels in natural water sources. Bacterial respiration results in decreased oxygen and increased carbon dioxide concentrations (Matsue et al., 1953). Under anaerobic conditions, significant amounts of methane and nitrogen may be produced (Koyama, 1964).

We have measured ΔP in Davis and Sacramento, California, at the source and after passage through city water systems (Colt and Orwicz, ms). Sacramento obtains its water from the American River while Davis uses deep (1500 feet) wells.

The ΔP of Davis well water (Figure 1) is high, but changes little during passage through the system. The ΔP of Sacramento water (Figure 2) increased from 50mm Hg (American River) to over 200mm Hg (Pet's Plus Store). The increase in ΔP is due to heating and entrainment of air into the system. The dissolved oxygen of well water and some municipal water may be very low and require treatment prior to use even if not supersaturated with gas. While the ΔP of surface and shallow well waters may typically be lower than deep well waters, significant changes may occur in the water system and direct measurement of ΔP is needed to assess the risk due to gas supersaturation. Dissolved oxygen is not a good indicator of ΔP.

Incoming hatchery water may be supersaturated at some time during the year, therefore the water should be degassed before use. The use of degassed water (i.e. water at equilibrium) does not assure that the system will be free of supersaturation problems. Gas supersaturation may also be produced inside the culture system due to heating without re-equilibrium of dissolved gases, air entrainment, and/or green water culture.

It is common practice to heat water to achieve optimum hatching, survival or growth. The solubility of gas decreases at higher temperatures; therefore heating can produce lethal dissolved gas levels if the water is not re-equilibrated prior to use. In closed heating systems (common water heaters) elevated hydrostatic pressure will prevent gas transfer until the water is discharged into the culture system. The mixing of water of different temperatures may cause gas supersaturation, since the solubility of gases are not linear with temperature.

A common mechanism for production of gas supersaturation is air entrainment. If the screens of a hatchery intake pipe clog, the pipeline may not be full, thus entraining air (Wyatt and Beiningen, 1971). Air leaks around pump seals, loose valve

connections, pinholes in tubing, or pump intake pipes not being fully submerged can cause sub-atmospheric pressures that result in air being drawn into the water system. Since gas solubility depends on pressure, entrainment of air into pressurized water systems can result in a significant amount of the entrained air being dissolved and the production of high levels of gas supersaturation with respect to normal barometric pressure. Airlift pumps or submerged aerators may also cause supersaturated water (Colt and Westers, 1982).

The use of algae in "green water culture" for larval forms can result in lethal ΔP's (Supplee and Lightner, 1976) from photosynthetic production of oxygen. Shading or increased water exchange can be used to prevent GBT.

Air transport of amphibians may also be a mechanism for producing gas bubble trauma, although documentation is lacking. Barometric pressure in a cargo area pressurized at 10,000 feet is equivalent to a ΔP of 245mm Hg with respect to sea level.

PREVENTION OF GAS BUBBLE DISEASE

Prevention of GBT will require degassing of influent water and design of aquatic systems to avoid production of gas supersaturation within the facility. Several methods of degassing are available. The specific method used will depend on flowrate, financial resources, and site specific conditions.

Supersaturated water will naturally lose gases to the atmosphere. In static systems, this mechanism may be adequate for prevention of gas bubble trauma if the water is allowed to stand several days before the animals are added. In flow-through systems, natural degassing is generally too slow, and the rate of degassing must be increased by other methods.

Packed Column Aerators

One of the most widely used devices to remove excess dissolved gas in the packed column aerator (PCA) which consists of a column filled with a high-surface area plastic packing media (Figure 3). Water flows down over the media in a thin film, creating a large gas-liquid surface area. Commonly used media range from 2.54 to 8.89cm (Figure 4) and are commercially

available from several companies (Appendix B). This type of media may be called pall rings, biorings or ballast rings. The key design parameters are column height, surface loading rate (flow rate/cross-sectional area) and media size.

The maximum hydraulic loading rate (flow/cross-sectional area) varies from 50-200 m/m h (21-84 gpm/ft) depending on media size (Hackney and Colt, 1982). For the 3.81cm media and a hydraulic loading rate of 100 m/m h, the capacity of common pipe sizes are presented in Table 1. The larger sized columns are preferred, as they reduce the amount of water that flows down the walls. The water should be evenly distributed over the media.

The height of the column needed will range from 1-3m depending on influent ΔP, dissolved oxygen and temperature. For the 3.81cm media, the total column height required to achieve a ΔP = 20mm Hg and a dissolved oxygen concentration of 90% of saturation is presented in Figure 5.

Vacuum Degassing

Vacuum degassing systems can reduce column height (Fuss, 1983). The vacuum systems reduce the effective barometric pressure, hence increases the ΔP and therefore increase the gas transfer rate but may result in unacceptable dissolved oxygen concentrations. A vacuum column may be useful for removal of gas supersaturation resulting from air entrainment, heating and photosynthesis, as these processes produce oxygen supersaturation as well as total dissolved gas supersaturation.

Nozzles

For low flow rates of 0.2-0.5 liters per minute (1-2 gpm), drip irrigation nozzles placed inside 2-3 inch PVC pipe, 2-3 feet long produce a fine mist and results in a ΔP close to zero. The nozzles can be obtained at most hardware stores for approximately a dollar a piece.

Diffused Aeration

Diffused aerators (airstones) have been used to degas waters (Penrose and Squires, 1976). These devices may be useful when compressed air is available, but cannot be used to reduce the ΔP to zero. For a diffuser depth of 1-2m, the minimum ΔP

produced by these types of aerators is in the range of 20-40mm Hg (Colt and Westers, 1982).

Hydrostatic Compensation Depth

At depth, the actual risk to the animal depends on the uncompensated total gas pressure (Colt, 1983). The uncompensated total gas pressure decreased 10 percentage points per meter (e.g. 120% to 110%) or 73.4mm Hg per meter. Increasing the depth of the holding system may reduce the risk of a given $\triangle P$ to animals that do not remain at the surface.

For the most part, any attempts to treat the signs of GBD with antibiotics or other medicine will be counter-productive, and, at best, merely mask the signs while the underlying problem remains.

CONCLUSION

Gas supersaturation produces a pathological condition known as Gas Bubble Trauma or Gas Bubble Disease. Primary clinical signs include hemorrhaging, formation of bubbles under the skin and occasional floating animals. Due to secondary infections, the advanced clinical signs of GBT may be misdiagnosed as a bacterial problem.

This phenomenon can occur in any aquatic system when the water becomes supersaturated through various means such as heating, photosynthesis and air entrainment. In fact, both surface and well waters may be supersaturated at some time of the year.

To prevent the adverse effects of gas supersaturation, all influent water should be degassed prior to use. Since it is difficult to detect entrainment of air into pressurized water systems, routine measurements of water quality ($\triangle P$) should be undertaken. If the need for degassing is determined, then one (or a combination) of the methods described herein should be employed to bring the $\triangle P$ to equilibrium ($\triangle P = 0$).

Which method(s) should be used depends upon several factors which include the source of supersaturation and available finances. However, in most cases the packed column aerator will be the most effective and cost-efficient method. Proper design

and operation of aquatic culture systems can prevent GBT and improve the health of captive amphibians.

Acknowledgments: We thank Ed Berryman for photographic work and David A. Hallsted for typing several earlier drafts of this article.

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List of Captions

Figure Number	Title
1	ΔP of Davis Campus Water (Colt and Orwicz, ms)
2	ΔP of Sacramento Water (Colt and Orwicz, ms)
3	Packed Column Aerator (Hackney and Colt, 1982)
4	Photograph of commonly used media (Hackney and Colt, 1982)
5	Total Column Height versus ΔP and Temperature (influent dissolved oxygen = 0.0 mg/l, effluent ΔP = 20mm Hg, effluent dissolved oxygen = 90% of saturation) (Colt and Bouck, 1984)

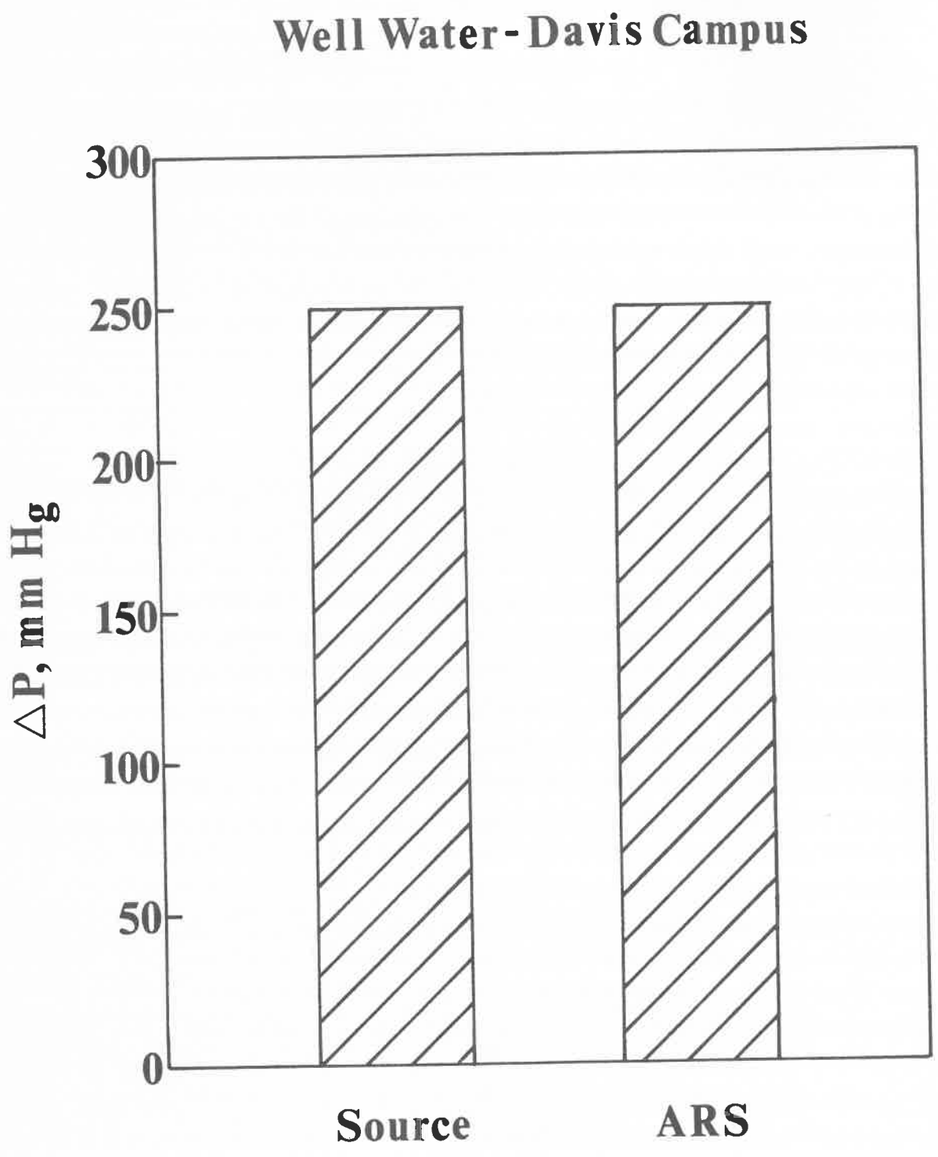

Figure 1

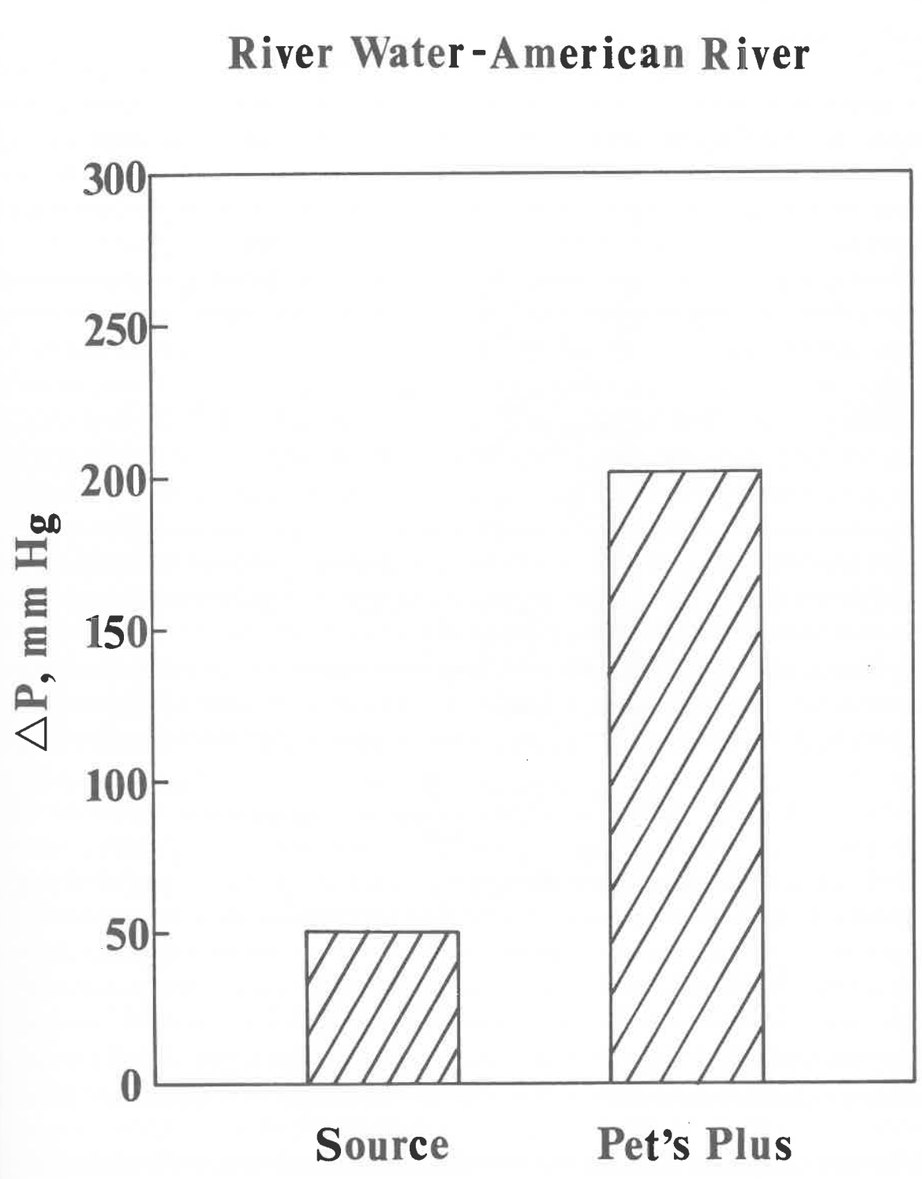

Figure 2

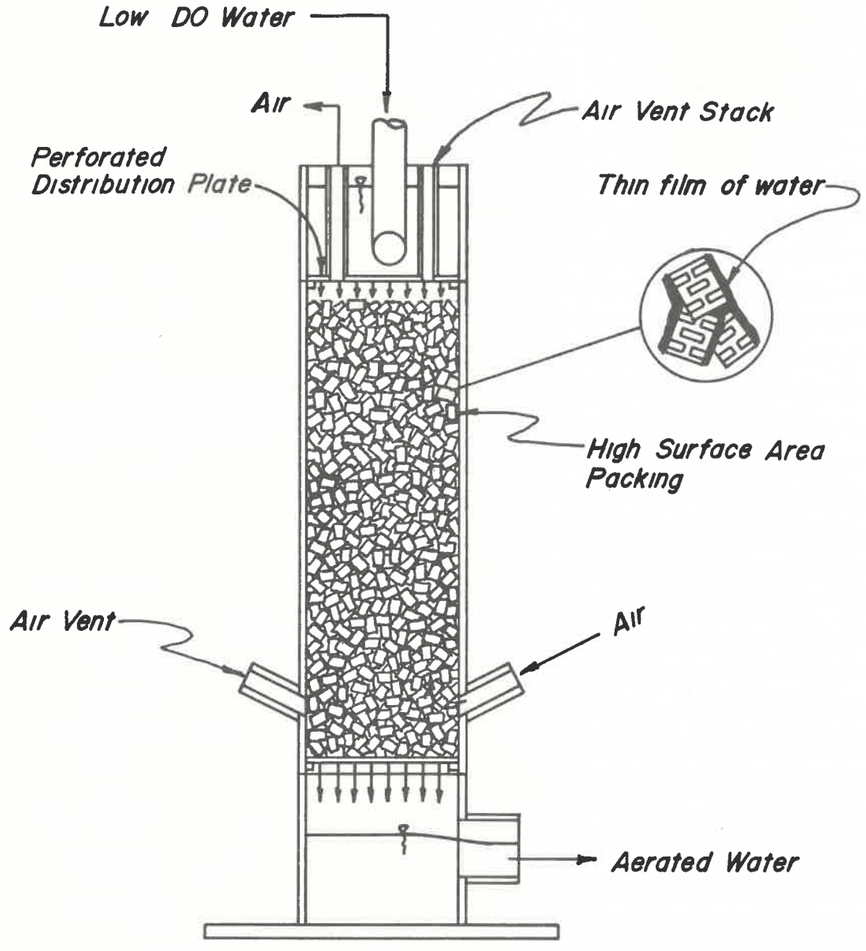

Figure 3

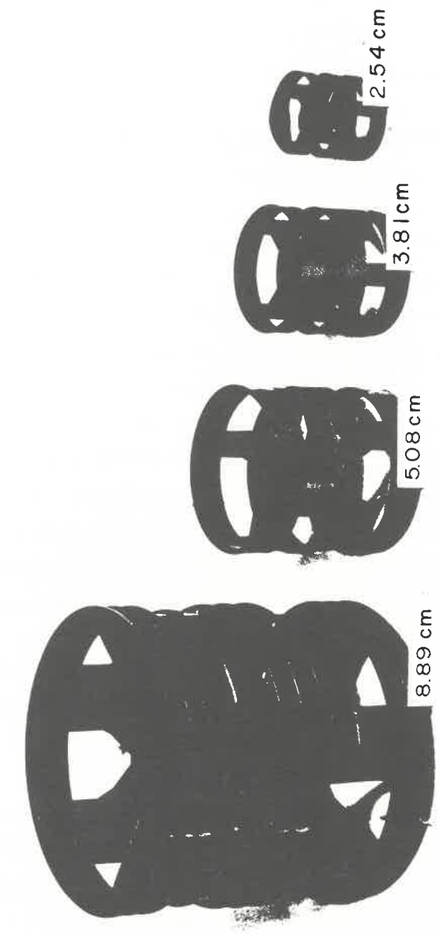

Figure 4

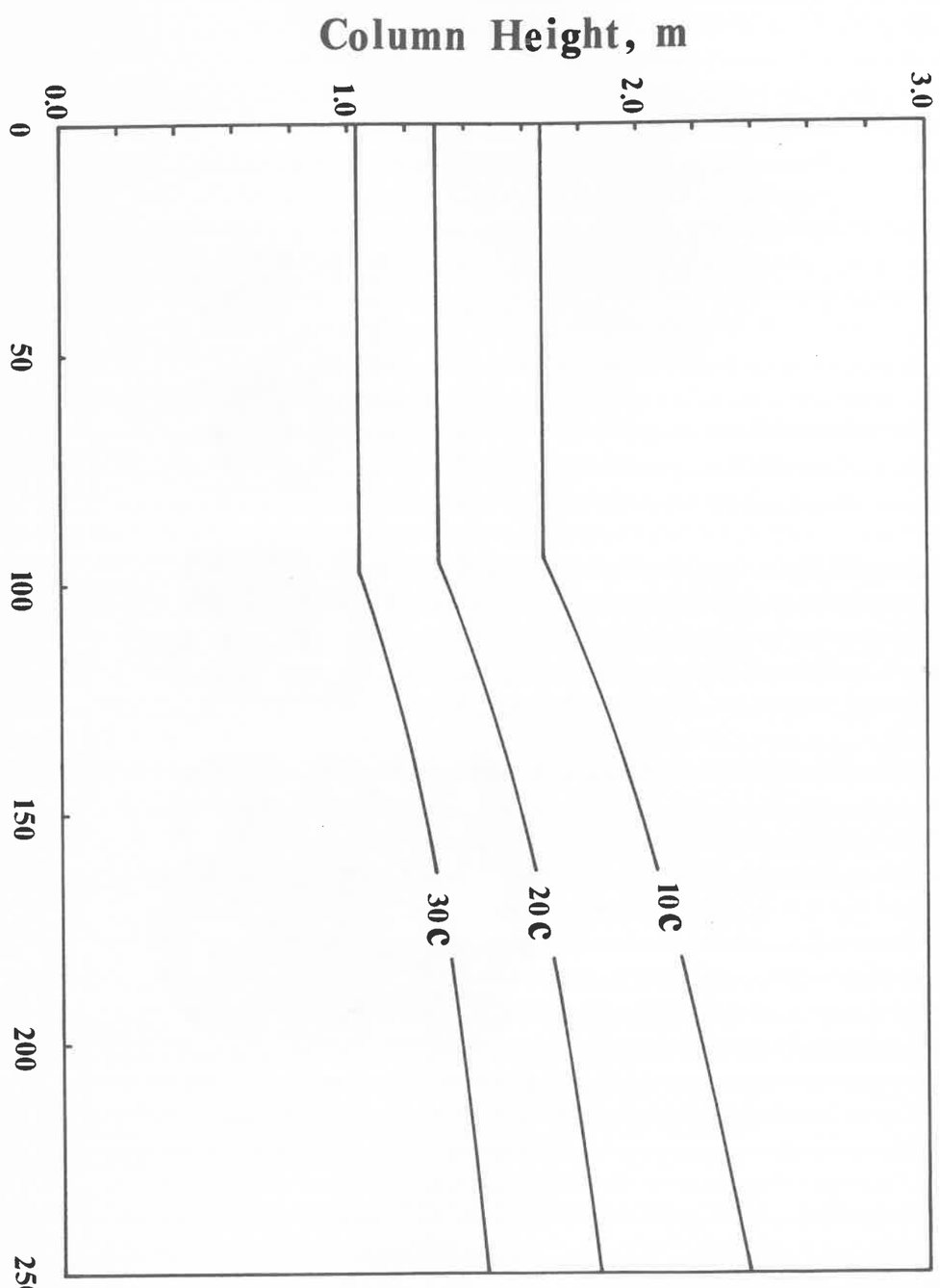

Figure 5

APPENDIX A

Commercial Sources of Membrane-diffusion Instruments for Measurement of Gas Supersaturation:

ECO Enterprises (800) 426-6937
2821 NE 55th
Seattle, WA 98105

Common Sensing (206) 842-4873
7595 Finch Road, NE
Bainbridge Island, WA 98110

Novatech Design, Ltd. (604) 381-1121
830C Pembroke Street
Victoria, British Columbia VBT 149
CANADA

APPENDIX B

Commercial Sources of Plastic Media:

Norton Company (617) 853-1000
1 New Bond St.
Worcester, MA 01606
(Plastic Pall Rings or Actifil)

Glitsch, Inc. (214) 631-3841
P.O. Box 226227
Dallas, TX 75266
(Plastic Ballast Rings)

Tri-Pack, Inc. (714) 662-0937
P.O. Box 8909
Fountain Valley, CA 92708
(Plastic Pall Rings)

Koch Engineering Co., Inc. (316) 832-5110
P.O. Box 8127
Wichita, KS 67208

Table 1. Capacity of Common Pipe Sizes Using 3.81cm Pall Rings

Column Diameter, inches	Flowrate	
	liters per minute	gallons per minute
4	13	4
6	30	8
8	54	14
10	83	22
12	121	32

CAPTIVE MANAGEMENT AND BREEDING OF THE BOLSON TORTOISE (Gopherus flavomarginatus)

Ariel B. Appleton

INTRODUCTION

Gopherus flavomarginatus, described by John Legler in 1959, is restricted to the Bolson de Mapimi, a northern Mexican plateau region located where the states of Chihuahua, Coahuila, and Durango adjoin. The common name for this species comes from the Mexican term (bolson) for a dry lake bed.

During the Pleistocene, Bolson tortoises ranged throughout south-central North America from Oklahoma to southern Mexico (Auffenberg, 1976). Now extinct in 90% of their former range (Morafka, 1981), there are estimated to be as few as 10,000 remaining in a dozen or so discontinuous locations in the Mapimi area; the western and northern populations are in considerable danger of extinction. The Man and Biosphere preserve maintained by the Instituto de Ecologia at Mapimi, Durango provides the only effective protection. Bolson tortoises were added to the United States Department of the Interior's Endangered Species List in 1979. Zoo populations have not thrived and, to the best of my knowledge, reproduction has not occurred in any zoo collection. The purpose of this paper is to describe pen construction, burrow establishment, mating, egg laying behavior, and care of the young. Hopefully, this information will be of use to those interested in the captive care and propagation of this species, as well as providing information necessary for future releases into suitable protected habitat.

MATERIALS AND METHODS

My experience with Bolson tortoises began with Gertie, a 15 pound female brought to The Research Ranch, in southeastern Arizona, in 1972 (Figure 1). The elevation of the ranch is 5000 feet, and the habitat is primarily high desert grassland and oak savannah. The climate is cooler than the Mapimi area. Winters are relatively dry, with some precipitation from November through March; the heaviest precipitation occurs from July-September.

Figure 1

Figure 2

The House Pen, 1973-1976 - In order to provide Gertie with an enclosure that approximated natural habitat, had ample foliage, and was near enough to my house for frequent observations, a relatively level open field was prepared for fencing. The field was four-fifths of an acre in size, and bounded by oak trees. Water was piped into two three-foot diameter sloped concrete basins set at ground level. The field perimeter was trenched eight inches deep. A three-foot high galvanized wire garden fence was set in the trench and supported at intervals by metal fence posts. When the trench was filled, an eight inch tall strip of one-half inch mesh wire was run along the fence interior, to prevent escape of any future hatchlings. In early June, when night time temperatures averaged 60^{o} to 70^{o}F., Gertie was released by the southeast drinking basin. She waded in, submerged her head and drank deeply for over a minute. During the next three weeks she circumvented the fence line and fed on Plains Lovegrass (Erigrostis intermedia) and several species of grama gross. She sheltered under oak leaves at night. After the first summer rain had penetrated the soil deeply, she started a burrow near tall grasses at the base of a slope at the southeast end of the enclosure. The burrow entrance was at approximately a 45^{o} angle. After encountering an oak root three feet down, she curved the tunnel to the right and continued digging at a more level angle for about three more feet, scraping in the rocky soil up to 13 times with one foreleg, then alternating to the other. Dirt built up in front of the burrow and spread out in a broad apron that sloped away from the entrance. When alarmed, she moved rapidly down the steep burrow ramp and turned sideways, her profile presenting an effective barrier. Occasionally, she would disappear completely into the burrow. She stopped circumventing the fence when she began her burrow, and she confined her movements to an approximate 100 foot radius after it was completed. She established trails through the grasses, where she browsed daily (Figure 2). In September, because I was unsure if her burrow was long enough for winter protection, I sprinkled the

immediate area with water for 24 hours, which prompted her to increase the depth of the burrow. By October, the burrow measured 2 1/2 meters in length. Gertie foraged throughout October and November, and continued to bask at the entrance of the burrow until night temperatures dropped below freezing in mid-December. She resumed basking behavior the following February, and began feeding occasionally from May to July. July through October were the months of greatest feeding activity.

The House Pen, 1976-1985 - In 1976 Dr. John Hendrickson, University of Arizona, made arrangements with Mexico's Instituto de Ecologia to transport 15 adult tortoises to The Research Ranch for purposes of ecological field work, experimentation, and observations on reproduction and general social behavior. On arrival, they were penned at ranch headquarters to be sure they were healthy. Dr. Hendrickson placed two males and two females in my care for captive breeding purposes. The house pen was divided into two pens: one male would join Gertie in the southeast pen, and the second male and two females were placed into the northwest pen. Gertie's burrow area was temporarily fenced in case the new male attempted to take over her burrow. In mid-July I released the four new tortoises into the northwest half of the field. They immediately began to forage, and also became more wary: when approached, they first tried to escape, and then drew their heads and feet in with a quick hiss when overtaken. Their behavior in the small headquarters pen had been passive. Also, they exhibited sexual and agonistic behavior. The larger male, subsequently named Potent, head-bobbed at one female and attempted to ram and overturn the small male. I had not observed sexual or aggressive action at headquarters. At sunset, they were placed in a large metal dog crate, that had a straw substrate. They remained in the crate overnight, emerged in the morning and began to forage. The following week was unusually overcast with light drizzles. The tortoises were less active and they sheltered in the crate from the rain. The first sunny day, I introduced a small male, Spry, into Gertie's temporary enclosure. They quickly advanced towards each other

(Spry bobbing actively) and clashed shells when they met. Spry moved away, with Gertie in pursuit. Because she was twice his size, I removed him from the small enclosure and released him into the larger area of the southeast pen, where he foraged for a week. He then began to burrow near the southeast fence line. The next day, when the burrow was sufficiently deep to shelter him, Gertie's temporary fence was removed and she spent considerable time sitting on Spry's burrow apron. He would retreat into the burrow on sight of her, and she occasionally tried to force her way in to the smaller tunnel, biting at the arch of dirt at the entrance and clawing in at him with one front leg when he turned sideways to block the entrance. His activity decreased after he dug his burrow, and he foraged cautiously, well away from her area. Once he encountered her as she was returning from his burrow, and he moved rapidly in circles, while she continued past him. He then stopped under a small oak and remained motionless for one-half hour before moving back to his burrow. Meanwhile a large female, Jane, had begun burrowing at the base of a bush in the center of the northwest enclosure. Soon after, a smaller female, Laura, began a burrow at the base of a large clump of Sacaton grass about 25 feet to the north. Potent did not start burrowing until late September. However, he appeared to lose interest, since the ground was hard and dry. While he foraged, I saturated the shallow excavation with water. He then resumed burrowing. This was repeated until the burrow reached a length of four feet. The tortoises all established separate foraging areas adjacent to their burrows, basked head up when morning sun entered the tunnels, then gradually moved up to their aprons to bask before leaving to forage. On their return they rested, at the top of the tunnel ramp with their heads down, often with one rear leg sprawled out behind them, until heat drove them into their burrows. They were seldom found deep in the burrow during the day, but remained close enough to the entrance to come up and block the entrance by turning sideways at any sign of interference.

Dr. Hendrickson's Pen, 1976-1979 - Dr. Hendrickson carefully

selected a level stand of Tobosa (Hilaria mutica) for his pen site, having observed that this grass was the prime forage for Bolson tortoises in the Mapimi area. A seven acre enclosure was fenced in similar manner to the House Pen, with a tall observation tower at one end. Eleven tortoises from the headquarters pen were then released into it. Over several weeks, a few of them dug laterally about a foot into a small bank at the upsloping northwest side of the enclosure. Others attempted shallow excavations in the Tobosa grass but, by late fall, they were not sufficiently sheltered for secure overwintering. A trench about four feet in depth was dug and covered with wood and soil, with an opening to the surface at one end. This was accepted by the majority of the tortoises, but a few still determined to burrow into the bank. They withstood many nights of freezing during the following two winters. The soil the Tobosa grass grew in was heavy, clay-like and unstable in heavy rains, and was prone to cave-ins at the trenched area. By late spring of 1979, six tortoises had died. Dr. Hendrickson terminated the project and placed the remaining five in my care, in hopes they would fare better in a different location.

Soil compositions at The Research Ranch are generally compact and rocky, which made burrow establishment more difficult than in the Mapimi area. Burrow lengths were shorter, on average, than those in Mexico. Dr. Hendrickson's less rocky site might well have proved superior to the House Pen. As it is, valuable information about soil preferences and about the ability of Bolson tortoises to tolerate low temperatures was gained through his efforts.

The West Pen, 1979-1985 - Dr. Hendrickson kindly donated his fencing, granted by Wildlife Preservation Trust International, for construction of the West Pen, located one-third of a mile west of the House Pen. A flat, grassy oval area of approximately five acres, it was enclosed and cross fenced in similar fashion to the House Pen, with water from a nearby windmill piped in to six widely spaced concrete basins. During construction, (June 18, 1979) one small male, marked 01, and four females, marked 07,

08, 11 and 90, were collected from the Hendrickson Pen and placed in a temporary division of Gertie's area (Bickett, 1980). The metal dog crate and a wooden bird blind were used to provide shelter. The tortoises foraged and drank in the early morning and late afternoon. The shelters were accepted, although occasional nights were spent under Sacaton grass clumps. The small male 01 daily head-bobbed, circled, and occasionally attempted to mount each of the larger females before they moved away from him. Aggression occurred when a larger female would ram a smaller one out of her way while passing, and the male Spry often tried to fight with the small male 01 when they saw one another through the fence separating them. Males attempted to climb the fence and ram each other while standing on their rear legs with their front legs braced against the wire; females occasionally rammed each other through the fence at ground level. The tortoises made no attempt to burrow in the small temporary enclosure approximately one-fifth of an acre in size the two months they were in it.

On completion of the West Pen (August 16, 1979), the five Hendrickson Bolson tortoises and the House Pen male, Potent, were introduced to it. Male 01 and the smallest female, 07, were placed in the east one-third of the pen, and females 08, 11, 90, and male Potent were placed in the larger two-thirds of the pen at the west end. They all began to forage and investigate the new pen. When they encountered fence lines, they spent the majority of their daylight activity moving along the fence. Seven plywood shelters shaped in an inverted V were set to provide shade in the treeless enclosures. The tortoises were monitored for heat stress, and removed during the hottest part of the day and placed in the wooden bird blind, located under some oak trees near the field. Since rainfall was sparse and the ground hard, the soil was loosened and dampened under the shelters in the hope burrow construction would begin. Each tortoise was placed under an individual shelter at night. The last week in August, both 01 and 07 began burrowing beneath the shelters, which were removed as soon as the tunnels provided

shade. In September, three of the four tortoises in the west half of the pen established individual burrows. When night temperatures cooled in October, female 90, still not settled, was removed to the vacant burrow in the northwest half of the House Pen.

Predator Proof Pen, 1984 - By fall of 1983, the Bolson tortoise population included 26 juveniles, both field-hatched and artificially incubated. At least six additional field-hatched and field-established juvenile tortoises had vanished during the prior winter and pre-rainy season months. I suspected raccoons were the cause since they had predated on egg clutches in both the House Pen and West Pen. Only one field-hatched juvenile survived four years in the West Pen. A grant from Wildlife Preservation Trust International funded construction of an approximately three acre pen west of the West Pen. It was designed to exclude ground predators. A gently sloping, south-facing hillside area was chosen. Water was piped to four concrete basins, and the oval fence perimeter was trenched eight inches deep. Six-foot high galvanized wire supported by heavy metal posts was set in the trench, with a three-foot high exterior overlay of aviary wire attached to keep large snakes out. A vehicular and a pedestrian gate were set at the southeast side. One foot metal brackets angled outward topped the metal posts and supported a strand of barbed wire and a second wire electrified by a Sears Solar Powered Collector. A fence divided the field in equal halves. Two 5 and two 3 year old juveniles fitted with transmitters were released into the west half on August 6, 1984. They were less active than the adult tortoises. Because of heavy rainfall, I had to take the tortoises to my house at night and occasionally during the day, which may have slowed burrow establishment. By the last week in August, three of the four had established burrows from 125 to 194 feet apart from one another. The burrows had an average depth of 15 inches. I ceased removing the tortoises until the following rainy season. The three established juveniles wintered in the field in excellent health. Their weight gains from July 1984 to June 1985

are as follows:

Age	July 1984	June 1985
5 year old	12 oz.	1 lb., 2 1/2 oz.
3 year old	8 1/3 oz.	12 oz.
3 year old	6 2/3 oz.	11 oz.

Hatchling Pens and Captive Care, 1979-1985 - Bolson tortoise progeny were initially housed indoors in large cardboard boxes, with a heat brick at one end and a cooler, covered area at the other. They were placed outside in small pens where they ate native dichondra; their diet was supplemented with squash blossoms and Evolvulus arizonicus blossoms. They were kept indoors during the hottest part of the day, at night, and during heavy rainfall. They reacted to the onset of cold weather by seeking the coolest areas in the cartons. They were then moved to small, ventilated, covered boxes, and placed in a closet where temperatures ranged between 50° and 65°F. The boxes were set on one-inch pads of foam rubber, and a small sponge in a plastic bag was attached to the interior of each box and kept damp to provide humidity during their winter dormancy.

During and after 1981, in order to provide more space and to observe hatchling food preferences, temporary pens of ten-inch high hardware cloth were built near the house in native grass and weed areas, and the young tortoises were placed in them as soon as the rains stimulated plant growth. They ignored mature grass clumps, showing strong preference for weeds, primarily Erigrostis intermedia, Sida procumbens, Portulaca sp., and Solanum aeaenifolium. Analysis of the above plants indicated high protein and phosphorus content. In 1983, the Ralston Purina Company investigated food preferences of adult and juvenile Bolson tortoises, both in Mexico and at The Research Ranch, and found that hatchlings and juveniles selected diets 50% higher in protein than did the adults.

Even the youngest hatchlings immediately burrowed in the hard ground of the temporary pens and established small tunnels within a day or two, in which several would crowd for shade. By late fall, they had established enough 15-20 inch burrows to

overwinter in; some burrows had only one tortoise, others were shared by two or three tortoises. During winter and spring, the pens were covered with chicken wire to keep predators out of the pens. In spite of heavy rains, occasional snows, and many nights of below freezing temperatures, they remained in good health. All juveniles will be released into the Predator Proof Pen during the 1985 rainy season.

MATING AND EGG LAYING, 1977-1985

Determining sex of Bolson tortoises is difficult since there are no obvious differences in carapace shape, plastron flatness, or gular shield length. In addition, both sexes have short, stubby tails. Adult size may be an indication; my six adult females weigh between 22 and 28 pounds and three of the four males weigh between 14 and 20 pounds. However Potent, the fourth male, weighs 22 pounds. Observations of successful copulation have been my only sure method of determining sex, since I have seen one known male mount another. Male Spry, originally paired with Gertie in the south half, refused to mate with her, taking refuge in his burrow during her numerous attempts to attract him. When I discovered that the smallest tortoise in the north half was a male, he was renamed Larry and transferred to Gertie's south field. He immediately began using Spry's burrow (after the latter was removed to the north field) and copulated with Gertie ca. 20 times during a six week period in July and August. While in the north pen he was subordinate to Potent, the larger male. He copulated with the large female Jane only when Potent was not present. When Spry was moved to the north pen he used Larry's burrow and was the only tortoise I saw involved in courtship activity with Jane. He also spent considerable time head-bobbing at Potent's burrow. Potent came out of his burrow and allowed Spry to mount him on several occasions, after which Potent would dislodge Spry by moving back into his burrow. My interpretation is that Spry was attempting to take over Potent's burrow, as he immediately moved there when Potent was relocated in the West Pen in 1979.

Outset of summer rainfall (from July to September)

stimulates mating activity, which usually takes place at either the male's or female's burrow. Mating has also been infrequently observed in early spring and mid-fall. The following is a description of courtship/copulation I have observed. Initially, males move to females' burrows or, if they encounter one in the field, circle and snap at the female's head and forelimbs. The female then generally moves toward her burrow, with the male following. The male then positions himself on the burrow apron and head-bobs. If the female does not respond by emerging from the tunnel, he moves closer to the entrance. When the female comes out of the burrow, she turns around and faces the burrow, and the male mounts her. During copulation, the male vocalizes with grunts that coincide with his thrusting motions. After copulation, the male returns to his burrow, occasionally stopping to forage. After being housed together for years, females were just as apt to initiate courtship by moving to male's burrow, and head-bobbing at the crest. After the male emerged, the female would position herself on the burrow apron to allow copulation. Possibly slope of the burrow apron facilitates copulation, since smaller males occasionally overturn while attempting to mount, especially on level ground. They right themselves quickly, however, and immediately resume mating activity.

During the past four years, Gertie has taken over Larry's burrow during the summer months, forcing him to shelter in her abandoned burrow until she chooses to return to it in the fall. Mating between them occurs most often when he approaches his former burrow. Female 08, in the West Pen, occasionally moves in with Potent for mating activity during the rainy season. In the mating season, males pace along the fence that separates them and attempt to combat. In the House Pen, the smallest enclosure, males Larry and Spry pace the fence perimeter daily. The breeding season is the only time of the year that such increased activity is displayed.

Egg laying usually occurs in the afternoon from late April to mid-July. Eggs are laid in male and female burrow aprons or elsewhere in the field enclosures.

Females dig five to six-inch deep holes with their hind feet, alternating from one foot to the other as they scrape out dirt to the rear edges. They then rock from side to side to reach down as the hole deepens. Two to seven eggs are deposited, and then the excavated dirt is used to fill the hole. The female fills the hole with circling motions of her rear legs, alternating from one to the other, and then tamps the dirt level. When the hole is filled, the female smooths the surface with backward and forward motions of the plastron; she then moves grass and twigs over the area with her front feet. Unlike in other tortoise species, urination and defecation in the hole have not been observed, but there is generally some dampness around the eggs that must result from the laying process.

In 1981, Gertie laid four clutches, in late April, late May, late June and mid-July (at the start of the rainy season). The first nest was located in the burrow apron, the second in her mate's apron, and the third and fourth were laid in the pen. When I removed the eggs at her burrow, she came out, turned sideways, and pushed against the arm that I was using to shield the excavation. During measurements of the burrow ramps and aprons, the tortoises have also pushed at tools in this fashion.

There is a Bolson tortoise behavior I call "house cleaning", which occurs annually in the early part of the rainy season. Dry fecal matter is brought up from the burrow and deposited across the apron. Possibly this serves as a moisture retaining agent for incubation of egg clutches deposited in the apron soil, or perhaps it serves to mark territories.

One morning I saw a garter snake examining a small depressed area on Gertie's apron, from which an egg clutch had been removed for artificial incubation. The snake nosed into and around the loose dirt for over a minute. Several days after, a four-foot long bull snake crawled past Gertie, who was basking on the burrow crest, and disappeared into the tunnel. It then emerged and slid over Gertie from the rear, and smelled her head and forelimbs. Gertie did not retract her head but remained motionless throughout the encounter. During March and April

1985, a large rattlesnake shared Gertie's burrow at night, and basked next to her at the burrow crest before sliding away through the grasses. I have also observed a mammal using a tortoise's burrow. In August 1983, a cottontail rabbit shared a burrow in the West Pen with female 07 for at least a week. The rabbit emerged before 07 to bask every morning. When 07 came out of her burrow, she head-bobbed at the rabbit, then positioned herself beside it to bask.

Report from Dr. David Morafka, June-September, 1984 - At Mexico's Instituto de Ecologia Reserve, in Mapimi, Durango, Dr. Morafka has been involved in extensive research into Bolson tortoise ecology and management. With his permission, the following report synopsizes recent activities.

Ing. Jose Trevino, of Mexico's Fish and Wildlife Services, conducted a census of the most northwestern populations of tortoises. He located four colonies, several ranches as hatchery sites. There are preliminary plans for a federal wildlife refuge in the Sierra del Diablo district of Chihuahua.

Maestro Gustavo Aguirre of the Institute supervised construction of a nursery enclosure, designed by Dr. Gary Adest and Steve Hale of the Arizona Sonora Desert Museum. The nursery is in a frame building that measures 13 m by 11 m. The walls of the pen are 3.5 m high; the foundation is cement. Wire mesh fencing is on all sides. The twenty stalls in the nursery are well drained and are lined with soil that provide the best consistency for burrowing. Unused stalls are cultivated with grass to provide forage on a rotating basis. The nursery houses approximately 50 tortoises ranging in age from newly-hatched to three years old.

Drs. Morafka, Adest and veterinarian James Jarchow took hematological, microbial, and urinary samples from 27 tortoises in order to define health and to improve reproductive monitoring. In 1982, under Dr. Jarchow's direction, egg laying was prompted using oxytocin, and the eggs were artificially incubated.

Additionally, research was performed on egg shell composition and egg yolk chemistry. Blood was taken before and

after the rainy season and frozen for examination. Analysis of the blood samples will help to define normal cell counts and blood chemistry values and define the breeding period, data that will provide a useful baseline for diagnostic monitoring of captive and wild populations.

CONCLUSION

Bolson tortoises under my care have adapted well to captive conditions at The Research Ranch. During Gertie's 13 year tenure she maintained consistent good health, growth and reproductive ability, as have the other nine adults from the Mapimi Reserve. Adults, hatchlings, and juveniles are exposed to and do well at winter temperatures considerably lower than those found in their natural habitat. Young tortoises thrive on a diet of native weeds; which are higher in protein than the diet of the adults, which is various grasses. Excluding a wider range of movement during mating and egg laying, adults forage in areas adjacent to their burrows. Adults do not share burrows; the young also prefer single burrows, but double or triple occupancy is not uncommon with hatchlings, two- and three-year old tortoises. Juvenile and sub-adult tortoises have not been observed to enter adult burrows. No tortoises have escaped from enclosures where fencing is sunk 6-12 inches into the ground; extensive digging activity is confined to burrow construction. Burrow ramps are utilized for mating activity. Courtship in captivity is initiated by both males and females during the rainy season, but interaction between adults is rarely observed during the rest of the year.

It is reasonable to assume that Bolson tortoises are stressed by close confinement. I believe that the freedom afforded by their one to five acre enclosures in relatively flat grassland has provided three important requirements for long-term health: space to select widely separated sites for their individual burrows, space for a diversity of plant growth from which to select their food, and space for the exercise intrinsic in the act of foraging.

Acknowledgments:

To Wildlife Preservation Trust International, my deep appreciation for their 1984 grant, which has made possible the release of young tortoises into a secure enclosure.

I thank Dr. John Hendrickson for the gift of his fencing and for valuable information about the importance of favorable soil types that facilitate burrow construction.

To Drs. David Morafka, Gary Adest, Gustavo Aguirre, and Tony Recht, my gratitude for their help, friendship, and generosity in sharing the valuable results of their investigations into Bolson tortoise ecology at the Mapimi Reserve.

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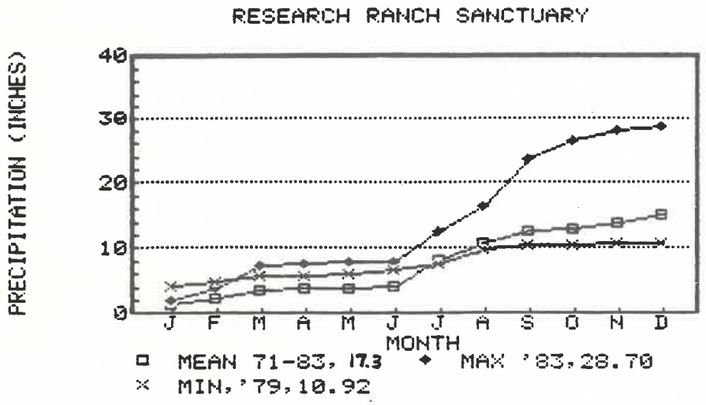
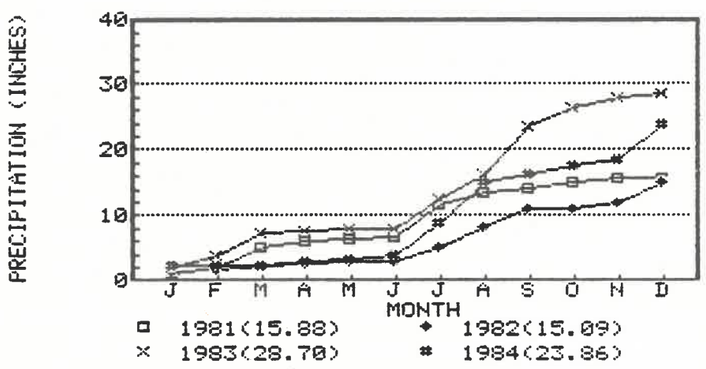
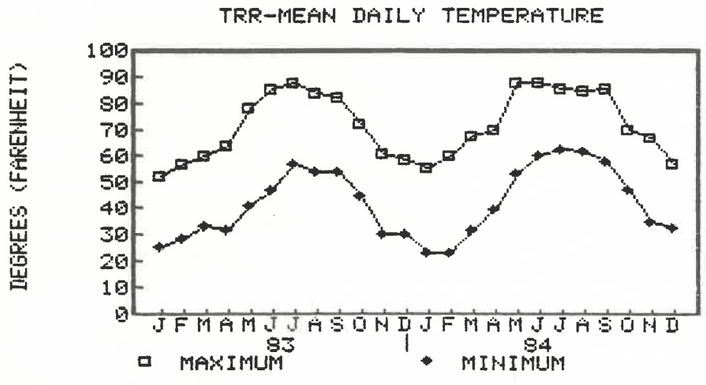






List 1

MICROBIAL ANALYSIS
SUMMARY FROM RESEARCH

Date of Sample: July 29, 1982

Location: Bolson Tortoise pens at Appleton home, Research Ranch, Elgin, Cochise Co., Arizona.

Source	Log	Sample No.	Microbial Assay (genera)
Soil in pens		#1	Micrococcus Bacillus Listeria
		#2	Klebsiella Pseudomonas r-streptococcus
Cloacal swap of yearling G. bolsoni	1	#6L	Serratia Listeria
" "	2	#RT6	Acinetobacter Serratia (?) Listeria
" "	3	#3R	Acinetobacter r-streptococcus
" "	4	#R7	Serratia Listeria
" " (2 years)	5	#R3M	Serratia r-streptococcus
" " (1 year)	6	#8L	Serratia r-streptococcus Listeria
" "	7	#7L	Serratia r-streptococcus Listeria
" "	8	#8	Micrococcus B-hemo Escherschia coli Citrobacter
" "	9	#7	Citrobacter Micrococcus r-streptococcus

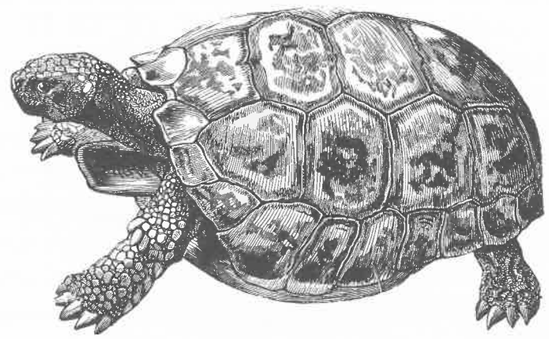
List 1 (continued)

Source		Log	Sample No.	Microbial Assay (genera)
"	"	10	#1	B-hemo Escherischia coli r-streptococcus ∝-streptococcus
"	"	11	#11	Staphlococcus r-streptococcus micrococcus

These results have only become available in September 1982; therefore, their significance remains to be determined. Preliminary inspection reveals that the Research Ranch tortoise pens contain a soil rich in potential pathogens: Pseudomonas, Streptococcus, etc. Yet tortoise infections have not been reported, even after a decade of pen use. It is assumed that these background pathogens are not a threat to healthy tortoises with adequate immunological defenses or physical shelter.

Weights, Bolson Tortoise Female Gertie

Month	Year	Weight	Comment
May	1972	15 lb.)	Sheltered in artificially constructed, shallow burrow in 8' square enclosure. Tethered by chain to graze on bermuda grass lawn.
May	1973	16 lb.)	
October	1973	19 lb.	Moved June, 1973 to House Pen -- ample native forage.
March	1974	18 1/2 lb.	1/2 pound weight loss after wintering in self-dug burrow, House Pen.
October	1974	22 1/2 lb.	House Pen.
March	1975	22 lb.	1/2 pound weight loss after second winter in House Pen.
October	1975	23 1/2 lb.	House Pen.
August	1979	25 lb., 13 oz.	House Pen.
May	1982	27 lb., 6 1/4 oz.	House Pen.
August	1983	26 1/2 lb.	House Pen.



THE REPRODUCTIVE BEHAVIOR OF TWO AUSTRALIAN CHELID TURTLES, Emydura macquarii AND Elseya latisternum, AT THE DALLAS ZOO

William Corwin

INTRODUCTION

Precoital and copulatory behavior resulting in reproduction has been documented in two Australian chelids at the Dallas Zoo. Measurements of eggs and hatchlings are presented. Oviposition occurred in both indoor and outdoor enclosures from March through April. Eggs deposited in the indoor enclosure were artificially incubated in a vermiculite and water mixture. Husbandry techniques and growth rates of the hatchlings are described.

HUSBANDRY

Two Emydura macquarii (male 250mm straight line carapace length, acquired 10 June 1967 from a private collection; female 290mm acquired 3 June 1975 from a dealer) and three Elseya latisternum (male 150mm, acquired 17 June 1971; female 230mm, acquired 17 June 1971; female 215mm, acquired 17 June, all from another institution) composed the breeding groups. All the specimens were wild-caught adults; therefore, ages could not be estimated.

The indoor enclosure in which the turtles were kept during the winter measured 310 x 145 x 260cm high. This enclosure had some natural light entering through skylights, but artificial light was also provided by ultra-violet sunlamps (275W/110V) and infra-red heat lamps (250W/110V). These were turned on at 0800 and turned off at varying times to simulate seasonal photoperiods. Air temperature varied between 26-35^{o}C. Relative humidity was approximately 50%. A 292 x 48 x 40cm pool in the front of the enclosure unit provided a swimming area. A 48cm wide, 24cm deep circular plastic tub filled with sand provided a nesting site. The enclosure was decorated with sculptured decor including artificial rock, plastic plants, and grape vines.

During the spring and summer, the turtles were placed

outdoors in a half-circle (radius of 17m) enclosure, decorated with stacked rocks. At the base of the stacked rocks there was two pools, one slightly larger in elevation than the other. The pools did not have a recirculating flow; municipal water flowed from the upper pool into the lower pool. A mixture of mulch, sharp sand, and soil was used to provide a substrate for cacti, grasses, succulents, and other plants.

The turtles were fed twice a week on a diet that included equal parts of horsemeat and smelt; added to this mixture was chopped spinach, trout chow, dry dog food, alfalfa pellets, turkey chow, and shrimp meal. Clovite (a vitamin supplement) and powdered oyster shell was added to the mixture. Crickets and chopped newborn mice were occasionally offered.

BREEDING

The courtship and copulatory behavior of the two taxa were quite similar and included the following sequences: approach, signaling, frontal contact for alignment of gular barbels, stroking bout, and mounting. In both species, males approached females with a series of vigorous head-bobs, employed cloacal touching, attempted to align their barbels with those of the females, and then stroked the barbels and snout of the females with their feet and claws. Mounting and attempted copulation was observed in the Emydura macquarii but were not observed in the Elseya latisternum. This was reported by Murphy (1978).

The Dallas Zoo had tried to breed Emydura macquarii for 7 years and Elseya latisternum for 11 years in the indoor exhibit with no success. In the spring of 1980, both species were placed in the outdoor exhibit for the first time and this seemed to trigger success. Three hatchling Emydura macquarii were found in the outdoor exhibit on 30 July 1982 and two Elseya latisternum hatchlings were found in the outdoor exhibit on 22 September 1983. In the spring of 1983, before the turtles were placed in the outdoor exhibit, the female Emydura macquarii laid 43 eggs in the indoor nesting box on 9 March. The eggs were weighed and measured, and were then placed in gallon jars with vermiculite and water mixed at a ratio of one part vermiculite to

one part water. Incubation temperatures ranged from 27°C to 30°C. The eggs had the following measurements: mean length, 34.5mm (range, 33-36mm); mean width, 21.2mm (range 20-25mm). One month later the female laid 23 more eggs. The young hatched after an incubation period of 46 days and had a mean carapace length (straight line measurement) of 28.8mm (range 28.5-30mm); the mean weight was 4.8g (range 4.2-5.5mm). The hatchling Elseya latisternum found in the exhibit measured 29 and 28mm (straight line carapace measurements), and weighed 4.5 and 4.0g. When the specimens were measured again on 15 June 1985, they measured 109 and 74mm, and weighed 128 and 52g, respectively. Five yearling Emydura macquarii were also measured on 15 June 1985; the average carapace length was 85mm and the average weight was 91.8g. Since the first successful breeding in 1983, the Emydura macquarii have produced viable clutches every year to date, but the Elseya latisternum have not had successful egg hatching since 1983. A clutch of ten eggs was laid in the indoor exhibit on 10 February 1984, but the eggs slowly deteriorated. One embryo went full term, then died in the egg.

Neonates were kept in small plastic tubes (40 x 30 x 14cm) with a water depth of 2cm. Floating plastic leaves were placed in the tubs to provide hiding places, and small pieces of flag stone that rose above water level provided basking sites. Flood lights (75W 125/130V) and Sylvania blacklights (F20T12-BL) were suspended 38cm over the tubs. The neonates' diet was essentially the same as the adults with the exception they were fed chopped newborn mice and 2 week crickets more often. Powdered oyster shell was added to the water to provide additional calcium.

Six young Emydura macquarii and two young Elseya latisternum were kept to supplement the breeding groups; the rest were released to other institutions.

Acknowledgments: Special thanks to the Dallas Zoo Reptile Department Staff and to the Secretary, Ann Bain, for typing this paper.

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Dallas Zoo, Texas

RESEARCH, HUSBANDRY, AND PROPAGATION OF THE BOG TURTLE Clemmys muhlenbergi (Schoepff) AT THE ATLANTA ZOO

Dennis W. Herman and Gregory A. George

INTRODUCTION

Zoological parks have advanced tremendously from the postage stamp menageries of yesteryear. Mankind's destructive influence has spread over every major land mass, threatening flora and fauna alike. Thus, habitat loss and decreased faunal populations have placed an emphasis on captive breeding and research programs in private collections and zoos. For many years the Atlanta Zoo has been known for its crocodilian research and its efforts to restock Mexican habitats with the endangered Morelet's crocodile. Although smaller in size and in scope of accomplishment, the work begun by the Atlanta Zoo on the bog turtle, Clemmys muhlenbergi (Schoepff), is equally important.

The Atlanta Zoo has maintained at least one pair of bog turtles since 1967, and has reproduced this species since 1974. Our field research began in May 1976, when the senior author assisted Robert Zappalorti of the Staten Island Zoological Society during his ecology study in southwestern North Carolina. The work initiated by Zappalorti (1975) was continued by the senior author in 1980, but the ecological study became a secondary part of the project. Primary importance was placed on a status and distribution survey and expanded into the mountains of Georgia and South Carolina.

HISTORY AND DESCRIPTION

Described in 1801, the bog turtle is considered by many to be the rarest and smallest chelonian species in North America (Eglis, 1967; Ernst and Barbour, 1972). Adults average between 75-90mm in carapace length with a maximum recorded length of 114mm (Conant, 1975). These turtles are readily identified by bright yellow, orange, or red-orange temporal blotches and dark brown to black shells which may or may not have light-centered scutes in a starburst pattern. The carapace usually has a low median keel, and the limbs may be suffused with orange or red

coloration. Male bog turtles have a concave plastron and long, thick tails with the vent located beyond the carapace, and the females have flat plastrons and short tails with the vent inside the carapace.

Bog turtles are distributed spottily from New York and Massachusetts southward to the southern Appalachian Mountains of Georgia and South Carolina. There is a broad gap separating the northern populations from Maryland northward and the southern populations from southwestern Virginia southward (Figure 1). The first southern populations were reported from North Carolina in Iredell County (Yarrow, 1883) and Avery and Transylvania Counties (Dunn, 1917). The bog turtle has since been recorded from Virginia (Hutchison, 1963 and Nemuras, 1974), Georgia (Hale and Harris, 1980; Herman and Putnam, 1983), and South Carolina (Herman and Putnam, 1982).

RESEARCH AND METHODS

Suitable habitats were located by using soil survey maps, topographical maps, and by driving back roads looking for "indicator" plants of wetland areas. Museum and literature records were used to "re-discover" old populations.

Potential bog turtle habitat was searched by using the following methods: a) observations of turtles basking, foraging, or digging in the mud; b) by probing the mud and around grass tussocks with a "turtle stick" or by hand; c) following tracks in the mud; d) looking for signs of a turtle's presence, i.e. bubbles or moving ripples in mud or water.

The following data for each turtle captured were recorded in a field notebook: a) air, water, substrate, and cloacal temperatures; b) carapace and plastron length; c) shell height; d) date, time, and locality; e) age (when possible); f) behavior; g) food preferences; and h) injuries, parasites, or shell anomalies.

Each turtle was assigned a number and permanently marked by notching a code in the marginal scutes with a triangular file. Usually one marginal per side was notched. This marking technique is similar to that used by Cagle (1939). The turtles

were released at their point of capture. Any recaptured turtles were measured as above to determine growth and then released.

RESEARCH RESULTS

The main study areas were the bogs, swamps, and marshy meadows of western North Carolina, although, several surveys were made in northeastern Georgia and northwestern South Carolina. Nearly sixty populations are presently known in these states; North Carolina (50+ populations), Georgia (3 populations), and South Carolina (2 populations).

We found bog turtles active from early April (7 April) to September (16 September) in North Carolina between 0900-2000 hours, when the ambient temperature is 18-31^{o}C. Their activity may be dependent upon air temperature (Zappalorti, 1975).

Cloacal temperatures of active turtles was between 13.2-33.8^{o}C (x = 23.6^{o}C). One pair was found mating at 15^{o}C (Herman, 1984) with cloacal temperatures of 14.2^{o}C and 15.0^{o}C, respectively. The earliest recorded activity was an injured male found in a cow print at 0715 hour in June 1985. The injury most likely prevented him from burrowing into the mud the evening before.

Bog turtles prefer shallow, spring-fed rivulets of sphagnum bogs, swamps, marshy meadows, and pastures. They range in elevation from near sea level in the Northeast to 4500 feet in the southern Appalachian Mountains.

Dominant plant species associated with bog turtle habitats include: alders (Alnus serrulata), willows (Salix sp.), sedges (Carex sp.), sphagnum moss (Sphagnum sp.), jewelweed (Impatiens capensis), arrow arum (Peltandra virginica), red maple (Acer rubrum), skunk cabbage (Symplocarpus foetidus), bulrushes (Scirpus and Juncus sp.), and ferns (Onoclea sensiblis, Osmunda cinnamomea, O. regalis, Dryopteris cristata, Thelypteris noveboracensis, and T. palustrus). The following rare plant species are associated with very few bog turtle habitats: pitcher plants (Sarracenia

flava, S. purpurea, and S. jonesii), sundew (Drosera rotundifolia), swamp pink (Helonias bullata), bog arethusa (Arethusa bulbosa), and various other rare vascular plants.

In the field, bog turtles feed on a variety of animal and plant materials. Potential prey includes: crayfish, slugs, earthworms, field crickets, young meadow voles or bog lemmings, and small amphibian larvae. Exoskeletons of the Japanese beetle (Popilla japonica) and arrow arum seeds (Peltandra virginica) were recorded in stool analyses by Zappalorti and Johnson (1981).

Predators, particularly on eggs and young, include raccoons, skunks, and foxes. Other predators may include snapping turtles, water snakes, and large birds.

A total of 339 bog turtles, including 63 recaptures, were found during the study. Population densities vary from 1-110 per site. The sex ratio of all the populations approached 1:1, which coincides with Bury's (1979) report for freshwater turtles.

Reproduction was observed in the field once; the male was firmly clasped on top of the female while biting the neck. Five nests were located; two had been predated on. The eggs were deposited at a depth of 51mm in sphagnum moss or at the base of sedge tussocks. Several hatchlings were found (carapace length, x = 26.2mm) at various sites in North Carolina. Over-wintering of eggs and/or young is unconfirmed, but is suggested by preliminary data.

HUSBANDRY AND PROPAGATION

The bog turtle's secretive nature is probably the main reason for its "apparent" rarity. As new populations are located, the status of this turtle should become more evident. Until then, captive studies and propagation should be conducted to ensure its survival and help alleviate collecting pressures on wild populations.

This species has been bred in several zoos (Tryon and Hulsey, 1977 and Herman, 1980) and private collections (R. Belmore and C.E. Putnam, pers. comm.). The Atlanta Zoo has

maintained bog turtles since 1967 and has successfully bred them since 1974. Our oldest pair (obtained 12 May 1967) has been in the collection 18 years and two months, which constitutes a longevity record.

Concern has been expressed over mixing native stocks and upsetting genetic variability (Bury, 1979). This is a valid concern that we have taken into account in our breeding programs. Presently, one male and three female specimens from the same population in North Carolina are housed at the zoo (under permit). After an adjustment period, the progeny produced from this group are released in their parents' bogs.

In cooperation with the North Carolina Wildlife Resources Commission, the Atlanta Zoo is permitted to collect up to five gravid bog turtles for egg and neonate data, with neonates and females subsequently returned to their respective bogs. So far, five neonates have been returned, and three 1985 clutches are presently incubating at the zoo.

Our breeding groups are housed in artificial bogs that closely resemble the natural habitat (Figure 2). The bogs are constructed in six to seven foot diameter (625 gal) stock tanks, which are buried to a depth of 18" in the ground for insulation. Tap water is filtered (by carbon and floss) before it enters the bog, to avoid harming the live plants. An overflow and drain are present at the far side of the bog; exit water drains into the sewage system. A two-inch layer of pea gravel is covered with a four to six inch layer of peat mud substrate. The water level is two to three inches above the peat mud layer. The land area is planted with live sphagnum moss, sedges, and other native bog species. Two rivulets flow from the filter box through the land area and into the water area.

Any activity is observed and recorded. The turtles overwinter in the bogs, with all temperatures (air, water, and substrate) periodically recorded. Between November and March, the lowest and highest temperatures recorded were: air, -4^{o}-18^{o}C; water, 6^{o}-15^{o}C; and substrate, 4^{o}-14^{o}C. Winter temperatures are variable in Atlanta and

fluctuations are commonplace.

The earliest emergence from hibernation recorded was 16 February. This is six to eight weeks earlier than that recorded for wild populations in North Carolina.

Copulation has been observed once in our specimens, and the earliest egg deposition occurred on 14 May. Temperatures in the nests are recorded and the eggs are periodically checked. The earliest hatching dates (from different nests) ranged from 2 June to 5 August.

Neonates are weighed and measured within one hour of hatching. They are placed on damp paper towels until the yolk buttons are completely absorbed. Housing for juveniles consists of five or ten gallon aquariums with undergravel filters. A land area is provided for basking and a one-inch water depth is maintained to prevent accidental drowning. Ultraviolet light is essential, and is provided for four to five minutes daily by a sun lamp on a timer.

Juvenile bog turtles are fed a calcium-enriched diet two or three times a week. The diet includes Frog Brittle (NASCO, Fort Atkinson, WI), chopped mice or small pink mice, minnows, snails, slugs, dusted crickets, and earthworms. Frog Brittle constitutes nearly 40% of the total juvenile diet.

Adult bog turtles are fed twice a week on a diet of chopped mice, pink mice, minnows, dusted crickets, earthworms, and occasional strawberries and watercress. Ultraviolet light is provided by natural sunlight in their outdoor bogs.

DISCUSSION

Habitat destruction is the primary cause for the decline in bog turtle populations. Ernst and Barbour (1972) reported that draining of the habitat has nearly eliminated the species over most of its original range. Several North Carolina populations have been destroyed by draining for the construction of roadways, fish ponds, and golf courses. Natural succession into a forest climax of red maple (Acer rubrum), tulip poplar (Liriodendron tulipifera), and sweet gum (Liquidambar styraciflua) is responsible for drying several bog turtle

habitats in western North Carolina. Fortunately, the U.S. Forest Service has implemented winter burning and clear cutting practices to insure the revitalization of turtle populations on Forest Service property (L. Luckett, pers. comm.). Another significant bog turtle habitat was partially cleared by the owner, the senior author, and his associates in Febrary 1985. This project also increased the population of mountain sweet pitcher plants (Sarracenia jonesii) found at this site.

The North Carolina Natural Heritage Program has registered several important sites based on the occurrence of bog turtles and rare plants (C.E. Roe, pers. comm.). The North Carolina Conservancy has purchased other significant areas to ensure their protection (A.S. Weakley, pers. comm.). So far, the southern bog turtle populations seem to be secure from habitat destruction.

Habitat requirements and the biology of the bog turtle remain poorly known. Many gaps remain to be bridged concerning its range and natural history. Through research and captive propagation at the Atlanta Zoo, the bog turtle will perhaps be assured of a future among the herpetofauna of North America.

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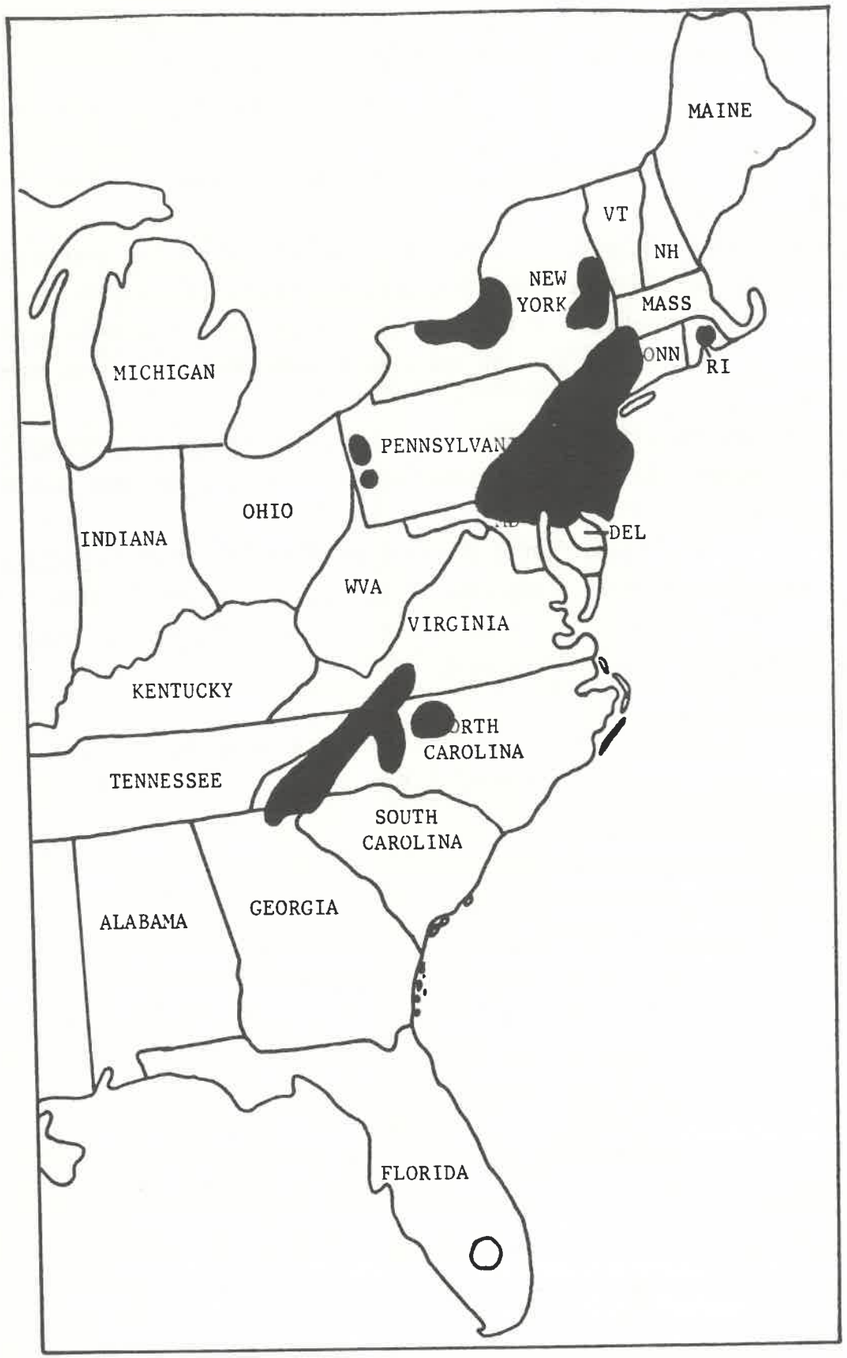
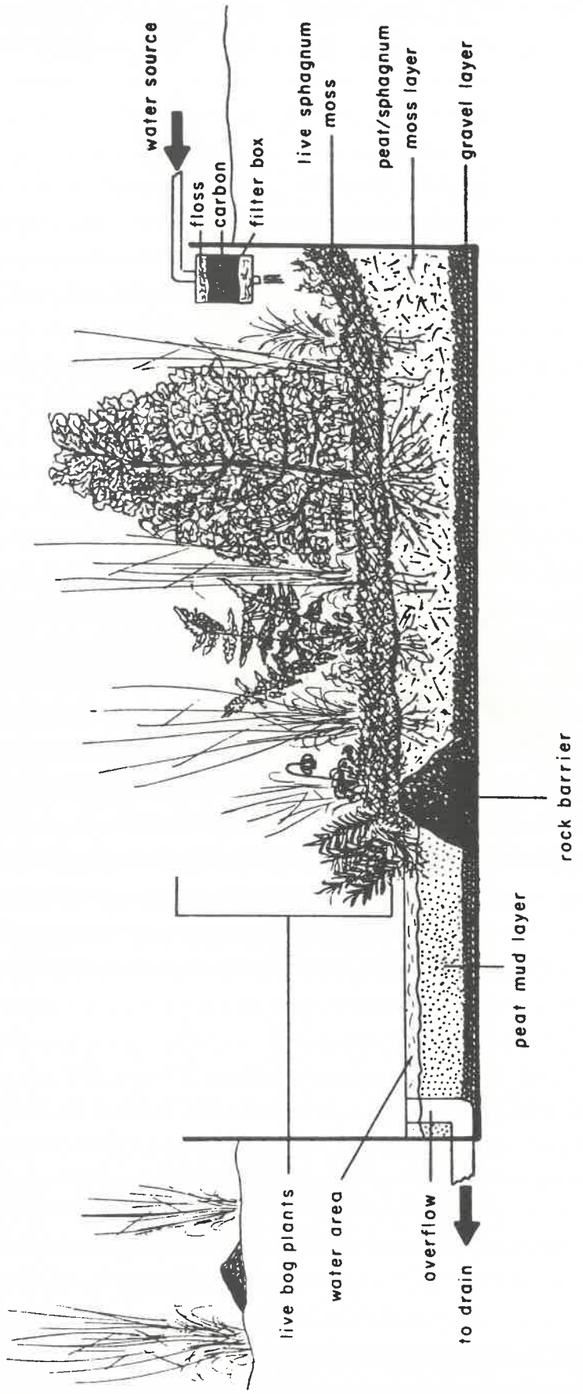
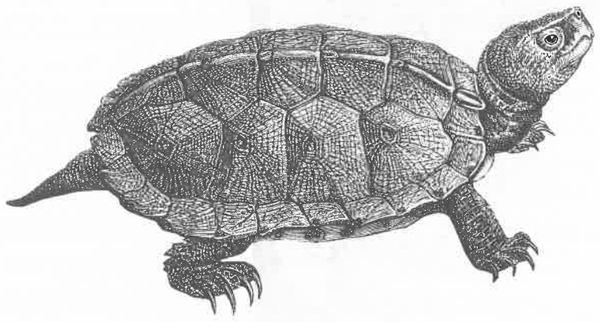


Figure 1



CROSS SECTION OF SIMULATED BOG

Figure 2



A CAPTIVE MANAGEMENT PLAN FOR LARGE IGUANINE LIZARDS USING THE ISLA SAN ESTEBAN CHUCKWALLA *Sauromalus varius* Dickerson AS A MODEL

Howard E. Lawler and James L. Jarchow

ABSTRACT

A colony of *Sauromalus varius* has been maintained at the Arizona-Sonora Desert Museum since 1977. A comprehensive conservation/propagation/research program has been formulated during the past four years, including the construction of a spacious outdoor enclosure to house the social group off display.

Captive management focuses on nutrition, health evaluation, veterinary care, group composition, spatial requirements, and genetic lineage of progeny. Routine health evaluation is performed twice yearly in addition to prompt treatment of health problems. Group composition has been experimental, based on social compatibility, our concern to maintain genetic diversification, and carrying capacity of the captive environment. A color-coded marking system allows individual identification of specimens from observation blinds around the study enclosure.

Problems involving nutrition, reproductive biology, ectoparasitism, and toe-clipping are discussed.

INTRODUCTION

Within the past decade, an alarming increase has occurred in the numbers of large iguanine lizards declared endangered or threatened by the United States Fish and Wildlife Service and/or the Convention on International Trade in Endangered Species. Many of these species' populations have been decreased by loss of habitat, use by indigenous peoples for food or tourist commodities, by wanton destruction, and by overexploitation for the animal trade (Fitch & Henderson, 1977; Fitch, et al., 1982). In particular, commercial exploitation and the increased use as food combined with increased habitat loss, has severely jeopardized the existence of some formerly common species. Faced with particularly serious threats are those taxa endemic to islands where overexploitation and habitat destruction can disrupt population stability in a relatively short period of time. For these reasons, the future of some large iguanine species may depend wholly or in part upon developing successful captive propagation and management techniques. Various authors have described methods for managing such species as *Conolophus* (Cepeda Proano; Snell, pers. comm.), *Cyclura* (Castro y Duval,

1979; Duval, 1983; Crutchfield, 1983), and Iguana (Werner and Miller, 1984).

Large iguanines generally exhibit social, spatial, and territorial requirements, and often specialized herbivorous diet may complicate their management in captivity.

Management of wildlife in captivity requires 1) the development of goals and objectives which consider the motives, capabilities and limitations of the management program, and 2) the captive requirements of the species and its conservation in the wild.

The first objective of any captive management program for a threatened or endangered species should be to engage in programs designed to support the survival of the species in the wild. This can be facilitated in numerous ways. The accruement of knowledge is essential to the long-term conservation of any wildlife. Ideally, such knowledge comes from detailed study of the species in its habitat. All aspects of the species' biology are essential in developing an effective conservation/management program, whether it be in captivity or in the wild. Numerous opportunities exist to integrate captive and field studies to provide information of benefit to conservation programs. Managers of captive wildlife often lack knowledge concerning the biology and ecology of the specimens. Responsible managers utilize various informational resources at their disposal to compensate for this sometimes critical deficit, and may acquire the information they lack through literature reviews, professional communication, experimenting with management techniques, and conducting studies of the species in the field. All of these approaches are productive, and contribute to the formulation of an effective captive management plan.

At the onset of a captive management program for a threatened or endangered species, the manager must decide whether the primary objective is to produce as many progeny as possible for as long as possible, or decide if there are other equally important long-term objectives. Our primary objective has been to maximize the project's potential for research and

conservation, rather than to design an "animal factory" to provide specimens for other uses, such as the commercial sale of progeny. While recognizing the possible benefits of using specimens for purposes other than research and conservation, we feel the integrity of our program would be compromised if there was commercial activity in captive-born progeny. In the case of Sauromalus varius (Figure 1), the primary threat to wild populations is commercial exploitation, since degradation of its habitat and significant use for food or other purposes are not likely in the foreseeable future. It is a species which protection from human profiteers may insure its perpetuity.

Because the greatest limitation in assessing the conservation needs of S. varius and many other iguanine species lies in our paucity of knowledge about them, critical information concerning the various aspects of their natural history can be learned through observations of captive specimens, a principle that should be the foremost objective of any serious effort to manage them in captivity. This requires careful attention to factors such as social organization and composition, ethology, spatial use and minimum requirements, maintaining genetic diversity, natural and captive-induced pathology, nutrition, and physiology. Each of these factors is fundamental in planning any long-term conservation program.

We will discuss aspects of captive iguanine management, using details from our conservation/captive management plan for S. varius (Dickerson), the Isla de San Esteban Chuckwalla.

ECOLOGICAL DATA CONCERNING Sauromalus varius

Sauromalus varius is the largest of 11 taxa in the genus, reaching a maximum total length of over 600mm. It is considered to be derived from Sonoran Sauromalus obesus-type ancestral stock (Shaw, 1945; Robinson, 1972). Case (1978, 1982) referred to S. varius and its insular counterpart S. hispidus as "gigantic" chuckwallas, in reference to their significantly larger size compared to the other taxa in the genus.

Sauromalus varius is endemic to Isla de San Esteban, a "deep water" island 43 km^2 in area, rising to 531m in

elevation, located in the midriff island series of the Gulf of California (Sea of Cortez). The habitat is described as Sonoran desertscrub, Central Gulf Coast subdivision (Turner & Brown, 1982) and is characterized by cacti, the most prominent of which is cardon (Pachycereus pringlei). Desert legumes are represented by species such as ironwood (Olneya tesota), mesquite (Prosopis sp.), and palo verde (Cercidium sp.). Other vegetation includes the elephant tree (Bursera sp.), sangre-de-drago (Jatropha cuneata), grasses, and other flora common to both sides of the Gulf (Felger and Lowe, 1976). Very limited salt scrub communities occur in restricted areas behind some of the high cobble beaches.

Sauromalus varius is classified as endangered under the U.S. Endangered Species Act and is listed on Appendix I of CITES. These designations were made primarily on the basis of documented commercial exploitation of the species and its occasional use as food by Seri Indians and Mexican fishermen. Case (1979) estimated the entire insular population at 4,500 specimens. He further speculated that most of that population is concentrated in Arroyo Limantur, a large arroyo which is marginally differentiated as riparian desertscrub, and which might provide a higher energy base (more plant biomass) for this herbivorous lizard. If a large percentage of the wild population is concentrated in this relatively small, easily accessible arroyo, it might increase the species' vulnerability to periodic commercially-motivated collecting. Furthermore, Case (1982) described a "boom or bust" reproductive pattern occuring in this species which, if correct, suggests even greater vulnerability if specimens were removed during a peak year in reproduction.

Sauromalus varius appears to differ significantly in social and behavioral aspects from other members of the genus. It apparently evolved in the absence of terrestrial predation, which has led to peculiar and inefficient defensive traits. Fortunately, there is no evidence that feral predators or competitors for habitat have been introduced on the island, although the rat (Rattus rattus) occurs in considerable

numbers on the cobble beach at Arroyo Limantur, and recent evidence suggests it may periodically infiltrate deeper into the arroyo. Its impact on S. varius is not known, although it is a potential predator of eggs and young. Birds are considered to have been the primary predator during the evolution of this species. Redtail hawks (Buteo jamaicensis), Kestrels (Falco sparverius), Osprey (Pandion haliaetus) and Ravens (Corvus sp.) as well as other marine birds are known from the Midriff Islands. Such avian predators undoubtedly exhibited selective pressures on this species, and probably still do. However, other predators may affect S. hispidus ecology. The spinytail iguana (Ctenosaura hemilopha) is omnivorous and has been observed feeding on small mammals and birds. An insular race of this species (Ctenosaura h. conspicuosa) occurs sympatrically with S. varius on Isla de San Esteban. Sylber (1985) observed Ctenosaura catching and eating a hatchling S. varius on Isla de San Esteban. This would seem to confirm our expectation that Ctenosaura is at least an opportunistic predator on juvenile S. varius.

A primary factor that limits reproduction in S. varius appears to be the cyclic nature of optimal vegetational growth, which is restricted to the infrequent years when sufficient rain falls on Isla de San Esteban. Case (1982) described the reproductive cycle of both S. varius and S. hispidus as a "boom or bust" cycle, and attributed their unusual reproductive cycle to an inability to store sufficient lipid levels to facilitate oogenesis, vitellogenesis, and/or spermatogenesis except during "boom" years (i.e. years of increased plant growth). He estimated four years to be the average reproductive frequency. A number of factors seem to support Case's description of a "boom or bust" reproductive cycle in S. hispidus and S. varius. One of the explanations for the evolution of "gigantic" size in insular Sauromalus has been inferred from their cyclical pattern of reproduction. The infrequent opportunity to reproduce (because of insufficient lipid levels) may have caused selection for larger size (with

correspondingly larger egg clutches); also large size favors survival during severe drought years (the "bust" years) because, in the absence of food, the rate of body weight loss is inversely proportional to the initial body weight. While both species may have a "boom or bust" mode of reproduction, it is possible that Case's estimate for the number of years between reproductive cycles was possibly biased by his difficulties in locating juvenile specimens. Our observations suggest the possibility of juvenile migration from the arroyo nesting sites to the slopes and ridges above the arroyo. If such juvenile migration does occur, it may be a mechanism to reduce competition with conspecific adults and/or to avoid predation by sympatric C. h. conspicuosa, which might explain the absence of juveniles in areas commonly frequented by adults and Ctenosaurs. Such migratory behavior by neonate iguanines has been described for Iguana by Rand and Dugan (1968). Thus, a small animal will starve to death more quickly than a large animal (Case, 1979). Interestingly, few mature females have nested at ASDM in consecutive years in spite of access to more food (and subsequent higher lipid levels) than they would have in the wild.

CAPTIVE HISTORY OF Sauromalus varius AT ASDM

Until 1983, all specimens were housed in a mixed Sonoran Desert lizard exhibit at the Museum entrance, where reproduction occurred sporadically from 1977-81. No records are available prior to 1981 pertaining to the specimens' identification or reproduction. Since the listing of the species as endangered further restricted prospects of acquiring new specimens from the wild, we decided to consider the entire group as founder specimens in our efforts at sustaining the captive gene pool. The lineage of the specimens in the group in 1981 were unknown, although some were suspected to be progeny of undocumented ASDM breeding or progeny from another breeding group (Sylber, 1985). The probability of limited genetic diversity in this insular species further supported our decision to include all the available specimens into our initial 1981 breeding group. On 3 March, 1983, four specimens were received on breeding loan from

Dr. Lester Harris of Loma Linda University, Riverside, California and added to the colony. This established an adult colony of 8.8 specimens.

PHYSICAL AND SOCIAL ENVIRONMENT

The captive management of most iguanid lizards requires consideration of spatial requirements and social interactions in the species. Our empirical observation has been that if available territorial space is reduced to the point where specimens will tolerate closer proximity of conspecifics than would occur in nature, a linear dominance hierarchy is formed, usually with a corresponding reduction in agonistic behavior, competition for space, and reproductive activity (Brattstrom, 1974; Carpenter, 1967; Prieto and Ryan, 1978). This intra-territorial repression may be responsible for the lack of reproductive success or even result in the death of subordinate male specimens, since their access to optimum basking sites and food is limited. For this reason, captive management programs for territorial species must supply specimens with micro-habitats of equal quality to minimize the decline in health of subordinate male specimens.

In 1981 we recognized inherent limitations in managing S. varius solely as part of a mixed lizard exhibit. In the mixed lizard exhibits, the S. varius were subject to numerous stresses including inadequate space, competition for both food and what limited space existed with other lizard species, including another Sauromalus species; in addition, they were exposed to an unknown degree of disturbance from the visiting public, who viewed the specimens in this exhibit at close proximity.

In order to eliminate these stresses, and 1) attempt to improve the potential for reproduction, 2) maintain the maximum degree of genetic diversity and 3) reduce the variables that were negatively affecting social behavior, we designed an off-display facility exclusively for the propagation and study of the insular gigantic chuckwallas (Figure 2). This facility, funded in 1982 by the ASDM Roy Chapman Andrews Research Fund, was constructed

entirely by the ASDM Maintenance Department in early 1983. The primary objective was to provide as much space as possible for the specimens and at the same time allow keepers to gain access to the specimens at all times. Heated winter quarters were essential since the occasional freezing temperatures experienced in Tucson do not occur on Isla de San Esteban. Finally, maximum spatial diversity was incorporated as a means of increasing the carrying capacity of the enclosure in an effort to manage as many specimens as possible together as a social unit.

Two fundamental tactics were employed when the facility was being planned. First, we went to Isla de San Esteban prior to designing the enclosure. The purpose was to assess the macrohabitat and observe the species' behavior in the wild. The Coastal Sonoran Desertscrub plant communities are similar in many respects to those of the Arizona Upland Subdivision. Thus, many plants eaten by the chuckwallas are common to both areas. Therefore it was possible to select a site for the enclosure which already had plants in the specimens' natural diet present. Additional landscaping with appropriate vegetation has encouraged ad lib browsing on other natural plant species.

The second observation we made evaluated the specific types of refugia (hiding places) the chuckwallas used on an intermittent or regular basis. Preliminary observations indicated they made extensive use of cave-like recesses in the banks of the arroyos and among large boulders strewn along the slopes. We made numerous observations of chuckwallas basking at the entrances of these refugia or fleeing to them when disturbed. Feces composed of vegetation was abundant at the entrances to these refugia and around other, less protective rock piles. We frequently saw C. f. conspicuosa in association with these refugia, and they occasionally occupied the same site with S. varius. We also found deeper burrows leading into the banks which had been enlarged or modified by lizards. These burrows were usually only slightly larger than the girth of large Sauromalus and often turned abruptly due to the rocky composition of the banks. Many of the typical refugia appeared to have been

selected by the lizards for natural suitability and, while showing signs of regular use, had been modified very little.

These key aspects of the autoecology of S. varius were used to plan and construct the facility; then recognizing that the paucity of knowledge about the species would dictate some modification as we learned more from direct observation and appraisal.

The ASDM enclosure has a concrete block perimeter wall subdivided into separate areas for S. varius and S. hispidus. The perimeter wall is one meter high, and is based on a concrete footing 30cm deep. The interior surface is skirted with sheet metal flashing to preclude escape. The dimensions of the enclosure for S. varius are 10.5m x 9.9m. The total surface area is increased by a number of large, rocky outcrops positioned away from the walls and the primary refuge building. The refuge building is constructed of concrete blocks and measures 2m high x 1.9m x 1.3m. One side of the building is an insulated door which allows the keepers complete access to the specimens. The roof of the refuge building is constructed of foam-insulated fiberglass and can be lifted off the building for thorough dismantling and cleaning of the interior as necessary. This feature has proven invaluable in treating periodic infestations of the mite Hirstiella pyriformis. The specimens' access to the refuge building is by 12.7cm wide PVC tubes leading from the exterior to enclosed individual wooden retreat boxes. No more than two tubes lead to a box, which enables the specimens to select individual retreat boxes. Specimens generally use the same retreat boxes except during peak summer activity, when their selection appears more random. The refuge building is essentially buried in the ground in rocky soil; the removable roof is covered with large, stable rocks, which leaves the retreat tubes and the keeper access door exposed (Figure 3). The refuge building is heated with a thermostatically-controlled 750-1500 watt space heater. The specimens normally have free access in and out of the refuge building unless the forecast night temperatures approach freezing. During these periods, the retreat tubes are plugged

with insulating material to prevent the exit of the specimens and to improve heat retention. Winter refuge building temperatures are maintained between 12-18°C. Throughout much of the year communal basking occurs daily, the most used site being the top of the refuge building and on the sloped substrate surrounding it. The numerous rocky outcrops away from the building are occupied sporadically by males during the warmer months (April-September). These outcrops seem to provide habitat for subordinate specimens during periods of increased agonism, and may correspond to the temporary refuges possibly occupied by subordinate specimens in the arroyos of Isla San Esteban.

SPECIMEN IDENTIFICATION

Accurate specimen identification is essential when managing any species on a colonial or "herd" basis. Toe-clipping was not considered due to problems discussed later in this paper. Because the major objectives of the project are to assess social behavior and manage the colony to maintain genetic diversity, we devised a method to identify specimens with highly visible markings that allow accurate specimen identifications by volunteer observers. We use a water-based acrylic paint: orange for females and blue for males. Each specimen's group number is clearly painted at the dorsal base of the tail. Vertical marks corresponding to the specimen's identification number are also painted on the latero-nuchal surfaces and latero-caudal surfaces right and left. Numbers 1 through 4 are indicated by the appropriate number of vertical marks. Specimens numbered 5 and above are marked with a broad horizontal bar indicating "5"; additional vertical marks are added to indicate their specimen identification number. This method allows the observer to determine the identity and gender of any visible specimen by its number and color without disrupting social behavior or unnecessary handling. A specimen's identification can be determined even if the entire specimen is not visible. The only disadvantage to this marking method is the need to periodically repaint the identification numbers on the specimens, since they are worn or shed off. In the event an identification number is

competely worn away, the identity of adult specimens is easily determined by comparing them to ID photos and physical statistics that are maintained for each specimen.

Juvenile specimens are marked in a similar manner. Their identification numbers must be repainted more often due to their more frequent ecdysis, and because of the rapid ontogenetic pattern change which occurs during the first 2-3 years, which makes photo identification useless until the specimen approaches sexual maturity (Figure 4).

HEALTH AND NUTRITIONAL MANAGEMENT

The S. varius health management program at ASDM has four major objectives: if it occurs, to prevent disease and promote the health of the captive population; to identify and effectively treat disease; to establish adequate dietary guidelines; and to record information regarding various physiologic processes of the species.

The early detection of disease is an important part of this program. Museum personnel examine each specimen on a daily basis. Morphologic abnormalities (such as swellings or weight loss) are noted, as are abnormal movements, postures, and behaviors. Often, a refusal to feed, prolonged lethargy, or persistent attempts to escape are early indications of stress or disease. Specimens that exhibit such symptoms are examined by a veterinarian.

All S. varius receive semiannual physical examinations. At this time each specimen is weighed, snout-vent and tail lengths are measured, and each specimen is marked with its identification number. Each specimen has its eyes, tympana, buccal cavity, vent, and integument examined. Each specimen is thoroughly palpated, and its reflexes and movements are observed. If symptoms of disease are found, the following diagnostic procedures are used to determine the causes: blood sampling, bacterial culture and sensitivities, fecal flotation and cloacal smears for endoparasitism analysis, radiography, and/or surgical exploration. In addition, each adult S. varius is annually radiographed in a dorso-ventral position. Individual health

records, with periodically updated photographs, are maintained for each specimen.

To date, the most persistent health problem in the specimens has been their infestation by the pterygosomatid mite Hirstiella pyriformis. Newell and Ryckman (1964) first described this species from S. varius, but subsequently found it is a common ectoparasite of Sauromalus sp. in general. DDVP impregnated strips (Vapona Pest Strip, Shell) usually effective against the mite genus Ophionyssus, and which were recommended by Frye (1981) for eradication of mites, proved ineffective in controlling the S. varius mite infestations. Trichlorphon (0.1%, Neguvon, Bayer) sprayed on the specimens as well as on the surfaces of their enclosure (as recommended by Cooper and Jackson, 1981) was initially effective, but the mites seemed to develop a resistence to this organophosphate after only a few applications. Currently, the most effective treatment for mite infestations includes swabbing the mites directly with isopropyl alcohol and periodic thorough washing of the refuge buildings.

The first series of routine radiographs, taken in 1981, revealed a significant incidence of osteomyelitis affecting the limbs of some specimens; four specimens exhibited osteomyelitic lesions. In each case, one limb was affected, and in each case, the specimen had been toe-clipped on the affected limb for identification purposes. Culture of caseous exudate from one lesion revealed bacteria (Neisseria sp.). All the affected specimens were treated with parenteral chloramphenical succinate, which the Neisseria showed sensitivity to; and subsequent radiographs indicated the specimens recovered from the osteomyelitis.

Stomatitis is occasionally found during routine physical examinations. The bacteria Pseudomonas sp. and Neisseria sp. have been isolated most frequently. The stomatitis infections have all been localized and have been treated successfully with topical applications of a povidone-iodine solution (Betadine, Purdue Frederick) diluted 50% with water. Occasionally, the specimens receive abrasions, lacerations, and fractures that

Mexican Burrowing Frog (*Rhinophrynus dorsalis*).
Photo by Rick Hudson.

Strawberry Poison Dart Frog (*Dendrobates pumilio*).
Photo by R. Andrew Odum.

Central American Horned Treefrog.
(*Gastrotheca cornuta*). Photo by R. Andrew Odum.

Madagascar Angulated Tortoise (*Geochelone yniphora*).
Female/male courtship. Photo by Sean McKeown.

Burmese Forest Tortoise (*Geochelone emys "nutapundi"*).
Photo by Sean McKeown.

New Caledonia Gecko (*Rhacodactylus auriculatus.*).
Photo by Sean McKeown.

San Esteban Island Chuckwalla (*Sauromalus varius*).
Photo by Sean McKeown.

Western Spiny-tailed Skink (*Egernia stokesii badia*).
Photo by Sean McKeown.

Aruba Island Rattlesnake (*Crotalus unicolor*).
Photo by R. Andrew Odum.

Mexican Lance-headed Rattlesnake
(*Crotalus polystictus*). Photo by R. Andrew Odum.

Fiji Banded Iguana (*Brachylophus fasciatus*).
Photo by T. M. Hanlon.

Seychelles Chameleon (*Chamaeleo tigris*).
Photo by Sean McKeown.

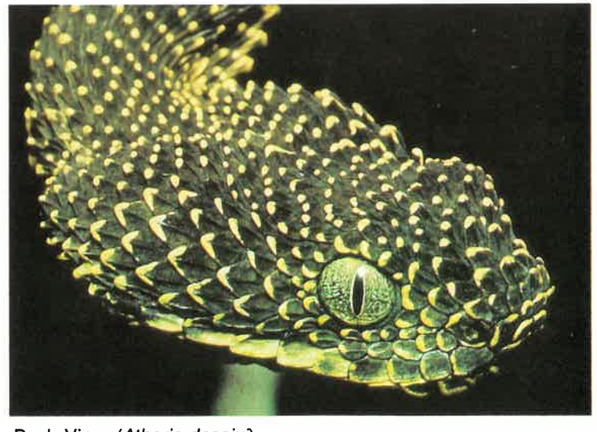
Shield-nosed Cobra (*Aspidelaps scutatus*).
Photo by R. Andrew Odum.

White-headed Viper (*Azemiops feae*).
Photo by John H. Tashjian at Dallas Zoo.

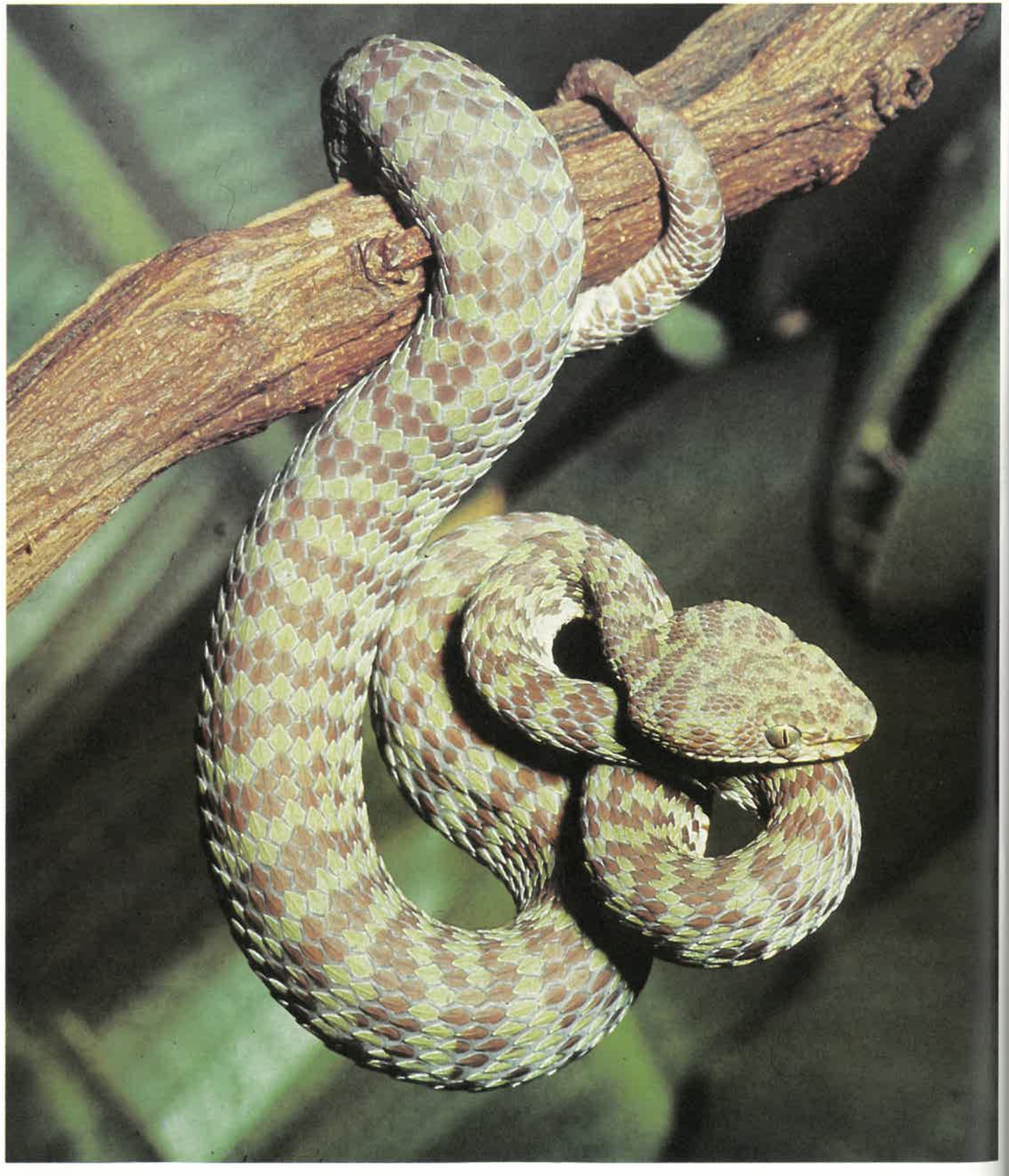
Dumeril's Boa (*Acrantophis dumerili*).
Photo by R. Andrew Odum.

Madagascar Tree Boa (*Sanzinia madagascariensis*).
Photo by R. Andrew Odum.

Wagler's Viper (*Trimeresurus wagleri*).
Photo by John H. Tashjian at Dallas Zoo.



Bush Viper (*Atheris desaixi*).
Photo by John H. Tashjian at Dallas Zoo.



Kamburian Pit Viper (*Trimeresurus kamburiensis*).
Photo by John H. Tashjian at Houston Zoo.

usually result from agonism or falls; such injuries are treated as in other species.

Cowan (1980) provides a good discussion of the effects of environmental stress on reptiles and its role in the pathogenesis of disease. Studies we conducted at ASDM on the changes in the intestinal flora of squamates during their acclimation to captivity support Cowan's (1980) contention that opportunistic infections and generalized debilitation are often caused by environmental stress. We have little doubt that the spacious outside chuckwalla enclosures have been instrumental in reducing stress and disease problems by providing the specimens with a diverse habitat and a choice between numerous refugia. The frequency of intraspecific interaction is also an important consideration in reducing stress as well as promoting reproduction (Crews, 1980). We continuously reevaluate the population densities and sex ratios of the specimens in order to maintain good health and maximize the specimens' reproductive output in these enclosures.

Like other herbivorous reptiles, dietary regimens for captive iguanines were historically formulated more or less arbitrarily, often with more attention given to what the specimens would eat rather than to their diet's nutritional content. Although feeding studies have not been conducted in captivity, the nutritional requirements of Sauromalus sp. have been established; Sylber (1985) determined by fecal analyses that 22 species of plants were consumed by S. varius on Isla de San Esteban. Sylber (1985) also documented seasonal variations in food preferences. This may be explained, in part, by seasonal availability. We contend that this seasonal variation may also reflect changing nutritional requirements associated with variations in hydration, growth, activity, and reproductive cycles. Our captive colony of S. varius are currently fed grated carrot and collard, kale, or mustard greens once a week. Alfalfa hay is available at all times. In addition, edible native plants growing in the S. varius enclosure include the following; the plant is listed, then the edible part of the plant

is in parenthesis: saguaro (fruit), palo verde (leaves, flowers, beans), mesquite (leaves, flowers, beans), acacia (leaves, flowers, beans), and brittlebush (leaves, flowers).

Our approach to formulating the optimum diet for the captive specimens will be to study the diet of S. varius in the wild, and modify the captive specimen's diet if necessary. One phase of our field study will be performing fecal analyses at three-month intervals. The plant species and their parts eaten will be determined, as well as how often the S. varius feed on each plant species. Fresh cuttings of the plant parts used for food will be analyzed to determine percentages of crude protein, ether extract, nitrogen free extract, crude fiber, ash, calcium, phosphorus, and the percentage of dry matter. Once we determine the feeding strategies of the wild population, and determine the nutritional content of their diet, we can give our captive specimens as natural a diet as possible.

As part of our current field research on Isla de San Esteban, wild chuckwallas are captured and subjected to the same physical examinations as our captive specimens are. Each specimen's weight and length are recorded, each specimen is identified by a painted number, and an individual file is maintained on each specimen. We give close attention to the state of each specimen's hydration, which is indicated by relative filling of lateral lymph sacs (Norris and Dawson, 1964) upon palpation. In severely dehydrated lizards, enophthalmus and an "emaciated appearance" are evident. Females are palpated for ova, and size estimates and number of ova are recorded. Males are palpated to estimate testicular size.

In June 1985, 38 adult S. varius were captured and examined on Isla de San Esteban. Mite (Hirstiella pyriformis) infestations were moderate on most individuals. Many specimens had scarred nuchal regions. Three specimens had excoriated lesions in nuchal areas, which were heavily infested with mites. Histopathologic examination of the lesions indicated they were probably traumatic in origin, and undoubtedly resulted from sustained scratching.

Two specimens we found had abscesses. The first had three pharyngeal abscesses, located on lateral surfaces of the pharynx. The abscesses were approximately 1 to 3mm in diameter, and contained a caseous exudate. Culture of the exudate revealed the bacterium Serratia liquefaciens. The second chuckwalla had one mandibular abscess approximately 6mm in diameter. This abscess also contained a caseous exudate. Culture of the exudate revealed the bacterium Serratia marcescens. We have also seen subpharyngeal abscesses in S. varius (Figure 5).

Conti and Crowley (1939) described numerous small tumors in the buccal cavities of captive S. varius at the San Diego Zoo. They isolated a bacterium from these which they tentatively described as Bacterium sauromali. Bostic (1971) found and reported on three cervical tumors in a recently captured S. varius, and recovered a Gram negative bacillus from the exudate contained in these tumors. Unfortunately, the bacillus could not be cultured, so identification was impossible.

A priority on future trips to Isla de San Esteban will be a study of the incidence and etiology of abscesses of wild S. varius. Our plans include histological examination of abscesses at various stages of development, further culturing to identify what bacteria exist in wild populations, and hematologic evaluation of the affected specimens.

OBSERVATIONS

Case (1982) provided new information concerning the ecology and social biology of S. varius. However, many of his remarks pertaining to social organization were conjectural due to limited opportunities for detailed observation. Our observations in captivity present a very different picture of social biology for the species. Whether our observations are affected by the captive setting is open to question.

Contrary to Case's (1982) conclusion that S. varius is unaggressive and non-territorial, we have observed agonistic and territorial behavior involving intensive social interaction. This behavior has included male-to-male agonism in late winter and early spring (February-April), which apparently is a behavior

that establishes a male dominance hierarchy within the social group. This is evidenced by the emergence of an "Alpha" male who repeatedly chases other males during this period. The "Alpha" male engages in the most courtship sequences, which we have observed from early April into May. Pair bonding appears to take place on a seasonal basis. At present, we do not know the precise mechanism or duration of pair bonding, although it occasionally involves a second female. Males show no agonism toward each other except during the pre-nuptial phase of the reproductive cycle.

Both males and females are exceptionally wary during the nuptial period. Great caution is required in order to observe courtship and copulatory activity. Observed copulations have taken place in mid-afternoon during April and May. Intromission may occur as long as an hour.

A period of relatively little agonistic and territorial behavior occurs from mid-May until mid-June. However, when nesting begins in mid-June, females become highly agonistic, both with conspecifics and keepers. Generally, younger and smaller females nest first, often choosing nest sites which are near the wall of the enclosure; these nesting sites are characterized by flat, open space. Nest holes are dug in the soil and are normally 60-80cm deep. A chamber is enlarged at the apex of the nest hole, and the female actively guards the entrance until the eggs are deposited (which may be up to a week). After oviposition, the burrow hole is immediately filled in. After oviposition, the female guards the nest site against intrusion from other females (Figure 6). Males are also chased away, but with less vigor than that directed toward females. On several occasions, a larger female has displaced a smaller female from the nest; the larger female has then dug her own nest hole where the smaller female laid her eggs. After removing the smaller female's eggs and laying her own, the nest hole is filled in; the larger female will then guard the nest site. Subordinate females quickly retreat following domination by a larger specimen. An area of 1-2 meters in diameter is controlled by females guarding

nest sites, and a conspecific intruder is signalled first by head-bobbing. If head-bobbing fails to repel the intruder, the female mouth-gapes and then lunges at the intruder. Large females close to egg-laying are not easily dissuaded from their chosen nesting site, and they often displace smaller females through sheer size. These observations suggest a sophisticated selection process for optimal reproduction involving the largest, fittest males and the largest, most fecund females. Size seems to be the primary factor establishing dominance in both males and females.

Inasmuch as Case's (1982) preliminary assessment of social organization was used as the basic guideline for the initial formation of the social groups, we have reevaluated our formation of social groups and some of our management techniques based upon our observations. Our observations suggest the need for more effective visual barriers and associated separation areas during male agonism in the spring, followed by sequential exposure of the dominant males to the females, which would allow pair bonding to take place. Once mated, gravid females may be kept together until immediately prior to the nesting period (June-July), when each should be provided with a suitable nesting medium. The nesting medium should consist of loamy soil with a reduced clay content, which is necessary so the nest holes will maintain their integrity throughout the 12-14 week incubation period. To date, efforts to artificially incubate the eggs have proven difficult, due in part to problems in determining proper humidity levels. A variety of media and incubation temperatures have been used with only marginal hatching success. On the other hand, nearly all the fertile eggs left in the natural nests have hatched (Figure 7). However, the hatchling specimens experience difficulty burrowing out of the nest hole. The hatchlings which have successfully emerged from the nests in the enclosures have done so by way of the maternal tunnel to the nest chamber. This route might be expected to offer the least resistance and there is some evidence that the rigors of excavation may be mitigated by the combined efforts of all the siblings. This is no doubt

attributable to the higher clay content in the soil in the propagation enclosure, so we provided sandy or loamy sites of sufficient depth (60-80 cm) at various sites in the enclosure. We feel additional watering of these sites prior to the summer rainy season may also be beneficial to the proper functioning of these nest sites. Observations from the 1985 summer expedition to Isla de San Esteban suggested sea mists may saturate deeper layers of the soil, even though the sun and high temperatures may quickly dessicate the soil's surface layer.

In order to prevent confusion as to which nest produced which progeny, circular cages constructed of hardware cloth with plywood tops to provide shade were placed over several nest sites in 1983. The hatchlings from the covered nests were thus identified as to maternal lineage for future genetic management.

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Lower Vertebrates and Invertebrates
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Tucson, Arizona

Captions for Figures 1-7

Fig. 1 - The San Esteban Island Chuckwalla, Sauromalus varius, also known as the Yellow or Piebald Chuckwalla, is an example of an iguanine species in need of captive propagation and study.

Fig. 2 - The ASDM propagation/research facility. The primary refuge building (left) can be heated and dismantled for thorough cleaning and access. The large screened enclosure (rear center) houses juveniles of various age classes. The observation blind (right) provides opportunities for behavioral and social evaluation. Vegetation natural to the diet of the species grows inside the enclosure.

Fig. 3 - The interior of the refuge building. PVC tubes lead from the outside to each retreat box. These provide a degree of segregation among the colony and can be removed for cleaning or refurbishment.

Fig. 4 - Ontogenetic pattern change can be seen in this juvenile S. varius at five months of age.

Fig. 5 - Subpharyngeal abscess in a wild S. varius. Knowledge and study of disease entities in iguanine lizards are fundamental to successful captive management.

Fig. 6 - A post-ovipositional female S. varius (center) defending her nest site against intrusion by a gravid female (foreground). Observation and interpretation of behavior in the captive setting are important to the refinement of iguanine breeding programs.

Fig. 7 - A brood of S. varius hatched in a nest inside the propagation/research enclosure.

Figure 1

Figure 2

Figure 3

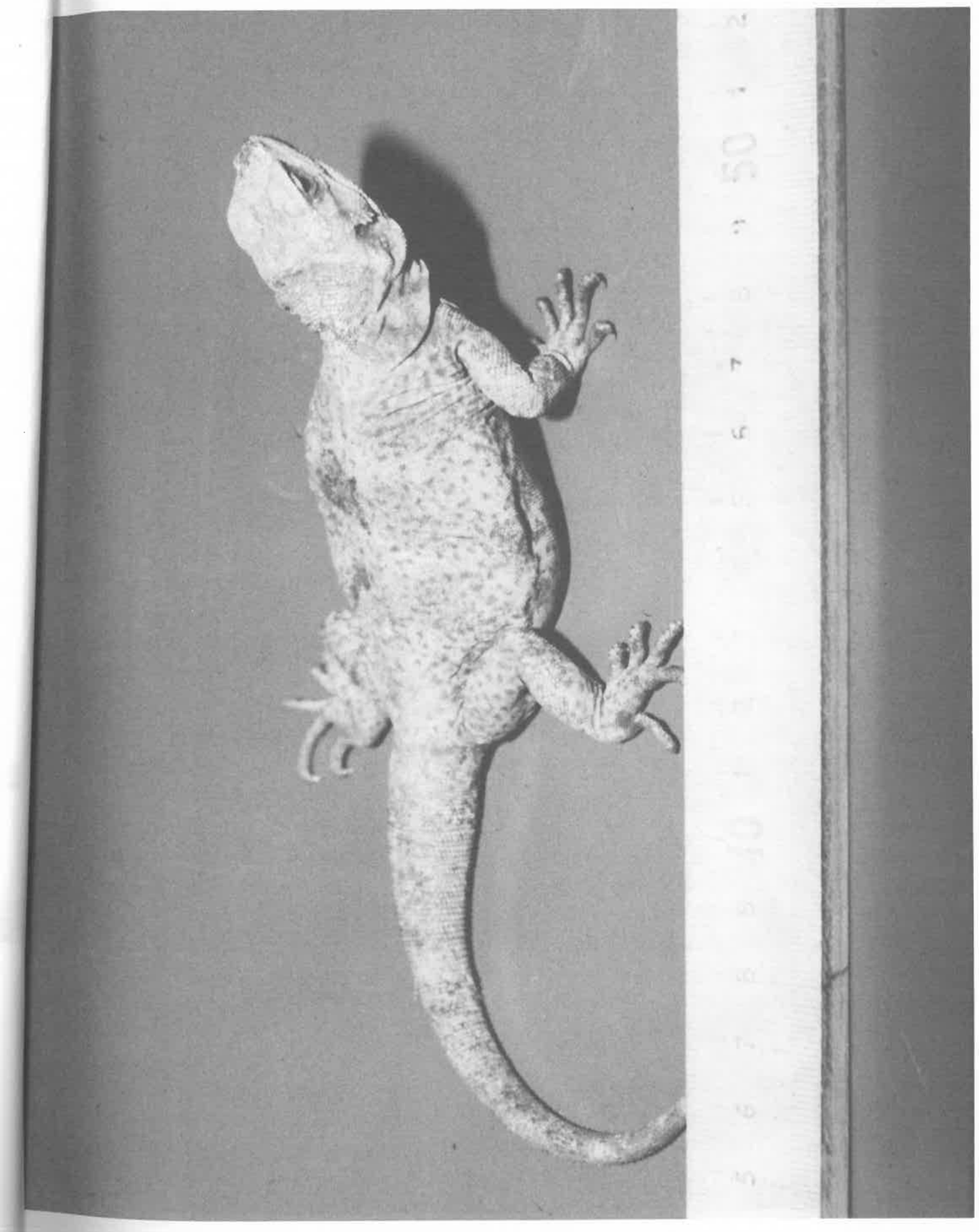

Figure 4

Figure 5

Figure 6

Figure 7

THE FIRST CAPTIVE PROPAGATION
OF THE GRAND CAYMAN ISLAND IGUANA
Cyclura n. lewisi
Tommy E. Crutchfield

DESCRIPTION AND STATUS

The species is nearly extinct, and I doubt whether more than a dozen individuals still exist on the island. In past years they are said to have been numerous in the interior of the east and north, and especially near Great Bluff. East End people say that since 1925 the 'guanas' have become so scarce that it is no longer worth their while to hunt them. Before we caught our two specimens, most people on Grand Cayman were unaware that iguanas existed on the island, as the few remaining representatives of the species inhabit the most inaccessible and unfrequented part of Cayman.

So wrote C. Bernard Lewis in the manuscript of The Herpetology of the Cayman Islands, published in 1940 by the Institute of Jamaica. If his population estimates were correct, it is amazing that this species is not extinct.

After speaking to many individuals who live or have lived on Grand Cayman, we believe his population estimates are on the low side. It currently is in captivity on Grand Cayman.

A potential threat to C. n. lewisi is the possibility that C. n. caymanensis (found on Cayman Brac and Little Cayman), has been introduced on western Grand Cayman, although Schwartz and Carey (1977) suggest that because C. n. lewisi appears to be absent or very rare in this part of the Island, no competition between the two subspecies is likely. However, we suggest that intergradation, not competition, is the potential problem threatening the existence of C. n. lewisi as an extant subspecies.

No one is quite sure why C. n. lewisi is so scarce. Probably it is a combination of many factors, including human predation for food, introduction of feral animals such as

rodents, cats, dogs, etc., and habitat destruction. In addition, intensive aerial spraying for mosquito control may have some affect, although aerial spraying is relatively recent. It is not known what impact this will have on surviving C. n. lewisi populations. To sum up all information to date, we believe this species may be the most endangered lizard in the world.

As far as we can determine, there are seven unrelated wild caught C. n. lewisi now in captivity in the United States. These specimens can hopefully be included into a long-term captive breeding program. Over the last four years we have successfully hatched ten C. n. lewisi; the total seventeen specimens in captivity in the United States probably outnumber wild specimens.

The type specimens were collected and described by members of the Oxford University Cayman Islands Biological Expedition, August 1938. The subspecies was named in honor of Mr. C. Bernard Lewis. Squamation and color were described by Grant and Lewis (1940): "Squamation apparently identical with that of C. m. caymanensis and C. m. macleayi (C. n. nubila) except for the relatively longer caudal spines in adults. The subspecies is based upon this difference and upon the blue basic color. The head, nuchal region and the spines of the back and tail are between powder-blue and sky blue. The fan is somewhat lighter and greenish. Dorsally the body is uniformally dirty blue-green; latero-ventrally lighter; belly pale greenish-blue. The tail loses its bluish tinge and becomes black posterior to the last long spine. Forefeet are black with dark greenish-blue scales on the upper surfaces; hind-feet lighter. 'Whites' of the eyes are dark pink. The young may show a pattern but none is visible in the adults."

We agree with the general description and color, however the color of these lizards fluctuates greatly depending on their temperature. In morning and evening the lizards tend toward being very dark in color (in some instances only the head looks blue). As they bask, they tend to become lighter and much bluer in color. This response to temperature is probably the same

response observed in other lizards that exhibit temperature-dependent color change. In addition, all adult C. n. lewisi we have seen have faint crossbars on the body, although the crossbars become less noticeable as the body temperature increases. One explanation why Grant and Lewis (1940) did not see crossbars on adult lizards might be related to the age of the specimens they worked with. Although hatchling C. n. lewisi have vivid black crossbars, the crossbars may fade completely away as they age. The type specimens were all adults and possibly very old specimens, which could account for the original description. Three of our youngsters are now 2.5 years old, and although the pattern is still obvious, it is beginning to fade.

CAPTIVE MAINTENANCE

Our C. n. lewisi are housed in an outdoor enclosure measuring 3.75 x 7.5m; a wall divides the enclosure into two 3.75 x 3.75m cages. The pens are constructed of concrete block with walls measuring 32" high. As the visual barrier is only 32" high it enables male lizards to display without being able to physically damage each other. Welded wire covers the top, and is also used in the bottom of the enclosure to insure that the lizards can neither escape or dig deep burrows. The lizards nest in the soil substrate, which varies in depth from 12-20 inches. A small concrete-block house with a 250 watt infrared heat lamp provides shelter and additional heat during inclement weather. Cork logs, rock piles, plants, etc., are utilized for basking places, visual barriers, and retreats. In this type of environment, we have successfully maintained our C. n. lewisi outside year-round.

Food is presented three times a week. The diet includes assorted vegetables and fruits (as much variety as possible), dry dog food, monkey chow, and occasionally mice.

Powdered vitamins are sprinkled on the food each feeding. Additional calcium is provided for gravid females by feeding chopped chicken necks and other meats containing bones. We think this is very important both before and immediately after egg

deposition. At this time, we would like to stress the fact that we feed mostly vegetables and fruit and not animal protein. Under natural conditions most Cyclura are foraging herbivores, only occasionally eating animal protein (Iverson, 1977).

REPRODUCTIVE STRATEGIES

Under captive conditions in Southwest Florida, breeding behavior begins in late March and ends in June. Peak reproductive activity occurs in late April and early May. A male will actively pursue a female around the enclosure, finally biting the female on the neck and twisting his body underneath hers to achieve successful copulation. Copulation may last from a few seconds to several minutes. Copulation may result in injury to female Cyclura. We have seen injuries inflicted during copulation ranging from tail and toes being bitten off to a major injury that exposed the peritoneal cavity, and resulted in extensive surgery.

Because of male to male aggression, females should not be introduced to more than one male during the breeding season. Since Cyclura establish dominance hierarchies, fights almost always ensue, not to mention the disruption of the established dominance order. We also think long-term courtship could be important in enhancing egg fertility.

We have observed egg deposition from the last week in July to the second week of August; thus far all egg deposition has occurred at night. Since we do not allow Cyclura to dig burrows, females excavate a nest cavity, and dig an egg chamber at a right angle into the side of the nest cavity. The female then deposits the eggs, and leaves a pocket of air above them. We are not sure exactly how the female deposits the eggs in the egg chamber, although we speculate that as she lays the eggs, they are grasped by the hind feet and placed in the egg chamber. The female then covers the entire nest. Sometimes the female will excavate several nests the same evening until she selects a suitable nesting site. Following egg laying the female will vigorously guard the nest against all intruders, including man and other Cyclura.

We incubate the eggs in Hova-bator chicken egg incubators at 31 $\pm$ 1^{o}C. The eggs are placed on the styrofoam bottom and covered with a thin layer of sphagnum moss. Humidity is maintained between 60-80%. Since we feel that air circulation over the eggs is very important, eggs should never be "buried" completely in any incubation medium. The incubation period is shorter (75-85 days) for C. n. lewisi eggs, unlike some other species of Cyclura, such as C. cornuta, which has an egg incubation period of 100-120 days.

Our hatchling C. n. lewisi measured 9-10cm (snout-vent length) and from 28-29cm in overall length. Color was brownish grey with black crossbars and some black spotting. The sub-adult specimens' maintenance is similar to the adults' maintenance, except that we include various types of insects in their diet. Because we utilize natural sunlight for at least part of the year, no artificial lighting is provided, except for incandescent heat lamps inside retreat areas during inclement weather. We have bred C. n. lewisi twice, and females have produced a total of eleven eggs. All of the eggs were fertile, and ten healthy lizards hatched.

SUMMARY

We believe that even though this C. n. lewisi is critically endangered, its prospects for survival, at least under captive conditions, is promising. In our opinion, this subspecies is easy to maintain and propagate. Presently there are seven known wild-caught C. n. lewisi in captivity in the United States, plus ten siblings we have produced. There are possibly other specimens in the United States and Europe of which we are unaware. We are in the process of conducting a census of United States and European collections to determine if any more C. n. lewisi exist in captivity. If so, we will make an effort to obtain and incorporate them in a breeding program. In addition, we are establishing satellite colonies of our offspring at other institutions for further breeding and isolation in the event our colony experiences disease or other problems.

Since some C. n. lewisi still survive on Grand Cayman,

we feel that a census of wild C. n. lewisi should be made as soon as possible. If this population is as critically low in numbers as we suspect, it is our recommendation that the remaining wild C. n. lewisi be removed from the wild and placed in a controlled breeding program in the United States or on Grand Cayman. These steps are difficult for us (as private breeders) to pursue because of the expense and the difficulty of dealing with foreign governments in terms of paper work, etc. We hope that the American Association of Zoological Parks and Aquariums as well as other conservation-oriented organizations will become more interested in the plight of C. n. lewisi and the other threatened Cyclura before they vanish from the earth forever.

Acknowledgments: We thank Ramon Noegel and Greg Moss of Life Fellowship for supplying slides and information about the current status of C. n. lewisi on Grand Cayman. Bill Love took most of the slides for the oral version of this paper. Both Chris McQuade and Bill Love reviewed the manuscript and made helpful suggestions. Thanks to the staff of the Houston Zoo for encouragement and suggestions for future propagation.

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AN IMPROVED TECHNIQUE FOR SEXING SKINKS OF THE GENUS Tiliqua

Ronald L. Tremper

For years there has been a lack of evidence to support the theories and/or "known" methods of sexing the large and interesting members of the genus Tiliqua. Much guesswork has been applied concerning the variables of: head width, tail length and thickness, and overall body-size at maturity. None of these characters can be used to determine sex accurately.

Due to the increased interest in captive breeding, the need to properly determine the sex of animals has become paramount. Although a preliminary report, this paper is intended to introduce a probing technique which is reliable. Based on some findings by Dick Goergen (pers. comm.), and my own recent investigations, we found a probing method that, when done properly, resulted in the best technique known to date.

PROBING TECHNIQUE

Two people are needed: one to restrain the skink, and one to position the tail and conduct the actual probing. The technique consists of the following steps: hold the skink with the ventral surface up and let it relax. Take a metal probe that is at least 5-7" (150mm) long and only 2mm in diameter, the person who is probing should lift the anal plate with his free hand. Do not use a probe that tapers. The probe should then be slowly inserted, keeping it as parallel as possible to the skink's tail, which should be straight with the axis of the body. Male skinks can constrict the muscles in the tail and compress the hemipene which is why it is necessary to use a 2mm diameter probe. The probe should be gently manipulated side to side to ease it pass the constriction (usually 1-2 inches deep) in the event the skink is male. Excess force must not be applied, but unless an attempt is made to insert the probe deeper, a male skink may be incorrectly sexed as a female. Only water is necessary as a lubricant. A number of the commercially available lubricants are spermicidal (Mengden et al., 1980).

PROBING DATA

This technique has been successfully used on the following species: Tiliqua scincoides scincoides, T. s. intermedia, T. nigrolutea, T. multifasciata, T. gigas.

Species	Total length	SVL*	Probe Depth	Sex
Tiliqua s. scincoides	17"	10.5"	2 3/4"	M
T. s. scincoides	16.5"	10.0"	1 1/2"	F
T. s. intermedia	21 3/4"	-	3 1/2"	M
T. s. intermedia	21 1/2"	-	2 1/8"	F
T. s. intermedia	19 1/4"	-	2"	F
T. s. intermedia	22 1/2"	13.0"	3 3/4"	M
T. s. intermedia	22"	12.5"	3 1/2"	M
T. s. intermedia	20"	10.5"	2 1/4"	F
T. s. intermedia	15 1/2"	8.0"	1 3/4"	M
T. nigrolutea	14 3/4"	7.5"	1"	F
T. nigrolutea	-	9.5"	3/4"	F
T. multifasciata	-	9.0"	1 13/16"	M
T. multifasciata	12.0"	6.5"	1"	F
T. multifasciata	11.0"	6.0"	1"	F
T. gigas	7.0"	4.5"	2 1/8"	M
T. gigas	-	10.0"	1 1/2"	M
T. gigas	-	11.0"	1 1/4"	F
	12.5"	6.5"	1"	F

*Snout Vent Length.

Except for T. gigas, there was a difference in all skinks tested. Perhaps the sample size was too small, or more likely, T. gigas has a similar probe depth for both sexes.

DISCUSSION

Before probing each skink, various predictions were made as to sex based on head width, tail girth, or behavior. A number of the larger skinks sampled were already of a known sex based on birth of young or observed copulations. To insure objectivity, this information was withheld until after each skink of known sex was probed; the sex was determined based on the technique discussed herein.

The results of probing skinks of known sex showed this technique is accurate. In addition, we found proof that other methods (based on morphology or behavior) are inaccurate. Females often had wider heads than males of the same size. Also, when probed, obese skinks with heavy tails thought to be males were usually females. Aggression between conspecifics proved to be an unreliable method of determining sex also. Females will fight with males and/or females in a colony situation.

In the past, people using a sexing probe that tapers have sexed many males as females due to the large diameter of the probe. If a probe is larger in diameter than the hemipene itself, then the probe will not penetrate far enough to allow accurate sex determination.

I did not get to test T. gerrardi. However, use of a perfectly straight 1mm diameter probe, would likely prove reliable for determining the sex in this species, as well as other taxa in this genus.

In summary, the problems encountered in the past for sexing Tiliqua have been solved by:

1) Using a small diameter, non-tapering probe of sufficient length,
2) Having the assistance of another person, and
3) Being aware of and getting past the mid-hemipenal constriction encountered in males.

Acknowledgments: I wish to thank Mike Bumgardner, Ronald Cauble and Dick Goergen for supplying animals to be tested and for allowing their data to be incorporated into this paper. Special thanks are due Sean McKeown for photographic assistance.

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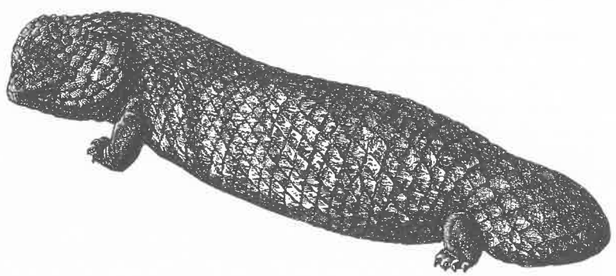

CALCIUM METABOLISM IN THE LIZARD GENUS Phelsuma

A Preliminary Report

Tim Tytle

Malnutrition has long been a leading cause of reptilian morbidity and mortality (Cowan, 1968; Keymer, 1980; Frye, 1981; Millichamp). Because calcium depletion must rank high as the cause of death of predominatly diurnal lizards, a basic understanding of calcium metabolism and the maladies due to a shortage of calcium in the diet is essential to the proper maintenance of any lizard collection. The purpose of this paper is to present an overview of reptilian calcium metabolism, and then to apply this information to the successful management of a lizard collection. The Day Geckos, genus Phelsuma, have been selected as the principal subject because they are frequently-kept diurnal lizards that frequently suffer from calcium imbalances in captivity.

Some research has been published concerning calcium metabolism in reptiles, and there appears to be a basic similarity between reptiles and the far more extensively studied mammals.

In vertebrates, two hormones [parathyroid hormone (PTH) and calcitonin] and the co-enzyme vitamin D_3 (1,25-dihydroxy-cholecalciferol), are important in calcium metabolism. Clark (1972) reported the parathyroid glands of lizards and snakes are similar in function to those of mammals; the parathyroid gland increases blood levels of calcium by resorbing (removing) calcium from bone tissue, but in most geckos, calcium stored in the endolymphatic sacs is most likely to be utilized for periods when higher blood levels of calcium are needed, such as during reproduction (Simkiss, 1967).

Calcitonin is secreted from ultimobranchial tissue of the neck in reptiles (Copp and Parkes, 1968; Clark, 1971). In mammals this secretory tissue is associated with the thyroid gland, so calcitonin is often referred to as thyrocalcitonin. In

mammals, calcitonin decreases blood calcium levels; in reptiles, its effect is variable. Dix et al. (1970) reported that injected calcitonin had no effect on the Green Anole Anolis carolinensis. However, Anderson and Capen reported the activity of the ultimobranchial gland of lizards may be responsive to changes in plasma calcium. The effect of calcitonin on calcium regulation in Phelsuma has not been documented yet.

In vertebrates the intestinal tract is not responsive to the absorption of calcium unless stimulated by vitamin D_3, which is manufactured in the skin under the influence of certain wavelengths of ultraviolet light.

The homeostatic element in calcium assimilation is the blood. When blood levels of calcium are above normal, excess ingested calcium is not absorbed, and the excess calcium in the blood is excreted by the kidneys or deposited in bone and/or in endolymphatic tissue in some species (Simkiss, 1967). When blood levels of calcium are too low, calcium is absorbed from the intestinal tract, resorbed from bone tissue, or probably resorbed from the endolymphatic sacs in those species that store calcium in these structures (Simkiss, 1967).

All vertebrates possess endolymphatic sacs, but they are "very small in birds and mammals, but enormously enlarged in the amphibia and some reptiles" (a few iguanids and most geckos) (Simkiss, 1967). In those lizard species that use them for calcium storage, the sacs appear as large swellings behind the ear. Radiographs of female Phelsuma clearly show calcareous masses at this location; because the sacs are functional only in adult females during reproductive periods, it is logical to conclude that this calcium is used during reproductive periods in the same manner as the other gekkonid species discussed by Simkiss (1967).

Much has been written about the calcium-phosphorus ratio and the deleterious effects of a calcium-phosphorus imbalance. Phosphorus combines with calcium in the gastrointestinal tract and forms calcium phosphate; the amount of calcium phosphate absorbed depends on the pH of the intestine. While a small

amount of phosphorus in the diet is required, an amount far in excess of that which is needed may be consumed. Most authorities believe the optimal calcium to phosphorus ratio is 2.0-1.5 parts calcium to 1.0 part phosphorus (Frye, 1981; Millichamp). While snakes and crocodilians probably receive adequate calcium from the skeletons of ingested prey, lizards are more prone to calcium-phosphorus imbalance due to their diet (Millichamp).

Langerwerf (1980) noted a high incidence of calcium depletion in predominantly diurnal lizards (i.e. iguanids, agamids, lacertids, teiids, and diurnal gekkonids). Those species of lizards that are less diurnal (i.e. some skinks and geckos) suffer less often from calium depletion. While sunlight is the optimal source for the ultraviolet radiation necessary for vitamin D_3 production, commercially available broad-spectrum lights may provide adequate ultraviolet light for most lizard species. Banks suggested that the light source be kept 1-2 meters from the cage bottom but a closer distance is probably more beneficial. In addition, since the element that produces the ultraviolet light in fluorescent tubes slowly degrades, the lights must be periodically replaced (at least yearly; six month intervals are better). While too much ultraviolet light may be harmful, no species-specific limits have been established.

The signs of calcium deficiency can be divided into two descriptions: acute and chronic. In the acute form, no previous overt signs of calcium depletion are observed. Instead, a seemingly healthy specimen may be found in a spastic state (hypocalcemic tetany). This is due to a calcium depletion in conductive nerve fibers, where calcium regulates electrical charges. I have only witnessed this phenomenon in reproductively active females, when calcium requirements are at their highest. This condition can sometimes be rapidly reversed by the infusion of about 2cc of calcium lactate or calcium gluconate into the stomach. The equipment best suited for infusing the solution can be easily made by applying a 3cc syringe to a small (21 or 23 French size) intravenous "butterfly" catheter with the needle removed.

The symptoms of chronic calcium depletion are subtle and variable. Reproductively active females and juveniles should be carefully watched for symptoms of calcium depleton. Scoliosis ("kinking") of the vertebral column, particularly in the tail of juveniles, is common. Another symptom is the condition known as "floppy" or "rubber jaw", which is manifested by the lizard's inability to use the lower jaw. I have found this to be an almost uniformly fatal condition. In reproductively active females thin-shelled eggs may be another symptom of chronic calcium deficiency. Finally, when calcium stores have been exhausted, a reduction or a lack of calcium in the endolymphatic sacs of adult females or bone demineralization (osteopenia) are symptoms of calcium depletion that can be detected radiographically.

If diagnosed early, calcium depletion can be corrected. However, if a calcium depletion results in skeletal abnormalities, the addition of calcium in the diet will not reverse the skeletal abnormalities.

Unfortunately, most commercially available foods do not provide Phelsuma with an adequate calcium-phosphorus ratio, so juvenile and reproductively active females need to have their diets supplemented with calcium carbonate. Allen et al (1982) analyzed composite samples of earthworms, mealworms, crickets, and wax worm larvae, and found a consistent imbalance in the calcium-phosphorus ratio in favor of excess phosphorus (Table 1). While Allen et al (1982) recognized that their investigation was not extensive and that the results of the research they quoted were variable, there was suggestive evidence that when crickets were fed a high calcium diet, the pre-existing calcium-phosphorus ratio was favorably altered (Table 2). Their paper supports my observations that, at least in Phelsuma, calcium supplementation is essential.

Dusting crickets and other food sources with various calcium preparations, particularly bone meal and calcium phosphate, has long been in practice (Allen, Olav, and Knapka, 1982). The best calcium supplementation is provided by calcium carbonate. It has

a much higher ratio of calcium and is assimilated more readily than calcium lactate. Calcium phosphate has an unfavorable calcium-phosphorus ratio, so it should not be used. In addition, female Phelsuma will eat their hatched egg shells, which are primarily calcium carbonate. This behavior may also occur frequently in the wild (Freedman et al., 1976).

Langerwerf (1980) recommends an aqueous supplementation consisting of one teaspoon of calcium lactate and 10,000 i.u. of vitamin D_3 added to each liter of drinking water.

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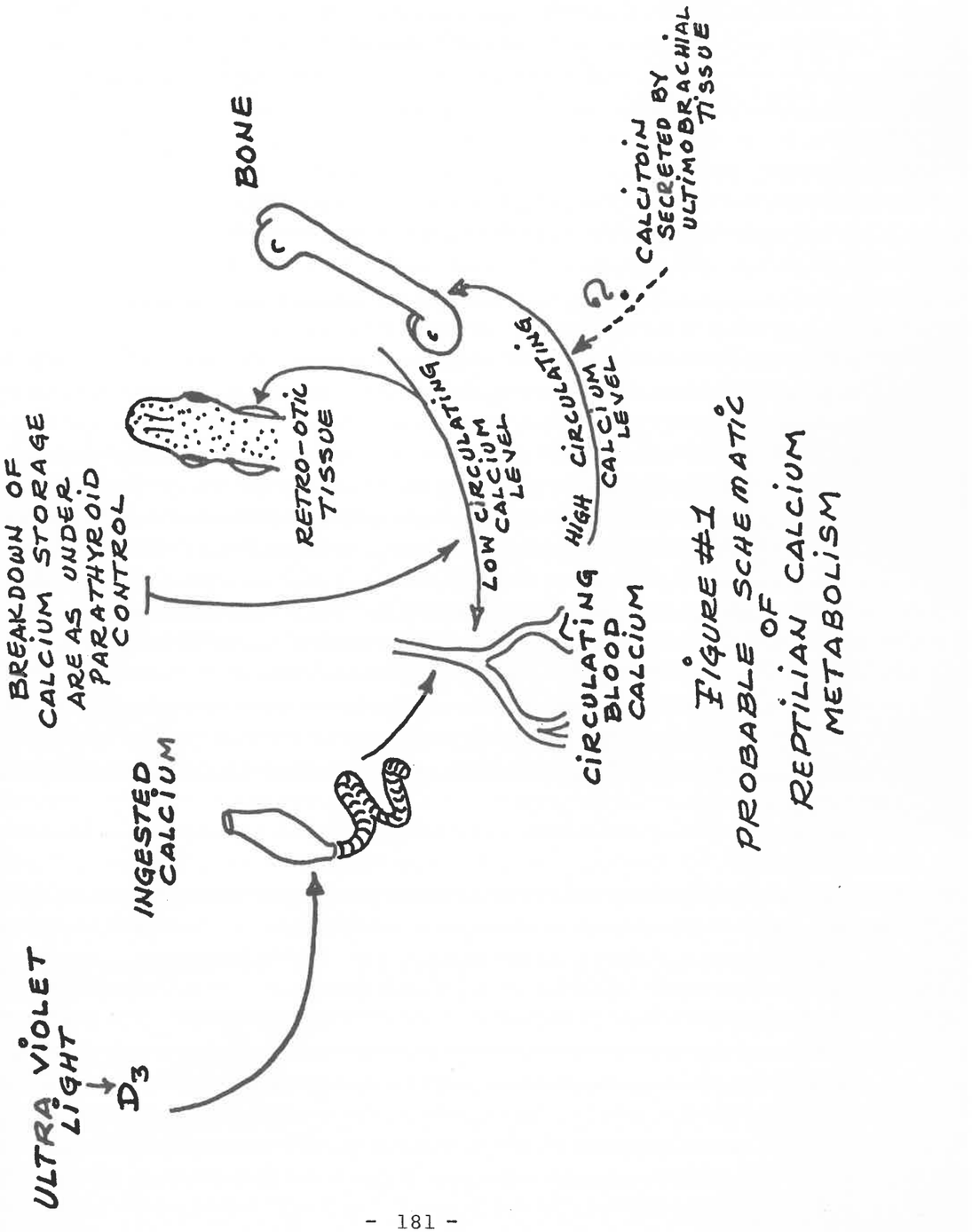


FIGURE #1
PROBABLE SCHEMATIC OF REPTILIAN CALCIUM METABOLISM

Table 1*

CALCIUM AND PHOSPHORUS COMPOSITION - INVERTEBRATES

	EARTHWORM		MEALWORM		CRICKET		WAX MOTH LARVA	
	DM[1]	FW[2]	DM	FW	DM	FW	DM	FW
NUTRIENT								
Calcium %	0.95	0.14	0.038	0.013	0.10	0.029	0.030	0.013
Phosphorus %	0.95	0.14	0.57	0.19	0.79	0.23	0.39	0.17
Ca:P	1:1	--	0.06:1	--	0.13:1	--	0.08:1	--

[1]Dry Matter

[2]Fresh Weight

Calcium by atomic absorption
Phosphorus by ammonium molybdevanadate colorimetric assay

*From Allen, M.S., Oftedal, O.T. and J. Knapka. 1982. Manipulation of calcium and phosphorus levels in live prey. Proc. NE Sect. Am. Assoc. Zool. Parks and Aquariums, Toronto.

Table 2*

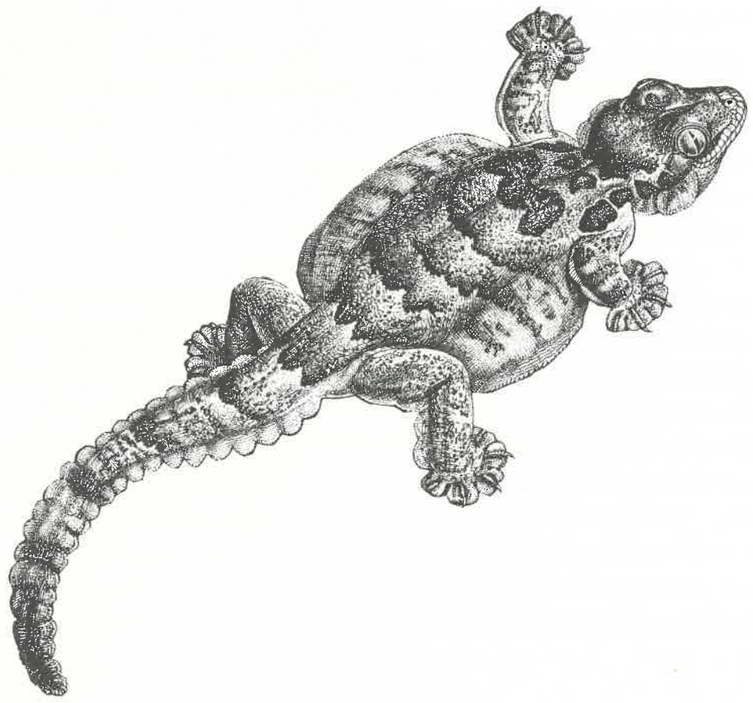
SUMMARY OF CALCIUM AND PHOSPHORUS MEAN VALUES

IN CRICKETS TREATED FOR 2, 3 AND 6 DAYS

	%Calcium[1]	%Phosphorus[1]	Ca:P
Control Diet	0.16	0.87	0.18:1
2% Ca Diet	0.26	0.90	0.29:1
4% Ca Diet	0.50	0.88	0.57:1
6% Ca Diet	0.55	0.90	0.61:1
8% Ca Diet	0.77	0.88	0.88:1

[1]Nutrients expressed as percent of dry matter

*From Allen, M.S., Oftedal, O.T. and J. Knapka. 1982. Manipulation of calcium and phosphorus levels in live prey. Proc. NE Sect. Am. Assoc. Zool. Parks and Aquariums, Toronto.



COMMENTS ON THE MAINTENANCE AND REPRODUCTION OF *Hydrosaurus pustulatus* AT THE DALLAS ZOO

Lyndon A. Mitchell

During September-October 1982, 1.0.4 *Hydrosaurus pustulatus* were obtained in eastern Luzon in the Philippines. Observations were recorded concerning the natural history of this species to aid in their captive maintenance. The specimens were quarantined upon arrival at the Dallas Zoo and endoparasites were eliminated. All specimens ate small live mice and crickets.

Juvenile *H. pustulatus* do not exhibit any prominent secondary sexual characteristics. Sibling rivalry and aggression has been observed at four months. Sub-adult males show initial "budding" of caudal sail-fin at about sixteen months. All four young adults (1.3) were introduced to enclosure housing adult male at eighteen months without incident. Younger male was removed after two to three months due to slight weight loss, lethargy, and occasional overt intimidation by older male. Females began laying eggs at two years. Eggs hatch in 72-84 days when incubated at 29^{o}C.

Juveniles are provided with two 20 Watt fluorescent blacklights and a 75 Watt incandescent spot light over a 20 gallon aquarium with a screen wire top. A large shallow pan enables juveniles to find the water source easily. Daily misting during the first two weeks prevents dehydration until water in a pan is recognized.

Hatchlings have not remained in the eggs after pipping, but

rather emerge abruptly with the umbilicus quickly releasing and falling off. They feed on two week old crickets within a week. Salad has been accepted within 2-3 weeks, and newborn mice are taken at 2-3 months. Juveniles need more space at 3-4 months due to sibling rivalry with the dominant animals biting off the tails of the sub-dominants.

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REPRODUCTION AND NOTES ON THE MAINTENANCE OF ARBOREAL AND TERRESTRIAL MONTANE *Bothrops* AT HOUSTON ZOOLOGICAL GARDENS

Karl H. Peterson and R. Andrew Odum

ABSTRACT

Houston Zoological Gardens has observed reproductive behavior (courtship/copulation/parturition) in the following species of montane *Bothrops*: Rowley's pit viper *B. n. rowleyi*, the green and black pit viper *B. n. aurifer*, the Mexican horned viper *B. undulatus*, and the Guatemalan jumping viper *B. nummifer occiduus*. Data concerning reproductive behavior will be given for these taxa.

Also, a general discussion concerning the husbandry of montane *Bothrops* will be included in the manuscript. This discussion will include information concerning temperature, humidity, light quality, and feeding of both neonate and adult specimens.

With the exception of March's pit viper *Bothrops nigroviridis marchi*, the montane species of *Bothrops* have not been well-represented in zoological and private collections. The Houston Zoo has maintained several species of montane *Bothrops* from southern Mexico and Central America, and we have collected reproductive data on Rowley's pit viper *Bothrops n. rowleyi*, the ornate pit viper *Bothrops n. aurifer*, the Guatemalan jumping viper *Bothrops nummifer occiduus*, and the Mexican tree viper *Bothrops undulatus*.

Data concerning courtship/copulation in the zoo's specimens are presented in Table 1. The courtship we observed was typical of that described for crotalids by Armstrong and Murphy (1979). In addition, we observed combat behavior in *B. n. occiduus*. Data concerning parturition in the zoo's specimens are presented in Table 2. Data concerning courtship/copulation/parturition reported in the literature are presented in Table 3.

The neonate *B. n. rowleyi* measured 170mm SV/200mm TL, and weighed 4.4 grams. Measurements were not taken of the stillborn neonate, but it weighed 4.9 grams. The neonate *B. n. occiduus* ranged from 138-188mm SV/159-214mm TL (± 168mm SV/192mm TL) in length; the average weight was 6.4 grams. Two premature, stillborn neonate *B. n. aurifer* measured 140 and 163mm TL; four living young produced two weeks later by the same

female ranged from 162-168mm SV/204-223mm TL (± 165mm SV/210mm TL); the average weight was 3.1 grams. Data concerning size and weight of neonate B. undulatus will be presented in a future publication.

While we cannot claim that the conditions we provided at the zoo for the montane Bothrops are responsible for the reproductive behavior we observed, observations on other snake species indicate their reproductive cycles are not endogenous but are instead environmentally controlled (Duvall et al., 1982). The montane Bothops maintained at the zoo experienced an annual temperature and humidity cycle, which we feel provided the necessary environmental cues for reproductive activity.

TEMPERATURE

At the Houston Zoo, montane Bothrops were maintained in the Cool Room, an air-conditioned section of the reptile and amphibian building. During the winter, the average temperature was 18°C, while during the summer, the temperature fluctuated between 21-25°C. Basking sites were available at all times; however, the arboreal montane Bothrops in the Cool Room used basking sites infrequently or not at all, while the terrestrial montane Bothrops routinely basked, particularly while gravid. We provided basking sites for females at all times (Murphy, 1982), although this allowed them the opportunity to bask at night, an opportunity which may not be available in the wild. In fact, the gravid female B. undulatus was observed routinely practicing voluntary hypothermia. While voluntary hypothermia is a behavior normally associated with lizards (Firth and Turner, 1982), the hypothesis that it prompts a lizard to seek shelter at the end of the day (before the temperature falls before a critical level) might explain why a montane snake would exhibit the same behavior.

We feel ambient temperatures above 20°C are too warm for many species of montane Bothrops. The average yearly temperature in the cloud forests of southern Mexico and Central America between 1000-2000 meters in elevation (roughly the altitudinal range of the species discussed) is between

15-20°C (Campbell, 1983). One indication of thermal stress may be a change in feeding habits; the zoo's B. n. aurifer and B. n. rowleyi fed poorly during the summer, when the Cool Room was 21-25°C, but as the Cool Room's ambient temperature began dropping in the fall and approached 18°C, they began feeding more routinely. In addition, too high an ambient temperature may inhibit reproduction. Prior to the construction of the Cool Room, the B. undulatus were maintained at an ambient temperature of 25-30°C. It was not until they were moved into the Cool Room (30 March 1979) that we began observing reproductive behavior with regularity.

In addition, the senior author maintains specimens of the Costa Rican palm viper B. lateralis in his private collection, a species which ranges from 850-1980 meters in elevation (Scott, 1969). During the winter, they were maintained at 12°C, with occasional drops in temperature to 10°C. All the specimens fed at these temperatures, and the only specimen observed routinely basking was a sub-adult male. One adult female was never observed basking, even following feeding at 10°C.

In the wild, the montane Bothrops receive a greater daily temperature fluctuation during the dry season because of lowered humidity and vegetation loss in their habitat. During the rainy season, the daily temperature is more constant. We feel an annual cycle of daily temperature fluctuations and decreased humidity followed by a more constant temperature and increased humidity is essential for maintaining and reproducing montane Bothrops.

HUMIDITY CYCLES

Humidity cycles may be of benefit in attempts to reproduce montane Bothrops. Fitch (1980) reported that most species of tropical reptiles that experience a wet/dry cycle concentrate reproduction during the wettest parts of the year, with reproduction declining or ceasing during the dry season(s). Southern Mexico has a defined wet/dry cycle (Campbell, 1983), and the cloud forests of Central America also vary in annual rainfall, as Campbell (1983) observed: "A little appreciated

fact is that all middle American cloud forests are seasonal and subject to considerable fluctuations in climate." As previously mentioned, a reduction in rainfall causes reduced temperatures.

The rainy season in southern Mexico is from May to October (Campbell, 1983). In central America, the Atlantic slope receives most of its rainfall in December and January, with some rainfall throughout the year. The Pacific slope, however, receives most of its rainfall from April/May to October/November, and has a pronounced dry season from December to March (Coen, 1983). At the Houston Zoo, it was not until 1983 that humidity cycles were instituted in an attempt to reproduce the B. n. aurifer. While we felt the temperatures in the Cool Room were adequate, and we did observe courtship/copulation on various dates from 1979-1982, the female B. n. aurifer did not become gravid until after we instituted humidity cycles. Unfortunately, one female died while gravid, but another gave birth to six neonates.

Although the B. n. rowleyi, B. undulatus, and B. n. occiduus all reproduced without being "rained" on, there is a winter/summer fluctuation in ambient humidity in the Cool Room from ca. 40% to ca. 80%, respectively. We feel that a seasonal fluctuation in ambient humidity may be important to a reproductive program for montane Bothrops.

PHOTOPERIOD/LIGHT QUALITY

Although gradually increased and decreased day lengths have been shown to affect some lizards' reproductive cycles, no effect has been shown in snakes (Duvall et al., 1982). However, maintaining constant photoperiods (i.e. the same light/dark cycle each 24th period) may be important for all reptiles, including montane Bothrops.

Tamarkin, et al. (1985) reported that the pineal body of mammals produces melatonin and serotonin (two enzymes that act on various parts of the brain, including the pituitary) on a day/night cycle, and that the presence of each acts to regulate reproduction in seasonally reproductive mammals. A disrupted photoperiod (brief exposure to light after darkness) alters the

melatonin/serotonin cycle in the species of mammals tested.

Because it is possible the pineal body of snakes responds to light in the same manner as the pineal body of mammals, disrupted or irregular photoperiods may have a deleterious affect on the reproductive cycle of Anolis carolinensis. Also, Duvall et al. (1982) cited several studies (Levey, 1973; Packard and Packard, 1977; Firth et al., 1979) that showed disruptions in the normal photoperiod and/or injections of melatonin affected the reproductive cycle of some lizards. Because the pineal body may be sensitive to disrupted photoperiods, timers should be used to maintain constant photoperiods.

When intensity and specific wavelength(s) of light act on the brain to signal the pineal body of mammals to produce melatonin and serotonin are not discussed by Tamarkin et al., (1985); however, Licht (1969) determined the light intensity threshold for photosexual response in Anolis carolinensis is between 0.5 and 12 foot candles, with red light (600-700nm) more effective than green light (500-600nm) for photosexual response; the least effective wavelength was blue light (400-500nm).

While it may seem speculative to examine the mammalian response to light, and then suggest reptiles (specifically snakes) share the same response, until research shows that snakes have no circadian melatonin/serotonin cycle, we feel it may be beneficial to provide montane Bothrops with full spectrum lighting (Laszlo, 1969) at a constant photoperiod.

FEEDING

With the exception of the zoo's adult female B. n. rowleyi, which was received as a wild-collected juvenile, all the B. n. rowleyi and B. n. aurifer received at the zoo were recently wild-collected adults; all were prompted to eat mice or two week old rats. The wild-collected juvenile B. n. rowleyi fed readily on Anolis, and after five months in captivity, began feeding on small mice. The B. n. rowleyi and most of the B. undulatus born at the zoo fed on pink mice. However, in most instances, we had to heat the pink mice in hot water (ca. 55^{o}C) above their normal body temperature before

the neonates would accept them. Since we began this technique, we have not had to scent food items as described by Campden-Main and Campden-Main (1982) or offer lizards or frogs as food as described by Murphy (1982). The adult B. undulatus and B. n. occiduus were received at the zoo as captive-born juveniles or adults already feeding on mice; the B. n. occiduus born at the zoo fed on pink or furred mice that did not have to be heated as previously described.

Feeding adult and neonate montane Bothrops (and Bothrops species in general) is greatly facilitated by tapping the posterior third of the body (in adults) or the tail (in neonates) with the food item until is is seized. If a specimen drops the food item after seizing it, lightly shaking the food item to simulate the struggle of a prey item sometimes causes the specimen to increase the pressure of its bite and subsequently eat. Also, a bitten and released food item will often be eaten if the specimen is left undisturbed.

The feeding response elicited when the body and/or tail of montane and other species of Bothrops is tapped with a food item may be the same response that causes cannibalism in some species, including B. n. nummifer, B. n. occiduus, B. schlegeli, B. undulatus, and B. n. nigroviridis. Because one specimen crawling over another may elicit a feeding response, most of the zoo's and all of the senior author's Bothrops are housed separately, except during reproductive efforts.

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Table 1. Courtship/Copulation Observed in Montane Bothrops at the Houston Zoo.

	Species											
	Bothrops n. rowleyi	Bothrops n. aurifer	Bothrops undulatus	Bothrops n. occiduus
January		8,23 January 1980	11,31 January 1981	
February		2 February 1982		
March		14 March 1982		3 March 1982
April				
May		12 May 1981	12 May 1981	
June		23 June 1982 1-14 June 1985	30 June 1983	
July	25 July 1983		27 July 1982 19 July 1983	8 July 1984
August		10 August 1981	10 August 1981	
September	5 September 1983		1,6 September 1982	5 September 1983
October	25,30 October 1984	21,22 October 1981		8 October 1981
November				17 November 1982
December		11 December 1979		5 December 1983

Table 2. Dates of Parturition in Montane Bothrops at the Houston Zoo.

Species	Dates of Parturition
Bothrops n. rowleyi	17 July 1984 (one live, one stillborn neonate, four infertile egg masses)
	25 July 1985 (eight infertile egg masses)
Bothrops n. aurifer	11 August 1985 (two stillborn neonates, one infertile egg mass); on
	28 August 1985, the same female produced four live neonates
Bothrops undulatus*	15 January 1979 (eight infertile egg masses)
	19 April 1980 (seven infertile egg masses)
	7, 8 February 1982 (one live neonate, eleven infertile egg masses)
	10 May 1983 (eleven live neonates)
	15 February 1984 (ten live neonates)
	25 June 1985 (thirteen live neonates)
Bothrops n. occiduus	4, 8, 13 October 1981 (unrecorded number of infertile egg masses)
	24 April 1983 (twenty-five live neonates)

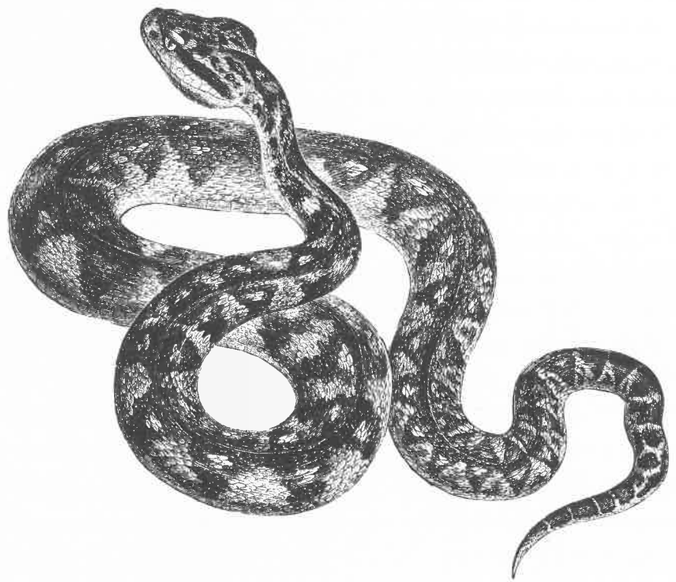
*Although it was not recorded which female passed infertile egg masses in 1979 and 1980, all the live and stillborn neonates were produced by one female.

Table 3. Dates of Courtship/Copulation/Parturition Reported in the Literature.

Species	Date of Activity
Bothrops n. aurifer	25 May[1], 17 June[1], 16 August[1], 13 December[1], (courtship, copulation); 18 March[1], 11 May[1] (parturition)
Bothrops undulatus	25 July[1] (courtship), January[2], February[2], 20 April[1], 25 July[1], 29 August[1], 4 October[1], December[2] (courtship/copulation); June[1] (captive parturition in gravid wild-collected females)
Bothrops n. occiduus	8 October[1] (courtship), 7 January[1] (copulation); 23 January[1] (parturition)

[1]Murphy, J.B. and L.A. Mitchell, 1984.

[2]Laszlo, J., 1984.



HYBRIDIZATION OF SNAKES: THE CURRENT STATUS

Richard Ross, M.D., M.P.H.

In 1978, reptile captive breeding was in its infancy. Few private collectors or zoological facilities could claim to be consistent breeders of any species of reptiles. The breeding of Burmese pythons, or of common boas, for example, was considered a major accomplishment. Incubation of python eggs was considered such a mystery that artificial incubation was felt by many to be impossible. Within a few years, this situation had changed dramatically. Many boid and colubrid species were bred regularly. Some breeders of colubrids and boids had achieved the status of "formula breeding" for some species. Pythons of the molurus group were being bred by hobbyists with little experience in herpetology. Other species of snakes which had been considered rare in collections became routinely available. Prices dropped for many species; newborn Burmese pythons, which and once sold for $75, were offered at $20 in quantity, and large adults were literally given away, having become nearly worthless.

Early in this period, commercial breeders of reptiles had been flourishing. The market for common species of boids and colubrids was not yet fully saturated, and the more unusual species still commanded good prices. However, this situation did not last. In particular, colubrids, which are less difficult to breed and reach sexual maturity at younger ages than boids, were becoming routinely available. The falling prices, the quest for a new market product, plus the incentive to produce offspring in order to make commercial herpetology fruitful produced a new phenomenon: the intentionally produced hybrid reptile.

Hybrid reptiles, as well as reptiles with aberrant colors and patterns, were initially produced primarily by accident or acquired directly from the wild. Communal caging of molurus pythons or colubrids, for example, occasionally resulted in accidental matings which resulted in hybrid young being produced. The aberrant wild specimens which were occasionally found or imported were avidly sought after by breeders. Initially, these

hybrids were no more than curiosities. Eventually, however, private breeders discovered that there was a commercial market for such hybrids. They often were reasonably attractive, and could satisfy the needs of amateur herpetologists who could not afford expensive reptiles. Such specimens appealed to collectors who were attracted to morphological characteristics rather than genetic soundness. Eventually, in order to take advantage of the novelty of these newly available animals, many breeders began intentionally producing hybrids and other genetic anomalies. Colubrid breeders interbred various tri-color Lampropeltis and Elaphe, and produced a bewildering rainbow array of hybrid snakes, taking great pride in their ability to produce different colors, band widths, and other morphological characters. Breeders of pythons interbred the Indian, Burmese, and Sri Lankan forms producing half-, quarter-, and even eight-bred specimens within the species.

Initially, many breeders attempted to keep careful records of their breeding results. However, as could have been readily predicted, such records became lost as the snakes changed hands again and again. For pecuniary reasons, such snakes could be represented as containing genes of various species and subspecies. Furthermore, legal implications of owning Indian pythons caused many specimens of the molurus group to be represented as pure molurus molurus for the purpose of intrastate sales, or molurus/bivittatus crosses for the purposes of interstate commerce. Some species and subspecies of colubrids protected by state legislation could easily be hybridized with non-protected species and subspecies, making their true identity difficult to determine. Needless to say, such hybrids acquired genetic anonymity, eventually being represented as whatever the current owner felt would make the specimen most valuable or marketable.

Currently, the situation regarding the hybridization of and the production of aberrant colors in reptiles has reached a state of chaos. The molurus group of pythons is so badly hybridized that most zoos and concerned private breeders will no longer

accept specimens of molurus molurus under any circumstances, unless they are still in the hands of the original importer or purchaser, a rather unlikely situation given the current protected status of molurus molurus. The situation with colubrids has not yet reached this stage, but will certainly do so in the next few years. Large numbers of hybrid colubrids are being produced and sold in the United States every year. As wild specimens become more difficult to obtain, there is a strong financial incentive to breed whatever specimens are available with the hope of producing young that can either be passed off as specific species or subspecies, or that can simply be sold to an amateur collector as an inexpensive pet store item. Regardless of claims made by various breeders, there is no way of determining the taxonomic status of hybrid snakes on the basis of scalation or color. However, molecular techniques could be used for this purpose.

Special problems exist with the production, purchase, and sale of aberrant animals. For instance, snakes that are heterozygous for albinism are indistinguishable from normally colored homozygous specimens. Thus, there is always the potential for inadvertent mix-ups or worse, the intentional misrepresentation regarding the genetic composition of such specimens. Also, the practice of inbreeding (between siblings and/or parents) to produce such aberrant specimens as albinos, "snow snakes", melanistic animals, etc., is not without risk, as evidenced by the albino rattlesnakes with reverse scalation produced at the Dallas Zoo. It is an error to assume that any genetically aberrant animal is fertile. Also, problems may occur during embryonic development that are genetically related. In 1984, a highly competent herpetologist bred two albino Burmese pythons that produced a large clutch of eggs. In spite of proper egg incubation technique, every egg eventually spoiled.

Further evidence of the danger of inbreeding can be seen when the problems plaguing inbred dogs are examined; among them are hip dysplasias, deafness, and blood disorders. Such problems are so widespread in dogs that breeders frequently import dogs

from Europe to avoid accidental inbreeding.

The final outcome of this sad trend is the unnatural alteration of the genetic composition of many reptile taxa. For those species which have become increasingly threatened in the wild, survival as species may depend on the avoidance of inbreeding and hybridization in captive populations. Many of these species reproduce readily in captivity; within a few generations, their numbers in the wild may be surpassed by the numbers of hybrids in captivity. With the current rate of destruction of rainforest and other habitats, who can doubt that it is only a question of time until many reptile species now common become scarce in the wild.

What can and should be done about this situation? Certainly, conscientious and responsible herpetologists should adopt a basic position regarding hybridization and inbreeding of reptiles. Intentional hybridization should be studiously avoided; accidental hybridization should be prevented wherever possible. Inbreeding should be avoided unless absolutely necessary for a species preservation. Hybrid specimens should not be knowingly purchased, and should not be passed on to other herpetologists without clearly indicating that they are hybrids.

It is only by scrupulous attention to these principles that we will be able to avoid the unnatural selection produced by inbreeding and hybridization as well as the expression of lethal genes produced by inbreeding. Future survival for many species of reptiles may depend on captive propagation; if we cannot find in ourselves the scientific ethics necessary to avoid the temptation to hybridize our specimens, the herpetologists of future generations will be the poorer for our short-sightedness and greed, and they will never be able to undo the damage that we may cause to captive populations.

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DISINFECTANTS:
THEIR SELECTION AND USE
IN MODERN HERPETOLOGICAL HUSBANDRY

Scott J. Michaels

I. ABSTRACT

A paucity of published information exists regarding the use and safety of chemical disinfectants in reptile and amphibian husbandry. The available information is widely scattered, at times contradictory, and highly anecdotal in nature. In the course of researching this topic, an information request was sent to 45 U.S. and Canadian public herptile collections. Information obtained on disinfectants used, protocols for aquatic and outdoor exhibits, toxicoses, control of disease outbreaks, and sanitation of rodent colonies was reviewed and summarized. The paper briefly reviews the spectrum of known infectious/parasitic pathogens of herptiles, including bacteria, viruses, fungi, protozoa, algae, helminths, and arachnids. The problem of contamination of disinfectant solutions is discussed. The paper concludes by reviewing the many disinfectants available to herpetologists, with emphasis on spectrum of pathogen sensitivity, use as antiseptics, and toxicity. Specific emphasis is placed on the more frequently encountered etiologies of herptile disease, particularly gram-negative bacteria.

II. INTRODUCTION

Cleaning and disinfection are components of sanitation and hygiene that are an essential part of successful reptile and amphibian husbandry. Although the effects of disinfection procedures are usually inconspicuous, there is little need to emphasize the importance of maintaining relatively pathogen-free environments for our animals. Kauffeld (1969) noted, "I am convinced that certain outbreaks of disease from time to time, in our collection of snakes at the Staten Island Zoo, have been limited and restricted by our sanitary methods..." A major percentage of captive herptile disease involves infectious agents. Therefore, the practice of good disinfection techniques is important for maintaining the health of our captive charges and to protect ourselves. Integral to the function of disinfection in herptile husbandry is the use of chemical disinfectants.

Many different types of chemical disinfectants are available on the market and used in herptile husbandry. However, use of these compounds is a double-edged sword. Proper and safe use of the various agents is multi-faceted. Many factors need to be considered when using disinfectants, including spectrum of

activity, chemical compatibilities, toxicity, thing being disinfected, etc. One problem that we as herpetologists face is that relatively little published information exists regarding the specific application of disinfectants in reptile and amphibian husbandry. What little information is available is widely scattered, sometimes contradictory, and highly anecdotal in nature (i.e., not based on controlled studies). A need for review of information on the use of chemical disinfectants in herptile husbandry exists. This paper attempts to bring together available information concerning the use of these compounds in herpetological husbandry. Used properly, disinfectants are valuable and safe agents.

III. METHODS

An information request in the form of a questionnaire was sent to 45 U.S. and Canadian public herptile collections seeking information on use of chemical disinfectants in their respective collections. Data from the survey was reviewed and summarized. In addition, information regarding disinfectant-related toxicoses was requested in the form of notes or ads in three regional herp society monthly newsletters.

A general literature search was conducted addressing all aspects of chemical disinfectants in herpetological husbandry. With respect to the question of disinfectant-associated toxicity, computer literature searches were conducted utilizing Medline^{R} and Toxline^{R} databases.

IV. SURVEY RESULTS

Of 45 questionnaires, 26 (58%) were answered and returned. The following information was determined:

A. Types of disinfectants used. Several major classes of disinfectants were represented, with chlorine (sodium hypochlorite, etc.) and quaternary ammonium compounds (primarily Benzalkonium chloride-related "quats"; 10 brand names given) used most frequently, both 65.4%. Iodophors 30.8% (6 brands given), chlorhexidine 19.2% (Nolvasan^{R}), phenolics 11.5% (One-stroke Environ^{R}; TRL-132^{R}), hexachlorophene 3.8% (Septisol^{R}), and dyes 3.8% were also reported. Of those

reporting the exclusive use of only one disinfectant, the following was reported: "quats" 19.2%, sodium hypochlorite 15.4%, and iodophors 7.7%. Four respondents reported using "quats" only in reptile areas. With regards to two respondents reporting use of One-stroke Environ^{R}, the following was noted:

1. "used only to scrub floors or areas that will not be contacted by animals, particularly aquatic."
2. "used for disinfection of tanks where serious disease problems have been diagnosed, e.g. TB."

B. Aquatic Reptile Units. Six respondents reported information on disinfection of aquatic reptile units. One zoo used only water, another employed Clorox^{R} only rarely, and four used "quats". Several reported use of chlorine compounds (sodium- and calcium hypochlorite) to control algae growth, but in most cases it was not clear whether they were used in indoor aquatic units and/or outdoor exhibit pools.

C. Amphibian Units. Fifteen respondents discussed disinfection of amphibian units. Eight (53%) reported the units disinfected only when broken down or, as a few respondents put it, a "disease problem existed." Of these, one reported only using dilute soap solution and hot water rinse when tanks broke down. In addition:

1. Three reported exclusive use of iodophors.
2. Three reported Clorox^{R} was used, although generally avoided.
3. Five reported "quats" were used, with the comments "when broken down", "very sparingly", "at 0.0087%", "almost exclusively used now due to incident of Betadine^{R} toxicity" (respondent maintains large amphibian collection).

Individual respondents reported:

1. tanks disinfected with 1% chlorine or "quat", rinsed well and air-dried (frequency not given).
2. use of hexachlorophene in the past [see Jordan (1969)].

3. use of rock salt (NaCl) as abrasive/"detergent", followed by thorough rinse.
4. tadpole containers never disinfected between water changes barring disease problems.
5. Roccal-D (a "quat") used daily to clean floors in all sections BUT the amphibians.
6. some aquatic displays (e.g. Axolotl) have U.V. sterilizers installed after outside filtration.

D. Outdoor Units. Seven respondents maintain outdoor exhibits. Four reported these units are never disinfected. Two reported use of HTH^R pool product (calcium hypochlorite), and one used "quats".

E. Aldabra/Galapagos Tortoise Enclosures. Seven respondents reported maintaining giant tortoise enclosures, as follows:

1. Three reported use of Clorox^R, with comments "used rarely due to fumes and irritation to lungs" and "used only because 'quat' too expensive."
2. Two reported use of "quats".
3. One reported dirt enclosures merely raked clean.
4. One reported soil changed in one exhibit (reason not given).

F. Toxicity. Eight (30.8%) reported information on disinfectant-associated toxicity, with two respondents reporting 2 and 3 separate incidents each. Details will be discussed in section on "Special Situations: Aquatic and Outdoor Units", but briefly the incidence was as follows:

1. Seven cases, quaternary ammonium compounds:
   a. 4 cases, death/skin irritation in frogs.
   b. 2 cases, frothing/gaping in snakes, death in one specimen.
   c. 1 case, death in Yellow-foot tortoise, severe lung damage. ("Accidentally fell in tub of 'quat'." Death due to aspiration of disinfectant solution.)
2. One case, sodium hypochlorite, "discomfort in

turtles exposed to excess concentrations".
3. One case, iodophor (Betadine^R)-associated death in 12 dendrobatid frogs.
4. One case, phenolic (One-stroke Environ^R)-associated death in frogs.
5. One case, chlorhexidine-associated ocular toxicity in chelonians.

G. Reptile Soaks. Three respondents indicated the use of reptile "soaks" as follows:

1. all new reptiles receive 15-20 minute soak in 0.05% iodophor, and it was mentioned "higher concentrations may be caustic to skin of some specimens" (details not given).
2. reptiles placed in holding barrel containing 0.024% "quat" during cage cleaning.
3. occasionally add "very weak solution of iodophor" to turtle tanks when animal exhibiting some shell rot (usually new import or fight injury).

H. Disease Outbreaks. Concerning the control of known or suspected outbreaks/cases of infectious disease, the following was reported:

1. Amebiasis (Entamoeba invadens):
   a. Three reported use of Clorox^R.
   b. Three reported use of "quats", with one also using chlorhexidine.
   c. One reported, occasional case (single animals); normal cleaning routine with iodophor, except repeated 2x over several days.
2. Misc. reports from individual respondents:
   a. Cryptosporosis (coccidia protozoan) in snakes; exhibit cleaned with 1) phenolic compound, then 2) steam, then 3) water, then 4) "quat", then 5) air-dried before reuse.
   b. Red Leg (Aeromonas) in frogs: temporary quarantine enclosure disinfected daily with iodophor.

c. "depending on disease outbreak:" phenolic or "quat", details not given.

d. When animal dies, if suspect contagious agent: cage disinfected with 1) iodophor, then 2) "quat", then 3) iodophor again.

I. Rodent Colonies. Nineteen reported on rodent colonies/holding cages, as follows:

1. Four reported on disinfectant used when cages cleaned.
2. Eleven used "quats" when cages cleaned.
3. Three used Clorox^R when cages cleaned.
4. One used iodophor when cages cleaned.
5. One used Clorox^R for bottles, but "quats" for cage cleaning.

J. Miscellaneous comments from individual respondents:

1. Snake bags treated with iodophor then soaked in bleach.
2. Three negative fecals before animals cleared out of quarantine (see p. 213, E). Most commonly seen parasites "strongyles, coccidia, nematodes" (note strongyles are nematodes); turn up mouse "nematodes" (ova?) passing through snakes fed fresh-killed mice.
3. Chlorhexidine used as cage, tool, and hand disinfectant only for suspected viral disease.
4. Wescodyne^R (an iodophor) causes slight irritation to person using it.
5. Snake hooks kept in "quat" when not in use; mentioned hearing "rodents kept on PCB (polychlorinated biphenyl)-treated wood shavings killing snakes due to PCB buildup;" suspected death/skin irritation possibly due to insecticide residues on plants used shortly after fumigation in greenhouse.

V. REVIEW OF INFECTIOUS/PARASITIC PATHOGENS OF HERPTILES

A brief review of infectious/parasitic herptile pathogens is important subsequent to the discussions on anti-microbial

spectrum of activity of chemical disinfectants. This review is not meant to be complete and all-encompassing. Rather, the purpose here is to illustrate the broad range of herptile pathogens with important points relating to their susceptibility to chemical disinfection. Where reference is made to "major" disinfectants, this includes: Halogen-based agents, quaternary ammonium compounds, phenolics, and chlorhexidine. Of particular interest are recently reported viral etiologies of herp disease (Heldstab & Bestetti, 1984), as some of these show a unique and broad resistance to many disinfectants.

A. Bacteria. Coming to be known as the most common and important group of infectious pathogens in all classes of herps are gram-negative (G^-) bacteria (Nace, 1974; Marcus, 1981; Hoff et al., 1984).

1. Pseudomonas sp., Aeromonas. Ubiquitous in moist environment. Considered normal flora but opportunistic pathogens in many herps and rodents, presenting in varied forms of disease (Marcus, 1981; Frye, 1981; Cooper & Jackson, 1981). Many authors mention Pseudomonas species being resistant to disinfectants. See discussion, page 216.

2. Salmonella/Arizona. Very important zoonoses. Often carried asymptomatically, especially snakes but also lizards and turtles (Marcus, 1981; Cambre et al., 1980; Cooper & Jackson, 1981). Variable degrees of susceptibility to disinfectants, but all tested species of these bacteria have been shown to be sensitive to all major types of disinfectants (Block, 1983).

3. Mycobacteria. Well-established etiologies of herp disease (Hoff et al., 1984). Resistant to many disinfectants, such as "quats" (Block, 1983).

4. Clostridia. Spore-forming organisms! Known to cause disease in chelonians (Murphy and Collins, 1983) and iguanas (Marcus, 1981). Clostridial species are resistant to most disinfectants. Require long contact time (over 15 minutes preferably) using halogen-based agent at higher "use-dilution" concentrations. Chlorine dioxide (ABQ^R) works well.

5. Staphylococcus/Streptococcus. Increasing importance as amphibian pathogens (Amborski et al., 1983). Well established pathogens in rodents (UFAW, 1972).

6. All other species of bacteria. Too many to list. One example: Citrobacter freundii, of "SCUD" in chelonians (Frye, 1981). The major point here is that while most of these bacteria have not actually been tested to determine their sensitivities to disinfectants, most probably are relatively susceptible to the major agents available.

B. Viruses. Only those known to be pathogenic in herptiles are mentioned.

1. Amphibian Viruses. As a group, Tadpole Edema Virus (disease in embryo/larval Rana sp., Lucke Herpes Virus (tumors in R. pipiens), Lymphosarcoma Virus (?) of Xenopus laevis (Nace, 1974.)

2. Herpes. "Gray-patch" in Chelonia mydas (Revell et al., 1975). Pathology in Clemmys marmorata (Frye, 1981) and Chrysemes picta (Cox et al., 1980). Iguana Herpes Virus, with evidence of latent carriers (like in mammals) (Cooper & Jackson, 1981). Elapid Venom Herpes Virus, associated with decreased venom quality in Naja n. kaouthia (Simpson et al., 1979). Herpes virus associated with mixed virus infection in Elaphe longissima (Heldstab & Bestetti, 1984). See Table 1. Herpes viruses are relatively susceptible to all major disinfectants (Klein & Deforest, 1983).

3. Irido-virus. Necrotizing hepatitis, enteritis, and splenitis in a Testudo hermanni (Helstab & Bestetti, 1982).

4. Oncorna-viruses. Sarcomas in Elaphe guttata, Lampropeltis g. californiae, and Vipera r. russelli (Clark & Lunger, 1981).

5. Paramyxoviruses. Respiratory and DNS epizootics in viperid snakes (Folsch & Leloup, 1976; Jacobson et al., 1980, 1981). Bitis, Bothrops, Crotalus, Trimeresurus, and Vipera affected. In no case were colubrids, elapids, or boids affected in any of the involved collections. However, Jacobson et al. (1981) performed serologic studies and found high antibody

titers in many non-viperid snakes with by far the highest titers in a Python reticulatus, although it and they were clinically unaffected. These authors suggested that non-viperid snakes serve as asymptomatic reservoirs, and that viperid snakes are "exquisitely" sensitive abnormal hosts. This may be, but Barker and Goltz (1980) mention "several pythons" that had similar clinical disease and histopathology possibly due to a paramyxovirus.

Point. All of the above viruses are susceptible to all major chemical disinfectants. These viruses possess a "lipid envelope" which surrounds the nucleic acid and protein portion of the virus. Because of this lipid coat, the viruses are considered "lipophilic". Many disinfectants destroy this lipid coat and thereby neutralize the infectivity of the virus. In contrast, the following recently reported viral families of reptile disease show variable degrees of resistance to many commonly used disinfectants, as described subsequently.

5. Parvoviruses. Recently found to cause gastrointestinal disease in Elaphe quatuorlineata and E. longissima (Heldstab & Bestetti, 1984). Not irrelevant is the fact that this family of virus was just recently (1978) discovered and now considered very important in the domestic canid worldwide. See Table 1.

6. Picornaviruses. Recent GI disease in a Boa constrictor sp. and E. longissima (Heldstab & Bestetti, 1984). See Table 1.

These last two types of viruses are "naked", in that they lack a lipid envelope, and are therefore "hydrophilic" in chemical nature. A lipid coat is not a requirement for their infectivity (Davis et al., 1980). Due to their morphology, they are uniquely resistant to all disinfectants except higher "use-dilution" concentrations of halogen-based disinfectants (Klein & Deforest, 1983). Sodium hypochlorite (i.e. Clorox^{R}) would be the best agent to use in cage/tool disinfection.

7. Adenoviruses. Associated with GI disease in 4 snakes: Elaphe quatuorlineata, E. longissima, Boa

constrictor sp., and Bitis gabonica (Heldstab & Bestetti, 1984). Note that in the first 3 species listed, these were mixed infections of 2, 4, and 2 types of viruses, respectively. See Table 1.

In addition, Jacobson et al. (1984) found two young Crocodylus niloticus infected with an adeno-like virus.

Adenoviruses are considered to be at an intermediate level of sensitivity to the major disinfectants (Klein & Deforest, 1983). Again, Clorox^R would be a good choice of disinfectants.

8. Papovavirus. Associated with papillomas in Lacerta viridis (Cooper & Jackson, 1981). Other papovaviruses have been shown to be resistant to the phenolic compounds in Lysol^R (Klein & Deforest, 1983).

Point. Epidemiology of viruses associated with herp disease is still in the embryo stage, limited by economics, manpower, and laboratory techniques required to diagnose the agents. Considering some of the herp species involved and their popularity among collectors, the distribution of some of these viruses is probably very wide.

C. Fungi. Numerous fungal species, all herptiles affected (Cooper & Jackson, 1981). Fungi show variable degrees of resistance to disinfectant compounds. The only known herp fungal pathogen to be tested for disinfectant sensitivity, Candida albicans, is reportedly very sensitive to gentian violet (Oster & Woodside, 1983). A plethora of non-disinfectant drugs are available for treatment of fungal infections, but they are beyond the scope of this paper.

Table 1. Viruses associated with gastrointestinal disease in snakes. Parvo-, Picorna-, and Adeno-viruses have been shown to exhibit varying degrees of resistance to disinfectants, as described in the text. Modified from Heldstab & Bestetti, 1984.

	VIRUS			
	Herpes	Parvo	Picorna	Adeno
Elaphe longissima quatuorlineata	X -	X X	- X	X X
Boa constrictor sp.	-	-	X	X
Bitis gabonica sp.	-	-	-	X

D. Protozoa. Many different types of protozoa known to infect all herps (Marcus, 1981; Nace, 1972). Of particular importance are those protozoa known to encyst. Entamoeba invadens is a well-established pathogen of snakes and carnivorous lizards (Marcus, 1981). However, there are recent reports of amebiasis in chelonians (Geochelone carbonaria [Jacobson et al., 1983] and others [Marcus, 1981]), and amphibians (Valentine & Stoskopf, 1984). More often however, chelonians at least are asymptomatic carriers. Coccidia species cause disease in most orders of herptiles (Marcus, 1981).

Cysts of both of these types of protozoa are known to be resistant to many disinfectants (Block, 1983). Available information suggests that higher "use-dilution" concentrations of the halogen-based disinfectants are the best agents to use in environmental decontamination.

E. Metazoan/Helminths. Too numerous to list. All herps affected. Many helminth ova are resistant to many disinfectants (Block, 1983; Soulsby, 1982). Animals can be parasitized and have negative fecal exams (Soulsby, 1982).

F. Algae. A problem in some aquatic chelonians (Murphy & Collins, 1983). Also need to consider indirect algal effects on animals, such as that through nitrates. A moderate amount of algal growth will help reduce nitrate in water, but excessive growth leading to decomposition may result in increased nitrate levels. Axolotls have been shown to be sensitive to nitrates (UFAW, 1972).

VI. GENERAL PRINCIPLES OF DISINFECTION

A. Removal of organic matter. Some disinfectants, most notably chlorine-based agents and "quats", have reduced germicidal efficacy in the presence of organic matter. With these agents in particular, a prior cleaning with a detergent is advisable.

B. Vehicle for disinfectant dilution. For aqueous solutions, distilled water is best. Note cases of Pseudomonas contamination have been traced to resin-deionized water (Block, 1983). Alcohols (i.e. isopropyl) are useful synergists to other

disinfectants (note: only in lower concentrations when used with phenolic compounds), and are valuable for preparing solutions. Perhaps consider its use with "quats" in known gram-negative bacterial problems.

For future reference, in controlling known Picorna-virus problems, hard water should preferably be avoided as magnesium ions are known to stabilize polioviruses, a subclass of picornavirus (Davis et al., 1980).

C. Temperature. Hot solutions are always more effective. Moist heat under pressure (i.e., autoclave conditions) is an obviously reliable method of sterilization. A practical modification of this is to use boiling water to disinfect such objects as cork bark, etc.

D. Ultra-violet Light. Wherever possible, after disinfection, bake the object in the sun. This is one of the major advantages of outdoor exhibits. Most useful for objects not suitable for chemical disinfection, such as cork bark and porous substrates for amphibians.

E. Contact Time. The longer the contact time, the more efficacious a solution of disinfectant will be. A minimum 10-15 minutes is preferable, especially for known contaminated objects.

F. Storing Snake-hooks and Other Tools in Disinfectant Solutions. Probably a more common practice than borne out by my survey. A good practice as long as solutions are not contaminated by organic matter at all, and that solutions are changed relatively frequently (say every 10 days if there is any soiling of the solution).

To prevent corrosion of metal forceps and snake hooks that are stored in "quat" solutions (and others?), anti-rust tablets can be obtained at most pharmacies.

VII. SPECIAL SITUATIONS: AQUATIC AND OUTDOOR UNITS

A. Aquatic Units. Disinfecting aquatic amphibian setups without "breaking down" the whole unit is a most difficult task. Of the 15 survey respondents reporting maintenance of aquatic amphibian units, eight reported that units are disinfected only when broken down, or in two cases, a disease problem existed.

Unfortunately my survey failed to determine how the other people handled their disinfecting protocols.

Nace (1967), a widely-published expert on amphibians, suggested that when amphibian enclosures are attended to for cleaning, that a portion of the cage should be left unchanged. He paraphrased another author by noting, "The habit of 'sanitizing' everything . . . with gallons of highly scented disinfectants is . . . undesirable." Disregarding the overtones of emotionalism (very few disinfectants are "scented" per se), the point was made regarding the possibilities that frogs become "attached to specific surroundings" perhaps based on patterns of bacterial colonization.

Also of importance is the role of normal flora in stimulating the immune systems of animals. In other words, it is actually good to have a certain basal level of microorganisms present to continuously stimulate the immune systems, especially in captive animals. This applies to other herps as well, not just amphibians.

Point. The implication is that we are NOT trying to eliminate all microorganisms from our animals NOR their environments!! This is an important point!

Another factor of which to be aware, no matter what disinfecting protocols are used, is the susceptibility of amphibians to disinfectant toxicoses. Available evidence suggests most, if not all disinfectants can be highly toxic to amphibians. Details are covered in discussion of the individual agents.

B. Outdoor Units. If an animal is found to be shedding nematode ova in a dirt enclosure, soil should preferably be discarded and replaced. Fowler (1978) recommends Orthophenylphenol or formalin be used to soak the soil. Huber (1982) indicated that a 3-5% "emulsion" of Orthochlorophenol has demonstrated larvicidal and/or ovacidal activity against several classes of mammalian nematodes. Borax^{R} (sodium borate) (Soulsby, 1982) or Quicklime (calcium oxide) (Fowler, 1978) are sometimes used to treat areas contaminated by nematode ova.

Soulsby (1982) indicated soil could be eliminated of coccidin oocysts by the use of 1.25% sodium hypochlorite. The same solution should work for Entamoeba cysts.

VIII. THE CHEMICAL DISINFECTANTS

A. Introduction. Because of space limitations, this review will be limited to only the major aspects of chemical disinfectants. Lesser-used agents, such as chloramines, will be discussed only briefly. Major topics of importance in this discussion include antimicrobial spectrum of activity, contamination of disinfectant solutions, chemical compatibilities, antiseptic applications and toxicity.

Regarding the chemistry of these compounds, it would be difficult to discuss this aspect without going into details which would be tedious to the general herpetologist reader. Primarily that "chemistry" which appears on product labels will be mentioned.

Before discussing the disinfectants separately, a topic of major concern is CONTAMINATION OF DISINFECTANT SOLUTIONS. As previously mentioned, many authors point out instances of contamination of Benzalkonium Chloride (the major "quat" in commercial products) with Pseudomonas aeruginosa (Marcus, 1981; Jackson, 1981; Ross, 1984). Some strains of Pseudomonas cepacia (a herp pathogen) are known to be resistant to "quats" (Gilman et al., 1980). However, phenolics (i.e., Amphyl^R) (Elliott & Masters, 1977; Needham, 1978), iodophors (i.e., Betadine^R) (MMWR, 1980), hexachlorophene (i.e., Phisohex^R) (Harvey, 1980; Morton, 1983), and chlorhexidine (i.e., Nolvasan^R) (Harvey, 1980; Gardner, 1983; Morton, 1983) solutions have all been found at one time or another contaminated with a Pseudomonas specie! In most cases, contamination occurred in dilute solutions (at "use-dilutions"), prepared with contaminated water, or involved a particular strain of a bacterial specie. Regarding this last explanation, an example is useful. In contention with authors stating chlorhexidine is effective against Pseudomonas (Facts & Comparisons, 1985; Russell, 1972; Gardner, 1983) is the warning on the commercial

Nolvasan^R label indicating the compound is ineffective against Pseudomonas. One would have to question why the manufacturer, who is selling the product, would state this if it weren't true! Gardner (1983) states, "a chlorhexidine-resistant Pseudomonas, which has a reduced content of lipopolysaccharide (a cell wall constituent) compared with normal strains, may owe its resistance to decreased ability to adsorb the agent." Russell (1972) found that six strains of Ps. aeruginosa, all of which carried R-factor for antibiotic resistance, were susceptible to chlorhexidine. This is just one illustration of the disagreement within the field of disinfection. There is no disagreement that G^- bacteria generally show an increased resistance to disinfectants compared to G^+ bacteria, with Pseudomonas species being among the most resistant. Many species of G^+ bacteria also exhibit strains of varying susceptibility to disinfectants as well (Block, 1983). However, prepared freshly, and used at higher "use-dilution" concentrations, all of the above mentioned disinfectants (except hexachlorophene) are effective against Pseudomonas, Salmonella, and other G^- bacteria. Due to insufficient space, this point will not be mentioned again as the individual disinfectants are discussed, but should be kept in mind. Because G^- bacteria are such important pathogens in herptiles, it is advisable, when disinfecting cages and other inanimate objects, to use the compound at the most concentrated end of manufacturers' recommended "use-dilution" concentrations. As antiseptics, where appropriate, the preparation must always be made fresh from commercial concentrates.

Another topic of major concern among herpetologists is TOXICITY of disinfectants. For now it must be stated that only a few controlled toxicity studies have been performed with herptiles, all limited to a few species of amphibians (Kaplan & Light, 1955; Kaplan, 1962). The biotransformation (i.e., metabolism) of disinfectants in herptiles is an unexplored science. Available evidence shows all major classes of disinfectants to be highly toxic to amphibians (see individual

agents). In reptiles, the toxicity more closely parallels the toxicity in mammals as a group. This is a broad general statement, based on available facts.

B. Cleaning Agents--Detergents

1. Soaps. (salts of fatty acids, i.e., Ivory^R). Not disinfectants, but rather cleaning agents. Remove some bacteria by emulsification, but not reliable.

2. Anionic Surfactants. (ex., sodium dodecyl sulfate, sodium lauryl sulfate) or Acid-Anionic Surfactant combo's (ex., phosphoric acid/hypochlorous acid-alkylbenzene sulfonates): Generally are poor disinfectants (Block, 1983), but some exceptions. Weakly bacteriocidal, more effective against G^+ bacteria.

Detergents are useful cleaning agents, but not reliable disinfectants in herptile husbandry.

Major advantages:

a. Work well in presence of organic matter; useful to use prior to a more effective disinfectant (especially Clorox^R and other chlorine-based agents). Note these agents are incompatible with "quat" type disinfectants; traces of these detergents will inactivate quaternary ammonium compounds.

b. Must also consider adsorption of detergent compounds to porous materials (e.g., cork bark).

c. Relatively low toxicity (known in mammals). No information could be found regarding herps.

C. Acid Compounds

1. Boric Acid. Considered a weak disinfectant (Harvey, 1980).

2. Phosphoric Acid. Combined with some detergents.

3. Acetic Acid (Vinegar). A 5.0% solution will kill Pseudomonas (Harvey, 1980). More of historical use. Frye (1981) described its former use in the treatment of "mouth rot" in snakes by noting, "Pseudomonas sp. prefer an alkaline medium; when the oral cavity is flooded with a dilute vinegar solution, the pH drops markedly and the organism cannot flourish." Perhaps a useful backup agent.

4. Hydrochloric Acid (HCl). See chlorine compounds (page 220).

D. Halogen-Based Compounds

1. Chlorine Compounds

a. Sodium Hypochlorite (NaOCl; Clorox^R); Calcium Hypochlorite ($Ca(OCl)_2$; HTH^R). Economical, reliable, very broad-spectrum agents. NaOCl will inactivate all known herp pathogens. Fast bacteriocidal action. Higher concentrations (up to 2-3%) may be required for bacterial spores, protozoan cysts, "certain fungal spores" (i.e., Aspergillus), and hydrophilic viruses (i.e., Parvo) (Block, 1983). For the control of Dermatophilosis (due to an Actinomycete), Frye (1981) recommended disinfection with a 0.0525% (1:100) solution of NaOCl. For control of G^- bacteria, a similar solution can be used.

Notable incompatibilities include:

1) Reduced activity in the presence of organic matter and ammonia (not ammonium compounds!), therefore prior cleaning with detergent needed if heavy organic loads.

2) Alkaline pH: the chemical species "OCl^-" (found in alkaline pH's) is markedly less destructive to Entamoeba cysts (Block, 1983).

Notable compatibilities:

1) Evidence small amounts of iodine is synergistic with chlorine (Block, 1983). No specific recommendations can be given.

2) Anionic surfactants: see page 218.

3) Hard water: NaOCl works in the presence of hard water concentrations of magnesium and calcium.

Toxicity:

Biggest disadvantage of NaOCl is noxious fumes. Many survey respondents mentioned this. Although it does not leave poisonous residuals, solutions of hypochlorite are well known irritants of tissues. High concentrations are corrosive.

Kaplan (1962) using $Ca(OCl)_2$ showed that when Rana pipiens were exposed to concentrations of free chlorine in excess

of 4 ppm (0.0004%) for a period of 10 days, petecchial and ulcerative lesions occur. At 5 ppm, deaths began to occur at day 5 of exposure. He pointed out that lesions appear very similar to "red leg"! One must wonder how often the bacterial infection associated with red leg is really a secondary infection due to exposure to excess free chlorine (occasionally seen in municipal water supplies)!! Aeration, activated charcoal or sodium thiosulfate (less than 4 to 5 mg/liter concentration) will help to reduce chlorine levels in water (Nace, 1974).

Kauffeld (1969) noted that reptiles "seem to be highly resistant to chlorine compounds." Using hydrochloric acid, Black (1978) showed reducing the pH to 2.5 in drinking water supplied to snakes was effective in reducing Ps. aeruginosa counts in the water. The snakes in the study were 8-12 weeks old, randomly assigned to groups, and included 13 Elaphe g. guttata, 1 E. o. obsoleta, and 4 Lampropeltis G. niger. The author indicated "the activity or health of the snakes exposed to the treated water did not appear different than that of the snakes exposed to untreated water." The exposure period ran 51 days. Acidification of water supplied to rodents has been shown effective in controlling Pseudomonas aeruginosa (McDougall et al., 1967; McPherson, 1973).

b. Other Chlorine-Based Disinfectants

1) Chloramines (i.e., Halazone^{R}). Organic chlorides. Slow bacteriocidal action by slow release of chlorine and formation of HOCl (hypochlorous acid). Boterenbrood (1972) indicated that a 0.001% solution was effective for treating "cutaneous mycotic" infections in axolotls (see also Organo-mercurial compounds, p. 233).

2) Chlorine Dioxide (ABQ^{R}). Reliable chemical sterilant, will destroy all forms of microbes (Product literature, 1984; Orcutt et al., 1981). "Use-dilution" concentrations are easy to work with (minimal fumes) and minimally irritating to tissues. Rapidly replacing peracetic acid in the germ-free research animal industry (Orcutt et al., 1981).

2. Iodine Compounds

a. Tincture of Iodine (commercial products = 2 or 7%). Generally regarded as one of the most effective topical antiseptics available (note: see Xenodine^{R} below). Disadvantages with the 7% solution especially, are a delay in wound healing as well as being highly irritating.

b. Lugol's Solution (5% "free" iodine in water). Similar to tincture of iodine above. Marcus (1981) mentions its use in the treatment of shell rot in chelonians (see also copper compounds).

The following group of compounds, iodophors, are much more useful as antiseptics, and are useful in disinfection of inanimate objects.

c. Iodophors. Complexes of iodine with inert organic polymer carriers. Types:

1) Polyvinylpyrrolidone (Povidone) complex. Betadine^{R}, Isodine^{R}, generic equivalents.

2) Poloxamer complex. Prepodyne^{R}, Septodyne^{R}, Wescodyne^{R}, etc. Efficacy equal to povidone-iodine (Gottardi, 1983).

3) Polyhydroxydine complex. Xenodine^{R}. Efficacy is reportedly 3 times that of povidone-iodine (Tindall, 1983).

4) Others. i.e., Iosan^{R} = iodophor + phosphoric acid combo, used by one survey respondent.

Iodophors serve to increase the solubility of iodine, provide a "sustained-release" reservoir of iodine, and allow compatibility with the aforementioned detergents.

Iodine products have a similar spectrum of activity compared with chlorine compounds (i.e. work against hydrophilic viruses, etc.), but are poorer algicides (Gottardi, 1983). In a table of common disinfectants, Jackson (1981) notes that povidone-iodine is "100 times stronger than hypochlorites." From my readings, this appears to be a bit of an exaggeration. Iodophors do have numerous advantages over chlorine, however. As examples, they are:

--effective over a wider pH range.
--less affected by organic matter.
--less affected by very hard water.
--relatively odor-free.
--non-corrosive as antiseptics.
--available in many forms, i.e., solution, scrub, ointment, etc.

An area of confusion concerns the actual percentage of "free" iodine present at various dilutions of an iodophor. Gottardi (1983) contended that the percentage of complexed iodine is not constant at all concentrations. He argued that above 0.1%, the more concentrated an iodophor solution, the less free iodine (and therefore less disinfecting power) that existed. He stated a maximum free iodine concentration is reached with a 0.1% povidone-iodine solution. Facts and Comparisons (1985) states, "povidone-iodine liberates approximately 10.0% free iodine." On the product label of Betadine^{R} solution, it is indicated that 10.0% povidone-iodine yields 1% available iodine. Harvey (1980) reported that "a 10% solution contains 1% available iodine, but the free iodine concentration is less than 1 ppm," which is in agreement with Gottardi. This situation is illustrated in Figure 1.

As an antiseptic, Harvey (1980) states "when the hands are contaminated by G^{-} bacteria, povidone-iodine is a more effective scrubbing disinfectant than is aqueous chlorhexidine. It is not as effective as 1% tincture of iodine."

Two survey respondents indicated using iodophors as treatment/quarantine soaks for reptiles (see p.207). Without repeating that which has been said already, the 0.05% soak is very close to the optimum free iodine level described by Gottardi. As a quarantine soak, this is probably a good alternative to a solution of tetracycline (1 tsp/gal water) mentioned by Murphy (1978). One caution must be considered when using any iodine (or any disinfectant) as a reptile soak is to make sure the animal is well-hydrated prior to the disinfectant soak. If a thirsty reptile were to drink a large volume of

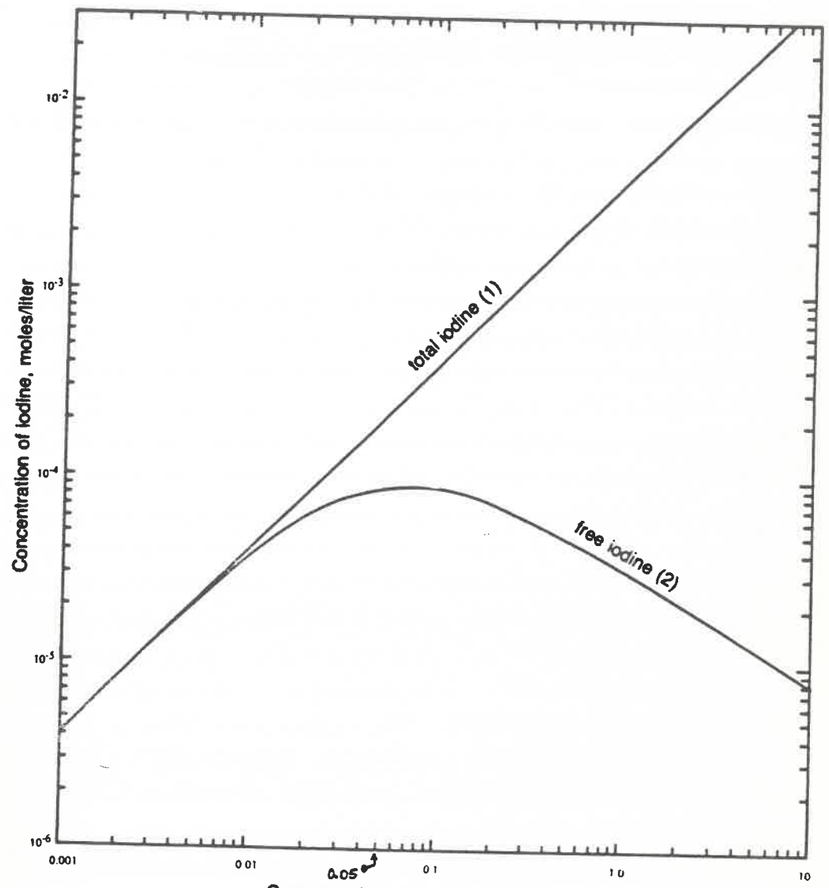

Figure 1. Total ("available") vs. "free" iodine at various dilutions of povidone-iodine. Notice a maximum "free" iodine is obtained with a 0.1% (1:100) solution of povidone-iodine, as discussed in the text. One survey respondent reported using a 0.05% solution of povidone-iodine as a reptile soak, which is an ideal concentration to use. Adapted from Gottardi, 1983.

iodinated water, there is potential for adverse effects on thyroid gland function (Gilman et al., 1980).

Frye (1981) and Marcus (1981) recommend povidone-iodine among the treatments for algal infections, "shell rot" and ulcerative stomatitis in chelonians, and "blister disease" and ulcerative stomatitis in snakes. Betadine^{R} ointment is very

good for these applications, and would be an alternative to Polysporin^{R} ointment (which is also very good).

Xenodine^{R}, a new antiseptic from Squibb, offers an alternative to povidone-iodine. In in-vitro tests comparing Xenodine^{R}, Betadine^{R}, and 2.2% tincture of iodine, it was shown that Xenodine^{R} exhibited 3 times more activity against Pseudomonas species compared with the other compounds (Tindall, 1983). Betadine^{R} and Prepodyne^{R} iodophors, and generic equivalents, would be more cost-effective as cage and tool disinfectants.

Toxicity:

Evidence suggests iodophors are well-tolerated when used as antiseptics in reptiles, and are the agents of choice as pre-surgical scrubs.

Amphibians are apparently quite variable in their susceptibility to iodophor-induced toxicity. One survey respondent indicated 100% mortality in a group of 12 Dendrobates h. sylvaticus after housing in a styrene-plastic container well-rinsed after disinfection with Betadine^{R}. Mortality was reportedly spread over several days with the initial occurrence within 24 hours of the exposure. Lab tests found substantial amounts of iodine remaining in the plastic. Gottardi (1983) reports "some plastic" adsorb elemental iodine.

However, Meier (1982) used Betadine^{R} as a pre-surgical scrub in repair of an abdominal hernia in an adult (213 gm) Madagascar Tomato Frog (Dyscophus antongili) without any problems.

E. Quaternary Ammonium Compounds ("Quats", QAC's)

1. Benzalkonium Chloride ("alkylbenzyldimethylammonium chloride"). Zephiran^{R}, Roccal^{R}, many others.

2. Related QAC's, i.e. "dialkyldimethylammonium chloride". One such product, Basic-G^{R}, also contains benzalkonium chloride.

3. Cetrimide ("cetyltrimethylammonium chloride"), closely related to benz. chloride, has been found contaminated with Pseudomonas aeruginosa (Jackson, 1981; Morton, 1983).

Jackson (1981) advises against its use.

Literally hundreds of other QAC's are available, but nothing is published about them with regard to herptiles.

Spectrum. G^{+} bacteria are much more sensitive to QAC's compared to G^{-} bacteria. Some G^{-} bacteria show high resistance, especially Ps. cepacia, as previously mentioned. At higher "use-dilution" concentrations (0.13-0.2%), most (and probably all) Pseudomonas and Salmonella species are susceptible (Zephiran product lit., 1975). Basic-G^{R} label information indicates a final concentration of total QAC's equal to 0.05% (15cc's/gallon water) is effective against these organisms. Cysts of Entamoeba are sensitive (Petrocci, 1983), but NaOCl is probably better to use. Mycobacteria, bacterial spores, and hydrophilic viruses are resistant. Zephiran product literature notes that if mycobacteriocidal efficacy is required, "a tincture of Zephiran will kill the tubercle bacilli in 30 minutes." However, ethyl or isopropyl alcohol alone generally are much more rapidly mycobacteriocidal (Block, 1983). This suggests an antagonistic effect on the alcohols! The spectrum of activity was summarized best by Petrocci (1983):

> ". . . algistatic, bacteriostatic, tuberculostatic, sporostatic, and fungistatic at low concentration levels; algicidal, bacteriocidal, fungicidal, and virucidal against lipophilic viruses at medium concentration levels; they are not tuberculocidal, sporicidal, or virucidal against hydrophilic viruses at high concentration levels."

Unfortunately "level" wasn't defined, but the following ballpark figures based on Zephiran^{R} product literature recommendations apply: low = 0.03%, med = 0.1%, high = 0.5%.

Other characteristics regarding use and compatibilities include:

a. QAC's act as mild detergents for cleaning action at "use-dilution" concentrations. Very heavy organic loads will reduce the efficacy of "quats" however, and a prior cleaning with a soap or anionic-surfactant is advisable in these situations. The detergent must be thoroughly rinsed prior to the use of the "quat" as they can chemically inactivate it.

b. Zephiran^{R} product literature indicates iodine,

potassium permanganate, and pine oil are incompatible with QAC's. Tap water greater than 500 ppm "hard" is not advisable to use in preparing solutions. Some commercial products contain sodium EDTA to make use of hard water less of a problem (i.e., Basic-G^R, 0.013% final concentration). Otherwise, better to use store-bought distilled water. Resin-deionized waters have been found contaminated by Pseudomonas (Petrocci, 1983). Isopropyl alcohol is good to use.

c. Porous materials can adsorb QAC's and thereby reduce efficacy or predispose to poisoning in amphibians.

Use of Benzalkonium chloride as an antiseptic. Used in dilute concentrations, benzalkonium chloride (BzC) can be used safely as an antiseptic in reptiles. In amphibians, they are highly toxic!! Frye (1981) and Marcus (1981) mention use of the agent in the treatment of mouth rot in snakes (percentages not given). Marcus also mentions use as an irrigant (0.1%) in the treatment of abscesses. In an earlier work (1971), he mentioned that "undiluted BzC has been 'reported' effective as an irrigant," although no reference was given. Avoid undiluted QAC's! Kauffeld (1969) indicated that (BzC) at 0.1-0.13% (1:750-1:000) solution was "excellent" to use against mouth rot, but that it worked less well compared to 25% aqueous sulfamethazine. Since sulfa drugs are not the drugs of choice in treatment of mouth rot, one should get an idea of the worth of BzC for use in ulcerative stomatitis treatment. That is, ancillary to parenteral antibiotics! Note that undiluted BzC can be corrosive to tissues (Harvey, 1980), so solutions above 1.0% should preferably be avoided. Mittleman (1963) reported a 0.0133% (1:7500) solution in tank water to be effective for turtles "suffering from superficial sores". One survey respondent indicated when using a 0.023% solution in reptile-holding barrels (see p.207), occasional toxicity was noted in some snakes.

Toxicity:

1. Corrosive to tissues at high concentrations. Mucous membranes more susceptible to this action. Where an antiseptic

is appropriate, probably best to go with an iodophor compound. As eluded to above, a 0.023% solution sometimes produced toxicity in snakes when the solution was drunk. It was reported that young Eunectes murinus froth at the mouth, and young Naja melanoleuca exhibit frothing and gaping. Mortality was reported in one Naja after showing these signs.

2. Potential allergic reactions, especially with chronic use (Harvey, 1980). Probably extremely rare in reptiles.

3. Potential effects on the autonomic and peripheral motor nervous systems. Curare, a well-known QAC, produces muscle paralysis by blockade at the "motor end-plate" of the nerve-muscle junction. Several QAC's are used pharmacologically for this and other nerve effects. QAC's used as disinfectants have this potential, especially in amphibians. Harvey (1980) indicates in mammals, they have "relatively low systemic toxicity". In reptiles, used correctly, the risk is apparently minimal. In white rats, while the acute oral LD_{50} for BzC is 445 mg/kg (Petrocci, 1983), Alfredson et al (1951) fed the same compound at 0.25% in the diet over a 2 year period without any demonstrable effect on growth, blood picture, or histopathology.

In amphibians, the situation is entirely different. Merck Index (1976) indicates for BzC an oral LD_{50} in "frogs" as 30 mg/kg. Kaplan and Light (1955) showed the highest average concentration allowing survival of "frogs" (specie not indicated, probably R. pipiens) as 0.0009% for continuous immersion (1 week) and 0.002% for 1 hour immersion. Above 0.0009% continuous immersion, frogs developed extensor rigidity, signs of edema, and superficial vascular damage.

Several survey respondents indicated high toxicity in frogs, with such comments as, "Hyla regilla will die in direct contact with Roccal^R in a matter of minutes" and "overnight death of 3 Megophrys nasuta in aquarium containing one inch of fresh water and a piece of cork bark which had previously been disinfected with QAC."

G. Phenolic Compounds

This is a diverse group of agents. They vary markedly in

disinfectant efficacy, chemical behavior, and toxicity. Several authors mention the highly toxic nature of phenolic compounds in herpetofauna (Marcus, 1981; O'Connor, 1966-67; Nace, 1974), but references are not given. However, certain members of this group of compounds, specificially o-PHENYLPHENOL (o-PP) and o-BENZYL-p-CHLOROPHENOL (BCP), indeed are less toxic than BzC in rodents (see below and Table 2, p.239). Because of their more-or-less ideal characteristics compared with other phenolics, these 2 compounds have found wide use in such products as Lysol^R, One-stroke Environ^R, and Amphyl^R.

Amphyl^R spray contains 0.136% o-PP. Other Amphyl^R products contain a low percentage of p-TERTIARY-AMYLPHENOL. This second compound has similar characteristics as o-PP and BCP.

Hycolin^R, a product found susceptible to contamination by Pseudomonas in a study by Needham (1978), contains in descending order (percentages not available), chloroxylenol, chlorophene, chlorocresol, sodium orthophenylphenate, and sodium pentachlorophenate. Jackson (1981), in a table of common disinfectants, notes that chloroxylenols, at 1.3% are "safe" to reptiles. However, no reference or proof is given that they are. In addition to o-PP (2.8%) and BCP (2.7%), Lysol^R contains 1.5% "xylenols." In mammals, it is known that xylenols are less toxic than chloroxylenols (Prindle, 1983), but I could find no information on herps.

Phenol itself is a relatively weak disinfectant compared to the above first three phenolic derivatives. Because of this and its markedly toxic nature (Harvey, 1980) (see also Table 2, p. 239), it has little role in herptile husbandry.

Pine Oil. Contains a mixture of cyclic terpene alcohols, creosols, phenol, toluene, and "other hydrocarbons" (Merck index, 1976). Examples of commercial products containing pine oil are Pine-sol^R (30.0%) and Hexol^R (57%). Fowler (1983) states that pine oil is probably safe for use around reptiles, but I could find no reference proving this. In fact, Gibbson (1985) reported a toxicoses involving Pine-sol^R in two juvenile Lampropeltis g. californiae. After washing an

Astro-turf^R "carpet" substrate with label-recommended dilutions of Pine-sol^R and a reasonable water rinse, the keeper placed the carpet and snakes back in the cage. A few hours later, the snakes were found in an apparent "anesthetized" or "intoxicated" state. The keeper originally thought they were dead. However, several hours later one specimen was found to have crawled a distance. This specimen soon recovered completely from the toxicosis. The other specimen died. This incident suggests that the ingredients in Pine-sol^R, in minute amounts, may act as some kind of anesthetic or narcotic-like drug, in L. g. californiae at least. I recommend extreme caution if this product is used around herptiles, especially amphibians.

"Essential Oils" - Found in low concentrations in some disinfectants (i.e. Basic-G, 0.0008% final diluted concentration). Contain a variety of phenolic compounds, such as thymol, eugenol, and terpineol. The latter agent has been shown to be baceriocidal to Ps. aeruginosa (Block, 1983). Listerine^R, a well-known antiseptic, contains thymol, eucalyptol, and menthol. This product could probably be used relatively safely on reptiles afflicted with small surface injuries when applied with a Q-tip. Otherwise, safer to go with an iodophor compound.

Spectrum of activity. Among bacteria, G$^-$ organisms again show a degree of increased resistance among phenolics. However, at higher use-dilution concentrations, o-PP and BCP are effective against Pseudomonas and Salmonella (Prindle, 1983). Mycobacteria, lipophilic viruses (i.e., not Parvo & Picorna), and fungi are relatively susceptible. Among higher parasites, o-chlorophenol has ovicidal and larvicidal activity for some nematodes, as previously mentioned (see p. 215). Although I could find no information, o-PP and BCP at similar concentrations would probably do as well.

Major compatibilities include:

1. Soaps. Prindle (1983) indicated certain soaps (i.e., those in Lysol^R) aid the antibacterial action of o-PP. Merck

Index (1976) indicated only anionic detergents are compatible with phenolic compounds.

2. Alcohols. Generally not compatible with phenolics at concentrations above 5-10% (Prindle, 1983). This isn't an inactivation-type of incompatibility, but rather a problem involving chemistry that is beyond the importance of this review. Small amounts (like that in Lysol^R products) are useful.

Toxicity:

As alluded to earlier, the toxicity of phenolics varies widely. Generally, an increase in the molecular weight of phenolic derivatives is accompanied by a decrease in toxicity. Halogenation (the addition of chlorine atoms to the molecule, strongly bound) can have the opposite effect, however (Prindle, 1983). What this all means is that you can't play guessing-games with phenolics!

In sufficient concentrations (no published figures regarding herps), all phenolics can be corrosive to tissues. Regarding lethality, in rodents, oral LD_{50}'s for phenolic compounds are listed in Table 2, p. 239. An average oral LD_{50} in rats for o-PP is about 4 gm/kg, which is significantly higher than for Benzalkonium chloride (445 mg/kg).

In the herp literature, O'Connor (1966-67) urged that disinfectants containing coal tars, pine oils, carbolic acid, phenols, or heavy metals be avoided around reptiles. Marcus (1981) states "Phenol, cresol, and other coal tar derivatives are highly toxic to herpetofauna and should be avoided." Later in the same work, he states, "Phenol- and cresol-type disinfectants such as Lysol^R are generally thought to be highly toxic to herpetofauna and should not be used in their vicinity. Kaplan and Light (1955) showed that exposure to concentrations greater than 0.03% phenol were fatal to "frogs." The previously mentioned "intoxication" involving the Pine-sol^R certainly suggests that phenolics can be highly toxic to reptiles.

However, Fowler (1983) states "in snakes, absorption or ingestion of o-PP causes convulsions." Contrary to this, Bonilla

and Seifert (1971) described the safe use of Amphyl^{R*} in Crotalus v. viridis suffering from mouth rot. In their study, the snakes were suffering from variable degrees of ulcerative stomatitis. Lesions were debrided and cleaned with cotton swabs soaked with Amphyl^R. The solution was then thoroughly sprayed in their oral cavities. Treatments were repeated approximately every 14 days. Reportedly, even advanced cases were markedly improved by 45 days, and eventually cured. The authors stated that it had become customary to spray the mouths of all new incoming specimens, whether "infected" or not, upon their arrival to their lab. In using the straight undiluted solution, these authors concluded, "The low cost, ease of application and above all, the efficacy of o-PP make it the method of choice in the treatment of ulcerative stomatitis in crotalid snakes." My initial reaction is that these researchers were a bit ambitious in trying this treatment. Ross (1984) indicated Amphyl^R is safe, producing no toxic effect when "snakes" are washed in it. It must be noted here that no information is available concerning the effects of chronic exposure to these compounds in reptiles.

In amphibians, as with all other disinfectants discussed so far, phenolics are apparently highly toxic. In Kaplan and Light's (1955) study, they found "frogs" very sensitive to phenolic compounds (see Table 3, p. 240), but less toxic compared to QAC's. Although, their 1955 Lysol^R product contained "tricresol" (Cresols are halogenated phenols, generally less toxic compared to phenol). One survey respondent indicated that after rinsing well a plexiglass holding cage that was disinfected with "a solution" of One-stroke Environ^R (o-PP 10.0%, BCP 8.5%, and p-tertamylphenol 2.0%), 6 healthy "frogs" (specie not indicated) were dead within hours after placement within. This suggests a high toxicity for these compounds in amphibians.

*Note in these investigators' 1971 product, o-PP (percentage strength not indicated in the report!!) apparently was the only phenolic compound in the solution.

G. Chlorhexidine

This compound combines rapid bacteriocidal action of iodophors (which are weakly persistent) with the persistent action of hexachlorophene (which acts slowly). In addition to what has been said about this agent and Pseudomonas with regard to contamination (see p. 216), Harvey (1980) states that as a bacteriocide, it is "somewhat" less effective against G^- bacteria. Povidone-iodine is considered a better agent against G^- bacteria according to this author (see p. 223). Goodner and Gray (1983) note that 0.01-0.05% solutions are "rapidly bacteriocidal." Finally, Fowler (1983) states that it is less effective against G^+ bacteria and Pseudomonas (no reference given). Fungicidal activity apparently is also variable. It cannot be relied upon for sporicidal, mycobacteriocidal, or hydrophilic virucidal (i.e., parvo, picorna) activity. With respect to virucidal activity, one survey respondent indicated use of chlorhexidine only for "suspected viral problems." Note that in the case of animals infected with parvo or picorna virus, chlorhexidine would not be the disinfectant of choice.

In the U.S., chlorhexidine is most commonly available as the gluconate salt, which is compatible with alcohols and anionic detergents (Gardner & Gray, 1983).

Antiseptic qualities. Chlorhexidine is well-tolerated on mucous membranes of mammals (Harvey, 1980). Nicol (1984, in print) reported that in some cases of shell rot in chelonians, that chlorhexidine is the only effective treatment, compared to "bleach, iodines, dyes, Merthiolate^R, tetracycline HCl, sulfas, plus a few others." I could obtain no other information on antiseptic use of this agent in herptiles except for the following information on toxicity.

Toxicity:

In mammals, compared with other disinfectants, chlorhexidine is of comparatively low toxicity (Harvey, 1980; Gardner & Gray, 1983). In rats and mice, the oral LD_{50}'s are all over 750 mg/kg. As a cage disinfectant, Jackson (1981) notes that 0.5% is "safe" around reptiles.

In chelonians, Nicol (1984) warns against exposing the eyes, as this "causes the lens of the eye to cloud up for several days until it heals itself." She mentions that in long-necked turtles, they may be held by the head, exposing just their shells and body.

H. Hexachlorophene (Phisohex^R, Septisol^R)

This agent is a "bis-phenol" that since 1972 commercial products containing greater than 0.1% are available only with prescription. The compound is known to produce neurotoxicity in humans (Harvey, 1980), and to be an uncoupler of oxidative phosphorylation (biochemical reactions in most cells that produce energy-rich ATP). The oral LD_{50}'s in dogs (Huber, 1982) and mice (Prindle, 1983) are 90 mg/kg and 80 mg/kg, respectively.

Hexachlorophene is useful primarily against G^+ bacteria only. While the drug exhibits high bacteriostatic activity, it is only slowly bacteriocidal (Prindle, 1983). Its major advantage in human medicine is a sustained bacteriostatic effect, especially after repeated use.

Due to its toxicity in mammals, spectrum of action, expense, and prescription requirement, hexachlorophene is not an important alternative to other disinfectants and antiseptics in herptile husbandry.

Only one survey respondent indicated using Septisol^R, as a hand disinfectant. Betadine^R scrub would be a better product to use. Another respondent indicated former use (see Jordan, 1969) in amphibian husbandry.

I. Organic Mercurials (OM's)

These agents are weakly bacteriostatic and fungistatic (Harvey, 1980; Grier, 1983). Virtually useless against bacterial spores. Weakly effective against Entamoeba and variable efficacy against viruses. Although OM products can be found in almost every retail pharmacy in the U.S., Harvey states "the belief still persists that these agents are highly effective germicides." They are rapidly becoming obsolete.

A unique characteristic of OM's is a transferable resistance among some G^- bacteria, including Pseudomonas species. In

other words, this resistance is very similar to a major type of antibiotic resistance, coded for on DNA. For a review, see Grier (1983).

Merbromin (Mercurochrome^R, 25% mercury) is said to be the least effective of available products, and the least safe to use (Harvey, 1980). Boterenbrood mentions the use of this compound on axolotls to "cure fungal as well as non-fungal skin diseases (see also p. 217). Affected animals were placed for three days in a 0.0002-0.0004% solution, then in "pond water" (?) for 7 days, then again in the OM solution for 3 more days. Detwiler and McKennon (1929) used a 0.00013% solution in "spring water" for larvae older than stage 37 to treat "mould infection". Continuous exposure for 2 months was said to produce no noticeable effect on growth. Murphy (1983) mentioned use of a 2.5% solution for wounds in chelonians.

Thimerosol (Merthiolate^R, 49% mercury) is another widely available OM. It is marginally more effective compared to merbromin (Harvey, 1980).

Toxicity:

Mercuric chloride ($HgCl_2$, an inorganic mercurial): In humans, while antiseptic concentrations of 0.5% or less are free of irritation, vesication, and corrosion, Kaplan and Light (1955) found that a 1 hour immersion in concentrations greater than 0.008% were lethal to "frogs". In rodents, the two above discussed OM's have acute oral LD_{50}'s on the order of 5-10 mg/kg (Grier, 1983). Compared with other disinfectants, a high incidence of contact dermatitis occurs with OM's (Harvey, 1980). As antiseptics, iodophors are preferable to OM's in reptiles. In amphibians, they are possibly of some use.

J. Dye Compounds (Gentian Violet; Crystal Violet; Brilliant Green; Methylene Blue; Acriflavin; Malachite Green; etc.)

As a group, these agents are primarily effective against G^+ bacteria. As such, Harvey (1980) writes "Gentian violet is bacteriostatic and bacteriocidal to G^+ bacteria and to many fungi. G^- bacteria and mycobacteria are very resistant

to the drug." Oster and Woodside (1983) report that gentian violet is very active against Candida albicans, a known herp pathogen.

Jordan (1969) mentioned he had success in the treatment of red-leg in frogs using a 30 second dip in a 0.0001% solution of aqueous acriflavin, followed by soaking in a 0.5% saline (NaCl) until the redness disappears (see sodium chloride, p. 237).

Marcus (1981) indicated a successful treatment for Saprolegnia (aquatic mold) infections in Necturus maculosus involves a 15 second dip in a 0.0067% (1:15000) solution of malachite green, repeated once daily for 2-3 days. However, he noted that "immersion in the dye solution for much longer than 15 seconds causes massive epidermal exfoliation."

Trypaflavin, at 0.001% aqueous solution, is reportedly effective in treating infections due to Oodinium pillularis (a flagellated protozoan) in tadpoles, axolotls, and newts (Marcus, 1981) (see also copper compounds, p. 236). For another flagellated protozoa, Trichodina, 0.1-1.0% is recommended.

Murphy (1983) recommended using malachite green for fungal infections and Frye (1981) for shell rot in chelonians. Murphy indicated placing the turtle for 5 minutes in a solution containing "enough to turn the water a dark blue", followed by holding in a solution containing 2 drops/gallon, has been effective. Frye gave no percentages, but said lesions should be painted daily until healed.

K. Potassium Permanganate ($KMnO_4$)

Harvey (1980) indicates that in general concentrations greater than 0.02% are required for effective bacteriocidal action, but that this concentration is irritating to tissues. Kaplan and Light (1955) showed that $KMnO_4$ in concentrations over 0.001% were effective in eliminating a reference strain of Pseudomonas hydrophila (now Aeromonas) from aquariums. In their study, it was shown to be safe when "frogs" were immersed in concentrations under 0.1% if limited to periods of less than 30 minutes. $KMnO_4$ is said to be a poor anti-fungal (Oster & Woodside, 1983).

Zwart (1974) recommended a 0.001% solution of $KMnO_4$ to bathe Thamnophis affected by a dermatitis due to the fungus Rhizopus arrhizus. Frye (1981) in discussing the treatment of shell rot in chelonians suggested painting the lesion with $KMnO_4$ soluton, but a strength of the solution was not given.

L. Miscellaneous Agents

1. Isopropyl Alcohol. Generally considered to be a better bacteriocide than grain alcohol, but less useful as a virucide, particularly against hydrophilic viruses (Block, 1983). Alcohols are useless against bacterial spores, but are effective for mycobacterial control. We can summarize the role of alcohols as antiseptics by noting that they are useful alternatives to other agents (i.e., iodophors), and are useful for their synergistic or additive effect when combined with other disinfectant agents, particularly QAC's (except perhaps for mycobacteria, as previously noted on page 225!). For example, in disinfection of smaller cages and aquariums, it is often of increased benefit to prepare QAC's as a tincture, using 70 or 90% isopropyl alcohol as a vehicle (also see p. 213).

Frye (1981) mentions use of alcohols in the removal of ticks from reptiles.

2. Hydrogen Peroxide. Harvey (1980) states the agent is a "relatively feeble" germicide. Commercial products (most are 3% active ingredient) are most useful for debriding necrotic tissue from an abscess, for example, but then followed with an iodophor solution for antisepsis. Frye (1981) suggests its use in lesions associated with Clostridial organisms, which prefer anaerobic environments.

3. Copper (Copper Sulfate; Copper Citrate). Copper is sometimes used for its germicidal action.

In superficial algal infections in chelonians, Hunt (1958) recommends 1% copper sulfate or Lugol's solution (see p.221) as a shell antiseptic. Frye (1981) for the same condition recommends use of "an aqueous copper citrate solution", or povidone-iodine.

Marcus (1981) as an alternative treatment to trypaflavin for Oodinium infections in amphibians, indicated a 0.0002% solution

of copper sulfate is effective. Note that in an early study by Kaplan and Light (1955) it was found that "frogs" survived a 7 day immersion in 0.14% copper sulfate solution, but a later study showed 0.0015% was lethal to R. pipiens (Kaplan, 1961). Nace (1974) states that copper sulfate is an inhibitor of tadpole growth (percentages not given). He indicated that EDTA added to the water at 50 mg/liter was effective in removing it.

4. Sodium Chloride (NaCl). Davis et al. (1980) indicates bacteria and fungi vary widely in their susceptibility to NaCl solutions.

As a general treatment in chelonians suffering from bacterial infections, Dowling and Spencook (1960) advised soaking affected specimens in lukewarm 0.9% saline for 15 minutes daily. With a reference strain of Pseudomonas (Aeromonas) hydrophila however, Kaplan and Light (1955) showed the organism resistant to 2.0% solutions of NaCl.

Murphy (1983) suggested 0.44-0.5% solutions for treatment of fungal infections in chelonians. Jordan (1969) noted that frogs sometimes swell when placed in 0.5% NaCl for prolonged periods.

5. Thiram; Tmtd (Nobecutan^R). This agent has been used on freshwater chelonians as a treatment for injuries (Sachsse, 1966). The author indicated it "protected the wound against water loss and infection." Merck Index (1976) cautions that the agent is an irritant of mucous membranes and a skin sensitizer, and is more toxic in the presence of oils and fatty solvents. I don't know if this agent is available now.

6. Formalin (37% solution of aqueous formaldehyde). Frye (1981) indicates 10-15% formalin is useful for tick removal in reptiles. Jackson (1981) notes that while 1% formaldehyde kills microorganisms very efficiently, it is toxic to reptiles and should be used with caution.

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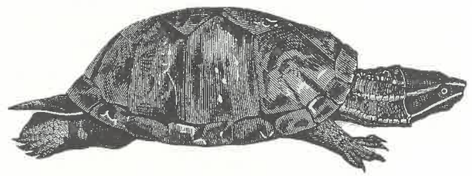

Table 2. Toxicity of selected disinfectant compounds with their source references. The toxicity of disinfectants is discussed in the text.

Substance	Dose/Conc	Specie	Source
Benzalkonium chloride	1% = safe	reptiles	Jackson, 1981
	acute oral LD_{50} = 445 mg/kg	rat	Petrucci, 1983
	0.25% diet for 2 years, no effect	rat	Alfredson, 1951
	oral LD_{50} = 30 mg/kg	frogs	Merck Index, 1976
Betadine®	"0.75% available" = safe	reptiles	Jackson, 1981
Chlorhexidine	0.5% = "safe"	reptiles	Jackson, 1981
Chlorine	greater than 4 ppm (0.0004%); fatal to 25% after 5 days.	frogs	Kaplan, 1962
	greater than 7 ppm 90.0007%); fatal to 75% after 10 days.	frogs	Kaplan, 1962
	greater than 10 ppm (0.001%); fatal to 100% after 4 days.	frogs	Kaplan, 1962
Formaldehyde	1% = poisonous, caution!	reptiles	Jackson, 1981
Hexachlorophene	1-3% = "safe"	reptiles	Jackson, 1981
Hypochlorite	10% = "safe"	reptiles	Jackson, 1981
Phenol	1% = toxic	reptiles	Jackson, 1981
Phenolic cmpds			
"Coal tar, Lysol"	under 5% = toxic	reptiles	Jackson, 1981
Chloroxylenols	1.3% = "safe"	reptiles	Jackson, 1981
o-Phenylphenol	LD_{50} oral - 2.48 gm/kg	rat	Merck Index, 1976
o-Phenylphenol	LD_{50} oral = 8.0 $\pm$ 1.1 gm/kg	rat	Prindle, 1983
	?% = safe	rattlesnakes	Bonilla and Seifert, 1971
o-Phenylphenol	0.136% = safe	reptiles	Ross, 1984
p-Tert-amyl-phenol	LD_{50} oral = 6.8 $\pm$ 1.0 gm/kg	rat	Prindle, 1983
o-Benzyl-p-chloro-phenol	LD_{50} oral = 6.4 $\pm$ 1.1 gm/kg	rat	Prindle, 1983
Sodium chloride (NaCl)	LD_{50} oral = 3.75 gm/kg	rat	Merck Index, 1976

Table 3. Toxicity of selected disinfectant compounds in "frogs". The species of frog was not indicated (!), but most likely R. pipiens. Information on toxicity is described more completely in the text. Modified from Kaplan and Light, 1955.

Chemical	Highest average concentration allowing survival of "frogs" (%)	
	Continuous immersion, 7 days	1 hour immersion
Benzalkonium chloride	0.0009	0.002
Copper sulfate ($CuSO_4$)	0.14	1.2
Formalin	0.02	0.06
Mercuric chloride	0.003	0.008
Phenol	0.01	0.03
Potassium permanganate	0.05	0.1
Sodium chloride	1.1	3.0
Tricresol ("Lysol^R")[1]	0.15	0.06

[1]1985 Lysol^R products contain o-Phenylphenol and O-Benzyl-p-chlorophenol.

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MANAGEMENT AND TREATMENT OF MEDICAL PROBLEMS ENCOUNTERED IN A PRIVATE CHELONIAN COLLECTION

Jim and Sandy Veverka

Although my husband, Jim, has always been enamored with snakes (a fondness I didn't share), three years ago we acquired our first chelonian, a red eared slider Pseudemys s. elegans. Promptly thereafter, we both caught what I call "turtle disease" and began to acquire every species of chelonian we could find. Our acquisitive habit kept escalating, and today our herp collection totals approximately 500 chelonians, about 130 snakes, 3 lizards, 2 frogs, 2 toads, and 1 salamander.

Having acquired many of these animals through the pet trade, we immediately started seeing the "sick animal syndrome", and soon discovered that because of the exposure to stress, and the great variety of bacteria many pet trade animals encounter, the majority of our chelonians were at a high risk for illness. Shortly after we started our collection, we were advised by another hobbyist that we could expect a 40% mortality rate, which we felt was totally unacceptable. Also, Dr. Walter Rosskopf advised us that because our collection consisted mainly of hatchlings acquired through the pet trade, we would experience a much higher mortality rate than the normal hobbyist, not only because of illness, but also due to birth defects in animals which were not meant to live in the first place.

To avoid high mortality in our specimens, or inevitable bankruptcy from frequent visits to the vet, we quickly decided we had to learn proper husbandry and feeding techniques as well as how to recognize, treat and care for sick animals. Although there is much information available in the literature, it is often difficult for the amateur to find and interpret, and even veterinarians and experts don't always have the answers or agree on the proper care and treatment. In fact, there are probably as many different opinions on the care and treatment of medical problems in reptiles as there are species, and the debates will likely go on forever. Until further research is done, many

questions will remain unanswered.

To learn as much as we could, we 1) read and studied every book and article we could find, 2) took our sick animals to veterinarians and asked them every question we could think of, 3) talked in depth to every hobbyist and breeder we could contact to compare experiences and ideas, 4) attended Dr. Rosskopf's reptile seminars, 5) observed extremely closely each and every one of our pets, 6) kept copious records, 7) discussed among ourselves and other interested people questions, thoughts, successes and failues, 8) had necropsies done, and 9) sometimes used what might be considered experimental procedures in an attempt to save a dying animal, or learn something from that particular animal which might be of use in a future medical problem.

During the first year our mortality rate from all causes was 13%. Over the last two years, with supervision, assistance, advice and testing performed by veterinarians Mary Isaac and Walter Rosskopf, we have had a great deal of success treating numerous medical problems in chelonians which, if left untreated, would have resulted in their death.

Our mortality rate has steadily declined as we have learned more about recognition, diagnosis, and treatment of medical problems; during the past year we have been almost 100% successful in treating medical problems.

Of course, there is no guarantee that an animal will never die. There will always be animals with medical problems that cannot be successfully treated. Unknown, untreatable or too-far progressed diseases may be present. Often there are no external or behavioral indications of such problems until shortly prior to death. We have seen conditions such as this when an animal has a heart attack, cancer of the intestine, hepatitis, kidney or liver disease, calcium non-absorption, septecemia, or an overwhelming bacterial or fungal infection.

Although viruses play a part in disease processes, very little is known about their treatment. Currently research is being done to isolate and identify pathogenic viruses; one day vaccines may be available.

We try to treat even the sickest animal we encounter, even when we are sure treatment won't be successful. Our philosophy is that it is better to attempt to treat an animal that we know is sick, even if it subsequently dies, than not to attempt treatment at all. As a result of our philosophy, we have had some miraculous cures. We have also had inexplicable deaths where the necropsy results were negative. At least we know we have done the best we could with the limited knowledge available, and necropsies have helped give us confidence to continue treating our animals when necessary.

Prevention of sickness and disease is always superior to dependence on veterinary medicine. Close attention must be given to all aspects of reptile husbandry, including diet, living quarters, temperature, humidity, water availability, photoperiod, sanitation, and behavioral differences.

In addition to proper husbandry practices, we feel the most important aspect in management of chelonian medical problems is observation of your animals. Through careful observation of your specimens, you can get a feeling for any deviation from normal behavior. The earlier a problem can be discovered, diagnosed, and treated, the more chance there is for success.

It is always best to have blood, culture, sensitivity, and fecal testing done by a competent veterinarian or laboratory so you know what problem is being treated. However, if this is not possible, the procedures we describe may be helpful, and we offer here the protocol we use to treat medical problems in our chelonian collection.

The main points we consider when we use any medicine are its effectiveness, side effects, ease of administration, and whether or not an exact dosage can be given. Whenever giving any drug to an animal, always follow exactly the recommended dosage, administer the drug the same time each day, give the required number of treatments, and follow all instructions on the label and package insert. Also be familiar with the drug's side effects, whether or not it reacts with other drugs, the expiration date, and it's storage temperature requirements.

Although our experience has been mainly with turtles and tortoises, much of the information, with necessary dosage and frequency modifications, can also apply to other reptiles.

For the sake of brevity, we will not attempt to review all the medical problems that affect chelonians, but instead only those that can be successfully treated. Treatable medical problems in reptiles fall into three major categories: bacterial diseases, parasites, and injuries.

BACTERIAL DISEASES

The first major category of medical problems is bacterial diseases, such as infections, respiratory problems, pneumonia, mouth rot, abscesses, and shell rot. Sometimes chelonians do not exhibit visible disease symptoms, but it is our experience that a chelonian who is active and appears healthy, but refuses to eat after an acclimation period, usually has an internal bacterial infection.

Bacterial infections in reptiles are almost always caused by gram negative bacteria, and need to be treated systemically to rid the body of the bacteria. To treat gram negative bacteria, it is necessary to use an antibiotic that is effective against gram negative bacteria. Even if gram positive antibiotics (such as the penicillin derivatives -- carbenicillin or piperacillin and the cephalosporins -- claforan) or broad spectrum antibiotics (such as tetracycline ad chloramphenicol) have some effectiveness against gram negative bacteria, they are never as effective as gram negative antibiotics. The antibiotics which are effective against gram negative bacteria are the aminoglycosides, such as gentamicin and amikacin. These antibiotics can be toxic to the kidneys and nervous system; at the same time, therapeutic dosages must be given. For an in-depth study of this topic, refer to The Bacterial Diseases of Reptiles, by Dr. Richard A. Ross and Gerald Marzec.

Another method of treatment we use is "heat therapy". In conjunction with the use of antibiotics, we increase the temperature of the specimen from a minimum of 30°C to a maximum of 45°C, depending on the thermal maximum of the

species. A rise in temperature causes an increase in the immune system's activity.

When antibiotic and heat therapy are applied, it is crucial that an animal does not become dehydrated. We prevent dehydration by keeping the animal in water or getting it to drink water on its own. We keep aquatic turtles and rain forest tortoises in water without any basking area (both at increased temperatures) 24 hours a day during treatment, and for 2 days after treatment. Tortoises other than rain forest species are soaked in water twice a day and observed to see if they are drinking. If an animal can't be kept in water or won't drink regularly, it then becomes necessary to hydrate the animal with fluids, Ringer's solution, either by means of a stomach tube or by intraperioneal injection in the rear leg cavity, at a dosage of 1-5cc/lb daily during treatment, and for 2 days thereafter. However, we do not advocate the injection of large amounts of fluids into the stomach or body cavity, this results in death from massive edema, which can cause the lungs to fill up with fluid.

It goes without saying that any animal which is not eating should be force-fed.

Using these treatment methods, and the drugs at the dosages that will be discussed, our chelonians have not had kidney or nervous system damage, and necropsies have shown any deaths which occurred to be a result of other causes. In addition, we have a number of friends who have used these treatments in over 300 animals with the same results.

Although we previously used gentamicin sulfate, there are now strains of bacteria that are resistant to gentamicin, and the drug we now use for treating bacteria is amikacin sulfate solution (veterinary brand Amyglide), which we have been using for the past six months. The dosage, frequency, and number of injections we use is as follows:

AMIKACIN SULFATE SOLUTION (Amyglide) (Bristol)	or	GENTAMICIN SULFATE (Gentocin) (Shering)

FOR AQUATIC TURTLES AND SEMI-TERRESTRIALS:

Dosage is 5 mg/lb	subcutaneously, s.i.d. every 24 hours for 3 days
	skip one day
	subcutaneously, s.i.d. every 24 hours for 3 more days
	total of 6 injections

FOR TORTOISES:

Dosage is 5 mg/lb	subcutaneously, s.i.d. every 48 hours for a total of 6 injections

The dosage, number, and frequency of injections for other species of reptile varies from this chart, so be sure to obtain the correct information if treatment in another species is contemplated.

Amikacin sulfate and gentamicin sulfate come in different concentrations. However, they can be diluted with sterile water to arrive at a suitable concentration. For example, Amyglide comes at 250mg/ml strength, so we dilute it 4 parts sterile water to 1 part Amyglide or 4cc sterile water to 1cc Amyglide to make a solution of 50mg/ml. At a strength of 50mg/ml the correct volume dosage would be .10cc/1b of weight (5mg of 50mg/ml strength being 1/10th of a millileter). As any drug reaches a minimum dosage level at which it is effective, a very small animal would receive a dosage higher than 5mg/1b, such as an animal weighing 2 oz. would actually receive 1/2mg, or .01cc of 50mg/ml strength.

Normally, improvement is noted in aquatics and semi-terrestrials after three injections, athough you may see little improvement in tortoises until two or three weeks after the treatment has been completed.

Due to the kidney and nervous system toxicity of aminoglygosides, it is tempting to stop treatment when improvement is noted, but cultures have shown it is necessary to give chelonians a total of 6 injections in order to kill all the bacteria. We have been told by many medical professionals if all the bacteria are not killed, subsequent generations of any surviving bacteria may be resistant to the antibiotic.

In addition to antibiotic treatment, some bacterial

infections require the following additional treatment:

1) Stomatitis should be debrided twice daily, flushed out with sterile water, and either Gentocin or Polysporin ointment should be applied to the affected areas.

2) Abscesses can occur any place on the soft parts of chelonians. Abscesses must be incised, debrided, packed with Gentocin ointment, and left open for healing to occur.

3) Shell rot should be totally debrided; the affected area should then be covered for three days with Gentocin or Polysporin ointment to kill the bacteria on the shell. After this treatment, painting the area every two days with Gentian Violet will help to dry the affected area. During this treatment, the animal should be kept dry except for daily soaking for more aquatic species. Although this treatment alone is sometimes sufficient for external shell rot, any deep shell rot may result in a systemic infection, and treatment with an aminoglycoside may also be necessary. However, due to the need to avoid dehydration during aminoglycoside treatment, internal and external treatment cannot be administered simultaneously. In these cases, we first treat the animal systemically with amikacin, and then begin the external treatment two days after finishing the antibiotic treatment.

Skin fungus or skin wounds can usually be treated by one of the following: drying the affected area and painting it with Gentian Violet, application of Gentocin ointment, Polysporin ointment or Silvadene Creme, or salt baths. However, if the skin is broken, systemic treatment with an aminoglycoside should be considered.

Yeast infections can be treated with Nystantin (1,000 units) at a dosage of .25cc/1b orally once a day for 6 days or Nizoral (ketoconazole) at a dosage of 5mg/1b orally twice a day for 6 days. Yeast infections can result from high dosages of cephalosporins.

PARASITIC INFESTATIONS

The second major category of medical problems is parasites, especially in newly acquired animals. A new animal may not eat,

may eat but not gain weight or grow, may be lightweight or suffer weight loss, may have a slight runny nose with no other respiratory problems, may not be very active, may be hyperactive, may have loose, runny or odd-colored feces, may have blood or mucus in the feces, or may regurgitate food. Any one of these symptoms may indicate parasite infestation, and fecal and blood testing should be obtained.

Nematode (round worm) infestations are common in all reptiles, although tortoises appear to be most commonly infested. Every fecal sample we know of that has been tested from a wild-caught tortoise shows nematodes of one kind or another, often more than one species. Tortoises in the wild live with internal parasite loads and do not seem to suffer deleterious effects. However, apparently due to the stress of capture, holding, shipment, and change in diet and environment, the parasites may flourish and adversely affect the animal.

It is our experience that every wild caught tortoise must be wormed as soon as possible. In fact, we successfully keep certain species of dwarf tortoises, that are known to be delicate in captivity, and we attribute this mainly to the fact that we treated them for the massive parasite infestations they had when we received them.

Fecal testing done on long-term captive adult tortoises invariably reveals nematodes. Also, fecal testing done on captive hatchlings from long-term captive adults usually reveals nematodes if they were kept with infected adults after hatching. Nematode eggs can live in and on the ground or grass up to three years. Because of the nematode life cycle, one tortoise in a group can infect an entire group, and unless all the tortoises are treated, they can constantly re-infect one another. However, an unstressed captive animal seems in many cases to coexist with the parasites with no ill effects unless the infestation becomes severe or the animal is stressed. In addition to worming immediately upon arrival, we now worm our tortoises once a year as a precautionary measure.

Although nematode infestation does not seem to be as common

as in tortoises, the above information applies to water and semi-terrestrial turtles. Indications that nematodes are present include worms in the water, low weight or weight loss while appetite is normal, or loss of appetite. Any of these symptoms should arouse suspicion.

Trematode (fluke) infestation sometimes occurs in reptiles, but may be cyclical and asymptomatic. In severe infestations, trematodes are indicated by the following symptoms: general listlessness, loss of appetite, weight loss, difficulty in breathing, or convulsions. No treatment is known for adult trematodes, except for removal by hand of adult stages seen in the mouth, and the only known treatments for the larval stage are toxic to the liver and kidney, and should never be undertaken without the advice of a veterinarian and appropriate blood testing. Until further research is undertaken, there is no treatment we can recommend.

Cestode (tape worm) infestation in reptiles does not appear to present problems unless the infestation is heavy or the worms large. However, caution must be used in cleaning or handling infected specimens, since humans can become infested with some types of tape worms that affect reptiles if expelled segments are ingested. Infestation is sometimes discovered when segments of the worm are found in the feces or in subcutaneous or intramuscular cysts.

Protozoan infestations in reptiles raise many questions concerning their identification, how pathogenic they are, and whether or not a treatment is available. Some anti-protozoal agents are effective against some protozoa, but not against others, and there is no known effective treatment for many of the protozoa. Identification of the specific protozoa should be made by a qualified veterinarian or laboratory prior to commencing any treatment, and the progress of treatment should be monitored.

The most common symptoms associated with protozoan infestations include loss of appetite, weight loss, anemia, regurgitation, blood or mucus in stools, runny or odd-colored (particularly gray or green) stools, bronchopneumonia, and

mid-body swelling. Protozoan infestations are readily spread from animal to animal and sometimes can spread to humans. Care must always be exercised when any protozoan infestation is suspected.

Although there are many different parasiticides that have been used on reptiles, certain of those recommended, such as Piperazine and Ivermecton, have been reported to cause serious complications and death in some reptiles, and should never be used. Also, keep in mind that a severe parasite or protozoan infestation can cause bacterial infections, which must be treated. Also, complications from severe parasites and protozoans may result in death, even after treatment.

The parasiticides, treatment regimen, and dosages we use for chelonians are as follows:

FOR NEMATODES:

Levamisole Phosphate [Levasole (Pitman-Moore) or Tramisol (Tramisol)] (136.5mg/ml) (13.65%)	Dosage is 2.73 mg/lb subcutaneously. Two injections 10 days apart - (May give third injection 10 days after second injection for severe infestation)

Using 136.5mg/ml strength, the proper dosage is 0.2cc/lb. Since this is such a minute amount, the strength can be diluted 7:1 using 3.5cc sterile water to .50cc levamisole phosphate. The dosage would then be .01cc/oz. Levamisole phosphate must be refrigerated or it quickly becomes ineffective. Treatments have shown that the exact dosage is critical with this drug, and a few fatalities have occurred through needless over-dosage. Although the drug has been approved by the FDA, for use in cattle only, we personally know of treatments at the above dosage on over 1,500 chelonians with no apparent ill effects. In fact, we have successfully wormed many hatchling one-ounce tortoises that continued eating normally during treatment. Levamisole phosphate is a broad spectrum parasiticide and is injectable, which insures the delivery of an exact dosage.

FOR TREMATODES:

We do not recommend the treatment of trematodes unless the animal is so infested that its death is likely, and then only

with competent veterinary supervision and proper blood testing during treatment. Very little is known about the effect of these parasites, and until further research is undertaken, extreme care should be exercised in attempting treatment. If treatment becomes absolutely necessary, the following drugs may be of use, although they are known to be toxic to the liver and kidneys.

Emetine HCl	Dosage is .23 mg/lb subcutaneously Single injection daily for 10 days Prevent dehydration
Tetrachloroethylene	Dosage is .10cc/lb orally four days after last feeding - repeat if necessary in 3-4 weeks Prevent dehydration

FOR CESTODES:

Niclosamide (Yomesan) (Haver-Lockhart)	Dosage is 75mg/lb orally One dose - repeat if necessary in one month

This drug appears to be standard recommended treatment for cestodes in reptiles. The only question is whether or not the infestation is severe enough to be pathogenic and require treatment.

FOR PROTOZOA:

In order to even consider treatment for protozoa, it is necessary to know and identify the different types, as some are pathogenic, some are not pathogenic, and some appear to be pathogenic only in conjunction with other parasites. Further, there is no known treatment for some protozoa, and others are susceptible only to a certain drug. Always exercise care when a protozoan infestation is suspected, as they are readily spread among animals and, in the case of some species, be spread to humans. The protozoa that are commonly known to affect chelonians and the known treatment for them is as follows:

I. FOR RHIZOPODA (Entamoeba invadens)
FOR FLAGELLATES (including Trichomonis)
FOR CILIATES (Balantidium) ** (SEE NOTE ON NEXT PAGE)

Metronidazole (Flagyl)	Dosage is 50mg/lb orally every day for 3 to 4 doses, not to exceed 400mg daily total or to lessen stress 125mg/lb single dose orally repeated in 10 days

Prevent dehydration and maintain temperature of 95° during treatment

**Balantidium should be treated when present in large numbers or with other parasites. When treatment is indicated, in addition to Flagyl, give oxytetracycline hydrochloride at dosage of 10-20mg/lb subcutaneously, single injection daily for 7 days.

II. FOR SPOROZOA (including Coccidiosis)

Sulfamethazine — Dosage is 20mg/lb subcutaneously
Single injection daily for 6 days
Prevent dehydration

III. FOR FLAGELATES (Trypanosomes)

FOR BLOOD SPOROZOA (Hemogregarines and Plasmodia)

Chloroquine — Dosage is 5mg/lb subcutaneously first day and 2.5mg/lb every other day for 3 more doses - can repeat in 2 weeks
Prevent dehydration

CAUTION: Chloroquine is not approved for use on any animal by the FDA and little is known about its effects other than its toxic to the liver and kidneys. It use is only recommended in the case of an overwhelming parasite infestation likely to result in the death of an animal, and only with appropriate blood testing and veterinary advise during treatment.

INJURIES, ACCIDENTS AND STRESS

The third major category of medical problems arises from injuries, accidents, serious illness, dehydration, and stress. While physical trauma is obvious, the shock that results is not, but it can just as easily result in the death of an animal.

At first we attempted to treat injured animals without any consideration to the effect of shock on the animal's system. Some animals appeared to recover following treatment, but did not do well. Some newly acquired animals never seemed to adapt to captivity or new surroundings (the so-called maladaption syndrome) and literally starved themselves to death. We have heard similar reports from many hobbyists.

Shock is the body's response to any severe trauma, and results when the blood flow to vital organs is decreased. The blood flow to the skin and muscles ceases first, and then blood flow to the intestines, kidneys, heart and brain slows, possibly leading to collapse and death if the heart stops. When shock occurs in chelonians it must be treated.

Over the last year, in addition to treating injuries,

illnesses, infection, or dehydration, we have been treating chelonians for stress and shock, and this treatment definitely increases their chances for survival. Since we began treatment for stress and shock, we have seen a higher recovery rate in animals being treated for accidents and illnesses, as well as a higher success rate in acclimating new animals.

The drug we use to treat stress and shock is as follows:

Dexamethasone Injection (corticosteroid) (Pfizer) 2mg/ml — .03 to .20mg/lb subcutaneously every 24 hours - for 1 to 5 injections, as needed

Dexamethasone is an anabolic steroid with diverse metabolic and hormonal effects. It should not be used for more than five days in any one 30 day period, since it can suppress the immune system. Also, the dosage and number of injections should be based upon the severity of the symptoms and injuries. For example, the lowest dosage at one injection would be indicated for shipping stress in a long-term captive. For an animal with a badly broken shell the maximum dosage at five injections would be indicated.

Keep in mind that situations may occur that are both physically and psychologically stressful to an animal. For example, we had a dwarf tortoise which exhibited stress each time we had to force open her mouth to administer oral medication. In such a situation, injections of Dexamethasone at the lowest dosage were indicated and were certainly preferable to anesthesia.

In addition to its use for shock and stress, Dexamethasone is anti-inflammatory and anti-rheumatic, and is being used to treat lameness and inflamed joints in race horses and other animals. Our only experience with use of this drug for this purpose concerned a yellow foot tortoise who suddenly stopped using his rear legs. An x-ray revealed an old injury to the spine which may have become painful as the shell grew and exerted pressure, but no other problems were found. Treatment consisted of Dexamethasone at a dosage of .15mg/lb every 24 hours for 5 injections, repeated again 30 days after the last injection, with

monitoring for any improvement. After the first series of injections, this tortoise began using his rear legs, and had no relapse nine months later. If faced with a similar problem we will try this course of treatment again.

GENERAL MEDICAL INFORMATION

All dosages we use are for gross weight without any deduction for the shell. We give all subcutaneous injections in the loose skin at the upper rear portion of the front limbs, varying the injection site from limb to limb. We never use the same needle more than once unless it is sterilized between use, and a used needle should never be inserted in sterile medicine. For injectable drug administration we prefer Lo-Dose 1/2cc insulin syringes, manufactured either by BD or Monoject, with a 28 gauge, 1/2 inch needle, which are clearly marked in .01cc increments. The use of these syringes makes accurate measurement of minute drug dosages simple, and the small gauge needle easily penetrates the skin and leaves a minimal puncture wound.

When anesthesia of a chelonian is desirable or necessary, we have obtained excellent results with ketamine HCl (Vetalar) at a dosage of 20-40mg/lb subcutaneously, depending on the degree of anesthesia required. Ketamine, like any anesthesia, must be used carefully, since over-dosage will result in death.

As we have acquired more knowledge in the recognition, treatment, and care of medical problems in chelonians, we have learned there are many conditions which previously baffled us that we now know can be either avoided, controlled or cured. We consider it crucial to keep up with the latest research being done on reptiles and to try new methods, medicines, and ideas, hoping that next month or next year some new treatment will prove helpful.

MEDICINE DILUTION AND COMPUTATION OF DOSAGES

Drugs are usually furnished as powders or concentrated liquids. To prepare them for use, powdered drugs have to be reconstituted, and concentrated liquid drugs have to be diluted to a usable concentration. The bottle label and package inserts provide information concerning the actual strength or

concentration of the drug. Depending upon the amount of sterile saline added, the amount or concentration of the drug per cc varies. Because of this, a dosage in cc or ml would give no clue to the amount of actual drug given, as cc or ml measures only volume. For this reason, drug dosages are set forth in milligrams. A designation of mg/ml indicates the number of milligrams in each cc of the drug, such as:

250mg/ml = 250mg per 1cc
100mg/ml = 100mg per 1cc
50mg/ml = 100mg per 1cc

Common terms used to measure strength of drugs are:

gr (gram)
mg (milligram)
1 gr is equivalent to 1,000 mg

Common terms used to measure volume are:

ml (millileter)
cc (cubic centimeter)
1 ml is equivalent to 1 cc

Usually drugs in powdered form contain either 500mg or 1 gram of drug per vial. When reconstituted with sterile liquid, the strength of each ml varies according to the volume of sterile saline added to the powered drug. To determine the volume of sterile saline to be added, divide the total number of mg's in the vial by the mg strength per ml or cc desired. The resulting figure is the number of cc's or ml's of sterile saline necessary to arrive at the desired concentration. For example, if a vial contains 1gr (1,000 mg) of drug, the following calculations would apply:

For 250mg/ml concentration, 4cc of sterile saline should be added (1,000 divided by 250 = 4). For 100mg/ml concentration, 10cc of sterile saline should be added (1,000 divided by 100 = 10). For 50mg/ml concentration, 20cc of sterile saline should be added (1,000 divided by 50 = 20). For vials containing 500mg of drug, the calculations would be as follows: for 250 mg/ml concentration (500 divided by 250 = 2cc), for 100mg/ml concentration (500 divided by 100 = 5cc), and for 50mg/ml

concentration (500 divided by 50 = 10cc).

When it is necessary to dilute the concentration of liquid medicines, the easiest way to figure the dilution is as follows: Divide the concentration per ml by the concentration per ml you desire. For example, 250mg/ml to be diluted to 50mg/ml (250 divided by 50 = 5), 100mg/ml to be diluted to 50mg/ml (100 divided by 50 = 2), or 100mg/ml to be diluted to 10mg/ml (100 divided by 10 = 10). The resulting number indicates the total number of equal parts required for the dilution. One part is always the amount of medicine and the remaining parts are always the dilutent. The parts can total any number, just so each part is equal, for instance:

5 parts = .20cc drug (1 part) plus .80cc dilutent (4 parts), or .50cc drug (1 part) plus 2cc dilutent (4 parts), or 1cc drug (1 part) plus 4cc dilutent (4 parts).

2 parts = .50cc drug (1 part) plus .50cc dilutent (1 part), or 1cc drug (1 part) plus 1cc dilutent (1 part).

10 parts = .10cc drug (1 part) plus .90cc dilutent (9 parts), or .50cc drug (1 part) plus 4.5cc dilutent (9 parts), or 1cc drug (1 part) plus 9cc dilutent (9 parts).

Having reconstituted a powder or diluted a concentrated liquid to the required concentration, the next step is to figure the actual volume of the drug to be given. Although many dosages are given in mg/kg (a kilogram equals approximately 2.2 lbs), our dosage chart uses mg/lb. To convert a mg/lb dosage to cc/lb, simply divide the dosage by the medicine strength. For example:

5mg/lb divided by 10mg/ml = .50cc/lb
5mg/lb divided by 25mg/ml = .20cc/lb
5mg/lb divided by 50mg/ml = .10cc/lb
5mg/lb divided by 100mg/ml = .05cc/lb
10mg/lb divided by 50mg/ml = .20cc/lb
25mg/lb divided by 50mg/ml = .50cc/lb
30mg/lb divided by 50mg/ml = .60cc/lb

The resulting figure is the volume measurement (cc) to be administered for each one pound of weight. To figure the volume dosage for an animal weighing over 1 lb, multiply the 1 lb volume

by the number of pounds of weight, such as 2.75 lbs times .05cc/lb = .1375 or .135cc, 4.5 lbs times .10cc/lb = .45cc, or 6.25 lbs times .05cc/lb = .3125 or .31cc. To figure the volume dosage for any animal weighing under 1 lb, divide the 1 lb volume by 16 (oz in a lb) and multiply the answer by the number of oz of weight, such as .05cc/lb divided by 16 = .003125cc/oz times 9oz = .028125 or .03cc, .10cc/lb divided by 16 = .00625cc/oz times 7 oz = .04375 or.045cc, or .20cc/lb divided by 16 = .0125cc/oz times 5 oz = .0625 or .065cc. Generally you can round off to the nearest hundredth (.00) of a cc (round off the figure higher for animals weighing under a pound, and lower for animals weighing over a pound) although we usually try to round off to the nearest thousandth (.000) of acc, especially when using drugs that can be toxic.

Always be extremely careful with arithmetic and decimal points, as a mistake varies the amount of drug by a factor of ten and results in an incorrect dose being given. If you are ever in doubt about the exact amount of a drug to be given, verify your calculations with a knowledgeable person.

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