CAPTIVE PROPAGATION AND HUSBANDRY OF REPTILES AND AMPHIBIANS

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Edited by Ralph L. Gowen

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Preface

This volume represents the end point of the Northern California Herpetological Society's Fourth Conference on the Captive Propagation and Husbandry of Reptiles and Amphibians held February 18-20, 1989. To reach this point was a tremendous undertaking that required countless man-hours from many selfless volunteers. We would like to acknowledge a number of people for their help and assistance in various phases of this conference. Heino Kemnitz was instrumental in the planning of the dinner and in arranging the motel and banquet room. Sam Bacchini, John Berger and David Muth had the formidable task of organizing the registration. Tom Sinclair and James Rexroth helped tremendously with coordinating the speakers who presented papers at the conference. James Rexroth also coordinated the advertising of the program. These people formed the nucleus of the NCHS conference committee and can be thanked for the success of the event.

The ultimate goal of this conference and its proceedings is to disseminate inormation on reptile and amphibian care that is useful to all herpetoculturists. We feel these proceedings exemplify this endeavor. We have tried to keep each author's style intact while molding their papers into a cohesive volume. Rick Staub and Dale DeNardo assisted greatly in the process of reviewing the papers for this volume. Tom Greek redrew many of the line drawings included in this volume.

As usual our failing memories have almost certainly allowed us to omit mentioning someone worthy of recognition for their efforts. To this end, we apologize.

Gerold Merker
Ralph Gowen
Conference co-Chairmen

On the Cover

The spotted turtle (*Clemmys guttata*) is one of the most elegant turtles found in the United States and has been used as a surrogate to help study the bog turtle (*Clemmys muhlenbergii*). Photo by David Collins

On the Back Cover

The bog turtle (*Clemmys muhlenbergii*) is one of the rarest of North American turtles. Photo by David Collins. The Mandarin ratsnake (*Elaphe mandarina*) is one of the most colorful of its genus; however, it has proven to be a difficult species to maintain in captivity. Photo by Bill Gillingham.

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Northern California Herpetological Society

The Northern California Herpetological Society is a federal and state non-profit organization dedicated to conservation, education and research of reptiles and amphibians. Founded in 1981 by a group of students at the University of California at Davis, it has grown into a society with members across the United States. NCHS held its first symposium on the Captive Breeding and Husbandry of Reptiles and Amphibians in 1983 and has held one every two years since.

Membership is open to anyone with an interest in reptiles and amphibians. Members of NCHS receive a monthly newsletter which contains primarily original articles written by the society's membership. NCHS meets on the first Wednesday of every month on the campus of the University of California, Davis.

Proceedings are available from each of the symposia. For current prices and further information about NCHS write to:

Northern California Herpetological Society
P. O. Box 1363
Davis, California 95617-1363

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Husbandry and Propagation of Salamander Species at the Cincinnati Zoo

Edward J. Maruska
Cincinnati Zoo
3400 Vine St.
Cincinnati, OH 45220

Introduction

In 1978, the Cincinnati Zoo and Botanical Garden opened Insect World, a unique, specialized exhibit building for the display of invertebrates with an emphasis on insects. The first building of its kind in the United States, Insect World was well received locally and remains one of our zoo's most popular exhibits. It has gained an international reputation with crews from Japan, Germany, France, Great Britain and Canada filming here. Like many invertebrates, amphibians have traditionally been a sadly neglected class in zoo exhibition, generally being relegated to a corner of the reptile house or aquarium.

Amphibians are not widely seen in large and varied numbers in most zoological parks and aquariums because of their exacting husbandry requirements. Nonetheless, amphibians are an incredibly diverse group ranging from the bizarre to the beautiful. Some species have a range of colors and splendor that rival the most exotic birds, reptiles, or fish. Amphibians come in all shapes and sizes and many have fascinating life histories. Taking all the above into consideration, the Cincinnati Zoo staff began to plan for another specialized zoo exhibit solely for amphibians.

In order for us to portray life histories and to prevent our exhibit building from becoming an excessive drain on wild populations, it would be necessary to propagate a wide variety of species. Some amphibians are a widely used resource in biomedical research and educational studies. Though interest is long-standing, for many species little attention had been focused on captive breeding with any regularity except for a few commonly bred species such as the clawed frog (*Xenopus sp.*), leopard frog (*Rana pipiens*), axolotl (*Ambystoma mexicanum*), Asiatic fire-bellied toad (*Bombina sp.*), and various species of newts (*Pleurodeles sp.* and *Triturus sp.*).

The conditions necessary for culturing a wide variety of amphibians are only now being studied in detail. The breeding of any amphibian species, even in many large zoological institutions, is often the exception rather than the rule. Although a greater number of species of anurans are now being bred with regularity, captive breeding of a wide range of salamander species is still uncommon. Except for the Mexican axolotl used extensively in biomedical research, amphibians in the order Caudata have been sadly neglected in terms of captive husbandry and exhibit potential.

Husbandry

The well over three hundred forms of salamanders present quite a variety in form, size, and colors, as well as habits and habitats. With the recognition of the great variation of species and their ecological differences, it immediately becomes apparent that no hard fast rules can be established to provide breeding parameters for the entire order. Not only may the necessary captive accommodations vary from species to species, including temperature range, foods and feeding schedule, but there may be variations in the disturbance of various physiological rhythms, seasons, and time tables which stimulate courtship and eventual mating.

The influence of light, humidity, and temperature upon urodele breeding behavior is still not completely understood for the majority of species. Too much or too little variation in the above may be responsible for the failure of many species to breed in captivity. More research and experimentation both in the field and laboratory is needed in this area.

The Cincinnati Zoo has probably bred more species of salamanders than any other institution, but space does not permit going into great detail on all of our separate species' successes. Instead, I will cover some general husbandry practices that will be applicable to any amphibian propagation effort and elaborate on some of our notable successes.

It was often said when keeping amphibians, "If you err with temperatures, err on the cool side." As a result of this fallacy, many amphibian exhibits are designed as walk-in refrigerators and amphibian species are kept with little consideration given to the species' natural habitat. Amphibians are found from the equator to the arctic circle. With all the variety of habitats throughout this range, it is not surprising that one species will live and thrive in conditions which may prove fatal to another.

Most commonly kept species of salamanders are native in the temperate latitudes. I have found through experience that three ranges of temperatures are suitable to keeping a world-wide variety of salamander species. The following charts denote some of the genera that thrive in these temperature gradients.

Cool Temperatures - 7-16°C; 45-60°F

Family	Genera
Ambystomatidae	*Ambystoma*, *Dicamptodon*, *Rhyacotriton*
Salamandridae	*Chioglossa*, *Euproctus*, *Neuregus*, *Salamandra*
Proteidae	*Proteus*
Plethodontidae	*Aneides*, *Bolitoglossa*, *Desmognathus*, *Eurycea*, *Gyrinophilus*, *Hemidactylium*, *Hydromantes*, *Plethodon*, *Pseudoeurycea*, *Typhlotriton*

Moderate Temperatures - 16-22°C; 60-72°F

Family	Genera
Ambystomatidae	*Ambystoma*, *Rhyacosiredon*
Salamandridae	*Cynops*, *Mertensiella*, *Notophthalmus*, *Pachytriton*, *Paramesotriton*, *Pleurodeles*, *Salamandra*, *Salamandrina*, *Taricha*, *Triturus*, *Tylototriton*
Plethodontidae	*Bolitoglossa*, *Haideotriton*, *Pseudoeurycea*, *Stereochilus*, *Typhlomolge*
Proteidae	*Necturus*
Cryptobranchidae	*Andrias*, *Cryptobranchus*

Warm Temperatures - 22-29°C; 72-85°F

Family	Genera
Salamandridae	*Notophthalmus*
Sirenidae	*Pseudobranchus*, *Siren*
Amphiumidae	*Amphiuma*
Plethodontidae	*Bolitoglossa*, *Oedipina*
All species of caecilians	

Terrestrial salamanders are best exhibited in a terrarium representing a slice of the animal's natural habitat enclosed in glass. Avoid bright light and direct sunshine in any amphibian exhibit. One must be careful of the degree of dampness provided, since the tolerance may vary for different species. Again, knowledge of the general habits and needs of your amphibian is essential if the proper environmental conditions are to be established.

Most salamanders are negatively phototrophic and strongly thigmomatic, and as a result of this behavior, most have traditionally been excluded from exhibition as poor display animals. Contrary to this, I have found that after a reasonable period of adjustment, many salamanders will remain visible throughout the day sitting on a well-placed rock or piece of bark, if their enclosure is illuminated with subdued lighting.

Aquatic species are best kept in aquaria. Aquarium set ups for aquatic salamanders should be equipped with substrate filtration, similar in design to those popularly used by the home aquarium hobbiest. The substrate used may vary from natural gravel to river stones, depending on the species.

Dechlorinated water (tap water is dechlorinated by adding a few crystals of sodium thiosulfate per gallon - 1/2 tsp/60 l) is recommended, as chlorine may damage the delicate external gills that occur in some species. Sturdy aquatic plants such as broad or curly pondweed (*Potamogeton sp.*) or willow moss (*Fontinatis antepyretica*)

may be used to decorate the exhibit and screen against excessive light. Precautions should be taken to anchor plants with lead weights or rocks to prevent them being uprooted by the tank's inhabitants.

Feeding

The success in keeping a captive animal depends on whether it feeds regularly. Again, we need to know something about the species we are keeping to determine the proper food to offer. Some salamanders in the family Plethodontidae have evolved protrusible, bell-shaped tongues to aid in catching insect prey. This tongue mechanism is highly developed in *Ensatina*, *Bolitoglossa*, *Pseudoeurycea*, *Hydromantes*, and to a lesser extent in *Plethodon*. Some salamanders like *Ensatina* and *Bolitoglossa* prefer insect prey (appropriate sized crickets) to other foods offered. Avoid feeding meal worms to most amphibians because of their hard chitonous body covering. Instead, fill out their diet with maggots or fly larvae.

The most popular salamander food is worms. Dug or red worms and earthworms (night crawlers) are the food preferred by most salamanders. Red worms and night crawlers can easily be acquired from wholesale bait suppliers. Avoid manure or tiger worms sold by most bait stores. Most amphibians would rather starve to death than eat them. These worms can be identified by their light bands and the foul odor they produce when broken.

Hormonal Induced Reproduction

Within the past ten years, there have been many advances in amphibian husbandry as more zoo herpetoculturists devote more time and energy to the problems of controlled reproduction. Hormonally induced breeding has aided in the captive reproduction of some species. Although hormones are valuable tools in some amphibian reproduction, they should not be looked upon as a panacea to all problems in captive breeding and should only be used when it is difficult to elicit natural breeding or egg deposition. There are basically two types of hormonal stimulants that have been readily used on amphibians. Pituitary extracts and synthetic gonadotrophic hormones are used (Johnson, in press) to stimulate the gonads. In recent years, releasing hormones, which give the pituitary a pulse that in turn stimulates the secretion of gonadotrophins, have been used in a variety of vertebrates (Wagner, pers. comm.). They show much potential for hormonally inducing amphibian reproduction.

Even with the use of releasing hormones, subtle changes in captive environmental conditions must be achieved to reach reproductive physiological readiness of the amphibian one hopes to breed. Only when the proper conditions of the immediate surroundings - including wet and dry periods, changes in photoperiod and temperature, or fluctuations in humidity - are satisfied, may hormonal induction result in fertile eggs (Beach, 1951).

In Vitro Fertilization

In ambystomatid salamanders the technique of in vitro fertilization is used widely under standard laboratory conditions today. This method of obtaining artificially fertilized spawn can be used effectively to produce large numbers of offspring from a limited number of parent stock. Humphrey (1962) clearly describes the methodology and dosages of follicle stimulating hormone (FSH) in his paper on the Mexican axolotl feeding, and care of adults and young.

Reproduction at the Cincinnati Zoo

Captive breeding of any species of the Plethodontidae is a rare occurrence; however, we have had a reasonable amount of success with this family at the Cincinnati Zoo. Five specimens of slimy salamanders (*Plethodon glutinosus*) were collected in Ohio in 1970. On August 18, 1976, a female was observed affixing her eggs to the under and top sides of a piece of cork bark. She laid a total of 23 eggs (average diameter 7.6 mm). Because the eggs were scattered, they were removed along with the female to a plastic crisper lined with damp paper towels. Eggs and female were removed without apparent disturbance when the towel substrate was changed. During the first two months of incubation, the temperature was maintained at approximately 13°C. In the ensuing month, the temperature dropped to between 6-8°C, and the embryos seemed to suffer because of this decrease and gradually all were lost even though the temperature was again raised to 13°C. This female devoured all of her subsequent eggs.

A number of temperate terrestrial species of the family Plethodontidae have laid egg clusters that failed to develop, apparently because the female abandoned the eggs. After the females ceased brooding behavior, the eggs would soon develop a layer of fungus. The following species have laid eggs that failed to reach full development: *Hydromantes italicus*, *Plethodon jordani*, *Ensatina e. ensatina*, *Ensatina e. klauberi*, *Phaeognathus hubrichti*.

The Tennessee cave salamander (*Gyrinophilus palleucus*) occurs in Alabama and Tennessee. Nothing was known of the reproductive habits of this cavernicolous species until a female *Gyrinophilus p. necturoides* was observed fastening her eggs to the underside of a rock on the evening of June 10, 1984 at the Cincinnati Zoo. She laid a total of 70 eggs depositing the majority in clusters attached to the bottom of the rock, and fastening the rest randomly to gravel and the aquarium airlifts. Each egg was enclosed in several layers of a transparent jelly-like mass which in total measured about 9 mm. The female has been in the zoo's collection since 1973. The male *Gyrinophilus p. palleucus* was collected in Tennessee in 1978. The majority of the eggs were lost to a fungal infection probably resulting from oxygen deprivation. One egg survived and the larva hatched at a water temperature ranging from 10-12°C on August 13 and measured 18 mm total length. Although ovarian eggs were visible through the transparent underside of the female in each of the previous four years during the Fall no reproduction occurred. A complete water change may have provided some stimuli for this year's reproductive success. Perhaps subtle chemical changes may trigger reproduction in cave-dwelling species, such as those caused by surface run-off during Spring or Fall storms which invades the otherwise stable cave system. Excess rainwater also carries nutrients into the cave system which starts the food chain ensuring abundant food for the larvae.

Giant Salamanders

Giant salamanders of the genus *Andrias* were once more widely distributed over the Northern Hemisphere. Fossils have been found from formations of the Oligocene, Miocene, and Pliocene epochs of Europe; the lower Eocene (60,000,000 to 70,000,000 years ago), through the Miocene in North America. Today only two living forms remain, the Japanese giant salamander (*Andrias japonicus japonicus*) occurring in the highlands of the western part of Japan, and the Chinese giant salamander (*Andrias japonicus davidianus*) in the mountains of western China. Both forms are listed as International Union for the Conservation of Nature (IUCN) endangered species and from personal communications with Dr. Jiro Kobara, the former Director of the Asa Zoo, and Dr. Li Yangwen, the Director of the Beijing Zoo, it seems that both forms could disappear within 50 years if present environmental changes continue.

After a number of unsuccessful trials by Kobara, the Japanese giant salamander was bred successfully in September of 1979 at the aquarium in the Asa Zoo. They kept four males and two females in four tanks 90 x 70 x 45 cm linked together by pipes (15 cm in diameter) and arranged in a circle so the animals could move about freely (see Figure 1). They set shelters in three tanks and water was circulated from a nearby stream,

establishing the following conditions: water temperature 4-20°C; pH 5.7; dissolved oxygen 8.5 (13.8°C); water circulation 12.8 l/min. On September 28, 1979, 1224 eggs were discovered in the breeding chamber. The eggs were deposited by the two females. The eggs hatched after an incubation of between 48-57 days.

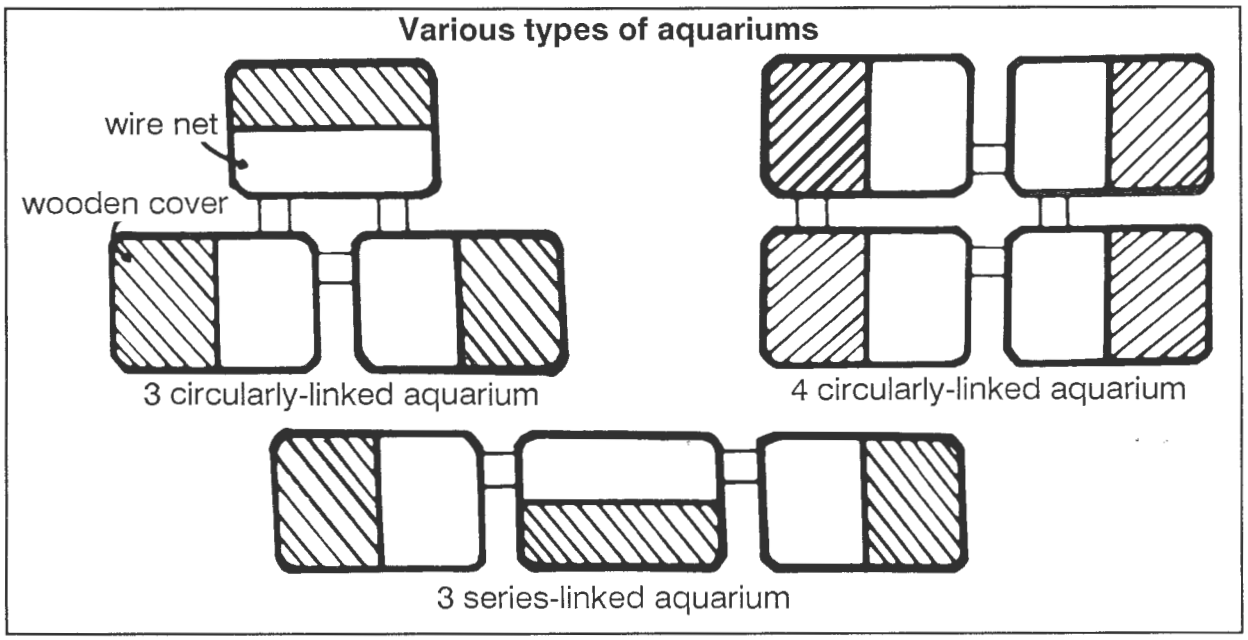

Figure 1 - Japanese giant salamander enclosure

Kuwabara et al. (1979) have described the reproductive behavior of *Andrias* in its natural habitat from field observations made between August 31 and September 3, 1978. They observed more than 27 animals congregated around a nesting site. A dominant male exclusively guarded the nest cavity and demonstrated territorial behavior, but would allow conspecific males to enter when a gravid female entered the nest. They observed five females enter the nest site to lay eggs, one followed by another. All five egg-laying sequences were similar and followed the same pattern. As a female ventured into the nest, several males followed. The territorial male and several other males took part in the courtship and spawning. Throughout the observation period, the giant salamanders' courtship activity was highest in the daylight hours. Males were also observed to be more active than females.

The Asa Zoo attributes its successful breeding to the following important conditions: Animals are kept in a group consisting of several females and males, not in separate pairs. The tanks are connected in a series so animals can move about freely and, if necessary, avoid each other. They are fed live food, loaches in this case. Artificial nest boxes are provided. After the first breeding in 1979, the animals bred for four succeeding years.

The larvae were raised under a variety of experimental conditions and fed a variety of foods starting with midge larvae, graduating to tadpoles, minnows, worms, and strips of beef liver (Kobara, pers. comm.). We have long had interest in propagating the Japanese giant salamanders and received several shipments of *Andrias j. japonicus* from the Asa Zoo and Aquarium containing a total of 30 specimens. A number of these are now reaching sexual maturity, and we have every hope of a successful reproduction with this species.

Texas Blind Salamander

One of the world's most highly specialized species of cavernicolous salamanders, the Texas blind salamander (*Typhlomolge rathbuni*) reproduced for the first time under laboratory conditions at the Cincinnati Zoo. The following account is based on three different spawnings deposited December 10, 1979, January 5-6, 1980, and October 24, 1980. Clutch size varied from 8 to 21 eggs.

The eggs (2 mm vitellus) were unpigmented and randomly attached to the aquarium airlift and substrate singly or in clusters of two or three eggs. No parental care of eggs was apparent. Eggs from the first clutch were placed under different controls of temperature and light intensities to determine the best conditions for embryonic development and hatching. Relatively high light intensity is not detrimental to the development of the embryo; however, it appears that a relatively constant water temperature approaching that of the cave habitat (21°C) is necessary for normal embryonic development. The newly hatched larvae (11-12 mm TL) had lightly scattered melanophores over much of their body surface. Undeveloped limbs and a prominent eye were distinctive at this stage.

The larvae rapidly assumed characteristics of adults (i.e., attenuated limbs and elongated snouts); however, pigmentation of the body persisted. As the months proceeded, the larval eyes were reduced in proportion with the growth of the head and pigmentation gradually diminished. *T. rathbuni* is a species that can be managed successfully in the laboratory when the proper environment for reproduction is maintained.

I hope the successful laboratory breeding and rearing of *T. rathbuni* and *G. palleucus* will encourage studies on the other taxa heretofore considered too difficult to maintain. The compilation of detailed documentation of life history information, which is lacking for most of the cavernicolous species of salamanders of the family Plethodontidae, appears to be well within the grasp of the inquisitive researcher.

Ambystoma Species

On Mexico's Neo-volcanic Plateau, there are a number of unique crater lake populations of neotenic ambystomatid salamanders. Some species are endemic to a single crater lake, and any disturbance to such a lake, like the introduction of non-native fish or pollution, could easily result in the loss of an entire population. The Lake Patzcuaro salamanders (*Ambystoma dumerilii*) suffered a decline in numbers when bass were introduced as a food fish. These salamanders are also fished heavily as a food item and for alleged medicinal properties. *A. dumerilii* is classified as IUCN endangered and is listed as a Convention on the International Trade in Endangered Species (CITES) Appendix II animal. A small breeding colony is being maintained at the Cincinnati Zoo.

The Lake Alchichica salamander (*Ambystoma taylori*), formerly *subsalsum* (Brandon, Maruska and Rumph, 1981), is restricted to the briny Lake Alchichica whose water approaches the specific gravity of sea water. Our experience with this species has been less than promising. A group of 20 animals collected September 15, 1979 lived for a year at the Cincinnati Zoo in a 55-gallon tank in artificial Lake Alchichica water mixed to match the salt composition reported by Taylor (1943). A second group of ten animals collected May 28-30, 1980, maintained under similar conditions died of a bacterial infection. A third group of about 30 animals, collected July 12-14, 1981 under excellent field conditions and accompanied throughout the transportation period to the Cincinnati Zoo, were also lost over a several year period and only one animal survives at this time.

The newly described Lake Zacapu salamander (*Ambystoma andersoni*) (Krebs, 1984) is restricted to Lake Zacapu in the state of Michoacan and was bred for the first time under natural conditions at the Cincinnati

Zoo in 1983. With proper nutrition and water conditions that simulate their natural lake's habitats, it should be possible to propagate any of the above species in captivity.

Conclusion

Our captive salamander research project began in 1970 and many of the original salamander stock is still alive at the time of this writing. Some examples are: *Plethodon glutinosus*, *Plethodon elongatus*, *Gyrinophilus palleucus*, *Phaeognathus hubrichti*, *Pseudotriton ruber*, *Desmognathus welteri*. Other species we have maintained at least for 10 years or more are as follows: *Plethodon cinereus*, *Typhlotriton spelaeus*, *Eurycea lucifuga*, *Eurycea longicauda*, *Typhlomolge rathbuni*, as well as various *Hynobius*, *Triturus*, and *Salamandra*.

Advances in zoological park and aquarium amphibian husbandry in recent years have been gratifying, especially the attention and effort expended to seek and provide the proper and often multi-facted inducers or stimuli necessary to trigger ovulation and successful reproduction in a wide variety of species being kept. If we are to accomplish sustained multi-generational captive reproduction of endangered amphibia, we must understand their nutritional requirements, photoperiods, optimal temperature and humidity requirements, and the myriad of variations of reproductive modes of these diverse species.

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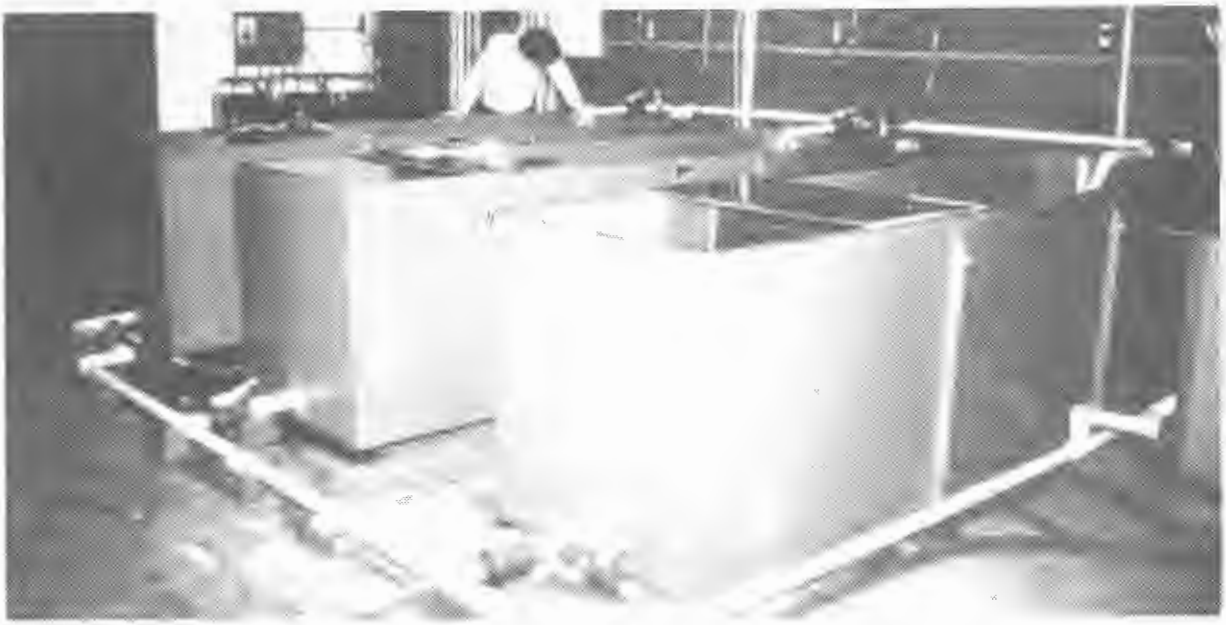

Japanese giant salamander enclosures

Frog Madness: Breeding Experiments with Ceratophryne Frogs

Philippe de Vosjoli and Robert Mailloux
P.O. Box 76
Lakeside, CA 92040

Introduction

Since 1984 we have been working extensively on the development of methods for the maintenance and propagation of tropical frogs, with a special emphasis placed on the leptodactylid frogs of the subfamily Ceratophrynae. This paper was titled "Frog Madness" in reference to a period of exalted thinking where all our beliefs regarding the scientific views on hybridization were temporarily suspended. Wild thoughts ran through our minds as to the possibilities of a type of herpetocultural engineering that would lead to the development of a new field of biological art - the creation of custom designed frogs of extraordinary form, beauty, and genetic character. All these demented processes were triggered in early 1988 by the importation of what was probably the first group of the Chacoan horned frog (*Ceratophrys cranwelli*) brought into the United States since their description as a new Ceratophryne species (Barrio, 1980).

Previously *C. cranwelli* had been considered the diploid form of the well known Argentine horned frog (*Ceratophrys ornata*), an octoploid species. We were fortunate enough to receive the first of the imported *C. cranwelli*, thanks to Dr. Luis Magnasco, a friend who in late 1987 set out on a collecting expedition to find this species. Subsequently, other specimens were brought into the United States through commercial herptile channels. The primary reason for our initial excitement was that we finally had obtained a diploid *Ceratophrys* that would allow us to test the relationships and genetic compatabilities of certain Ceratophrynes, particularly the possible role of hybridization in the evolution of the two octoploid species, the Brazilian horned frog (*C. aurita*) and the Argentine horned frog (*C. ornata*). Underlying any scientific interest in these matters was an intense herpetocultural excitement and curiosity as to the offspring these breeding experiments would generate. This paper describes our preliminary experiments with these frogs.

Systematics of the Ceratophrynae

To elucidate any confusion regarding current views on the systematics of the Ceratophrynes and for the purpose of clarifying the nature of our breeding experiments, figure 1 contains an overview of the subfamily Ceratophrynae.

Polyploidy in the Ceratophrynes

Two species of Ceratophrynes are known to be polyploids, *C. aurita* (Becak et al., 1967) and *C. ornata* (Becak et al., 1966). Polyploid amphibians carry several sets of respective genes through an abnormally high number of chromosomes. Most animals are diploid inheriting one set of chromosomes from a male and one set from a female. Polyploidy in amphibians may occur either as the result of the hybridization of two or more

Family: Leptodactylidae
Subfamily: Ceratophrynae

Genus: *Ceratophrys*	- 6 species	
Subgenus: *Ceratophrys*	- 3 species	
Ceratophrys aurita.		Southeastern Brazil from Minas Gerais and Bahia to Rio Grande do Sul : Ploidy = Octoploid. 26 x 4 = 104
Ceratophrys cranwelli.		Chacoan region of Argentina, Bolivia, Brazil and Paraguay. Ploidy = Diploid. 26
Ceratophrys ornata.		Pampean region of Argentina, Uruguay and Rio Grande do Sul, Brazil. Ploidy = Octoploid. 26 x 4 = 104
Subgenus: *Stombus*	- 3 species	
Stombus calcarata.		Northeastern Columbia and Venezuela. Ploidy = Probably diploid. 26
Stombus cornuta.		Southern Venezuela, Brazilian Amazonia and the Guianas. Ploidy = Diploid. 26
Stombus stolzmanni.		Northwestern Peru and the Gulf of Guayaquil, Ecuador. Ploidy = Probably diploid. 26
Genus: *Chacophrys*	- 1 species	
Chacophrys pierrotii.		Chaco region, Argentina. Ploidy = Diploid. 26
Genus: *Lepidobatrachus*	- 3 species	
Lepidobatrachus asper.		Chaco of Paraguay and northern Argentina. Ploidy = Probably diploid. 26
Lepidobatrachus laevis.		Chaco of Paraguay and northern Argentina. Ploidy = Probably diploid. 26
Lepidobatrachus llanensis.		La Rioja and Formosa Provinces, Argentina. Ploidy = Diploid. 26

Figure 1 - Overview of the subfamily Leptodactylidae. This information was gathered from Frost (1985) except for the addition of *Chacophrys pierrotii* which was added from a paper by Maxson et al. (1988). The ploidies were obtained or hypothesized from Duellman et al. (1986) and Bogart (1967).

species (allopolyploidy) or it may occur spontaneously in a single species (autopolyploidy). According to Duellman et al. (1986), "Presumably most if not all polyploid species of amphibians are allopolyploids". In many cases, the polyploids exist in at least partial sympatry with closely related diploid congenerics (e.g. octoploid *C. ornata* with diploid *C. cranwelli*). A key puzzle to us concerned *C. aurita*. If this animal was an allopolyploid, what was its closely related congeneric? Furthermore why did *C. aurita* have the basic dorsal pattern of *C. cornuta* and "horns" intermediate in size between *C. cornuta* and *C. cranwelli*? Indeed what would happen if one crossed *C. cornuta* with *C. cranwelli*? As for *C. ornata*, we wondered what would happen if we crossed *C. cranwelli* with *C. ornata*? And if we obtained viable offspring, what would we obtain back-crossing hybrid F1 with respective parent species or crossing F1 hybrids with each other?

The key trigger had in fact been allopolyploidy. If hybridization was a mechanism by which some frogs could evolve into independent bisexual polyploid species, then maybe any preconceptions regarding hybridization in frogs should be ignored.

Procedure

Our approach to these breeding experiments was strictly pragmatic. Based on our previous work with the breeding of Ceratophrynes (de Vosjoli et al., 1986 and 1987), we induced breeding in all of the species mentioned by injecting the individual animals with the luteinizing hormone releasing hormone, LHRH(D alanine, 6 des-gly 10 ethylamide), at a dosage of 0.1 mg/kg for females and 0.01 mg/kg for males. Following the injections, we placed the frogs into 63.5 cm x 48.3 cm polyethylene bins containing well water of moderate hardness and a pH ranging from 7.4-7.6. The water level was just below the dorsal surface of the smallest animal at rest. Room temperature ranged between 25-28°C.

Breeding, when it was successful, usually occurred within 24 hours of the hormone injection. Adults were removed from the enclosure within a few hours of breeding completion. Well water was slowly added to the breeding bin to a depth of 0.5 cm and an air stone connected to an aquarium pump was placed in the water to provide aeration. If the eggs were clumped or deeper than a single layer on the bottom of the enclosure, we would stir them with our hand to spread them into as close to a single layer as possible. In our experience eggs of Ceratophrynes will fail to hatch when they are not distributed in a single layer. In most, but not all cases, fertilized eggs distributed themselves in a single layer on a bottom surface and did not readily adhere to each other, probably through a mechanism of membrane polarization. With hybrid breedings, we have found clumping and adhesion to be common. Manually unclumping and distributing hybrid eggs significantly increases hatch rates without apparent harm to the embryos if done once during the early stages of development.

Larvae

To accommodate the tadpoles, the water level was increased to 10 cm within 24 hours of hatching. Food in the form of live, thoroughly rinsed (for at least 24 hours) blackworms were offered within 72 hours of hatching. At that time, all tadpoles are distributed in additional bins at a density of 10 tadpoles to the gallon. Live blackworms were offered daily and at least one fifth of the water changed daily in conjunction with the siphoning of wastes and residues from the bottom.

At a room temperature ranging from 25-28°C, the first metamorphosing frogs will emerge within 21 days. The froglets are first placed in sloped containers which prevent drowning and yet supply enough water while they are absorbing the tail. The froglets can be kept in groups, in large shallow polyethylene containers with lids, as long as they are fed at regular intervals (every 48-72 hours) and their water is changed daily. Froglets are fed tiny sections of catfish fillet dipped in a vitamin powder/calcium carbonate mix. The frogs are fed from the end of tweezers or they are force fed with a plastic wedge until they are large enough to feed on live day old mice.

Breeding # 1 *Ceratophrys cranwelli*

This species bred readily following the standard procedure. Female response to LHRH is rapid, about twice as fast as that of *C. ornata*, with egg-laying occurring as early as 8 hours after injection. As a rule, only a few hundred eggs are laid, usually less than 600. The tadpoles are more sensitive to cold temperatures than those of *C. ornata*. In our first breeding of this species in January 1988, we obtained froglets with a wide variety of colors including what appeared to be mutations. Subsequent breedings of *C. cranwelli* have confirmed that

there are probably a range of genetic color lines that can be bred selectively. At least some of these lines are phenotypically expressed in the wild (see Figure 2).

a) Brown phase - typical wild type with faded spots in mature females.
b) Green phase - similar to brown phase, but a dull green.
c) Bright green phase with clearly defined brown spots
d) Reddish phase - reddish or orange between spots with a creamy colored background.
e) Green paint phase - In some wild types. Essentially a brown phase with bright splashes of green on the dorsum. Often a reddish color makes up the background.
f) A probable mutation - Nearly patternless green. Absence of stripes on hind limbs. Weak, stunted strain.
g) Another probable mutation - Bright green, highly spotted. A lot like *C. ornata* in appearance, but unmistakably different. Another weak, stunted strain.

Figure 2 - Our current summary of *C. cranwelli* lines

One of the most interesting aspects of rearing many of the *C. cranwelli* froglets is that captive raised adults are markedly brighter and stouter in appearance than imported adults. In fact, they look almost like a different species. For the time being, we are attributing these differences to external growth regulating factors. We suspect that our captive rearing conditions combined with a frequent and regular feeding schedule affect both bone and skin development in a manner significantly different than the harsh conditions of the Chacoan habitats of *C. cranwelli*. Our initial success with this species played a critical role in the breeding experiments that followed.

Breeding #2 *Ceratophrys cranwelli* x *Ceratophrys ornata*

We have tried this hybrid breeding once using a male *C. cranwelli* and a female *C. ornata*. Over 2000 eggs were laid with what initially appeared to be almost 100% fertility. After 14 hours, a single tadpole was swimming amidst eggs barely showing embryonic development. The tadpole was isolated and raised separately and was dubbed Richard. Within 36-48 hours of laying the rest of the eggs hatched. Within the first two weeks, the majority of the tadpoles died.

123 tadpoles eventually metamorphosed after 25 to 45 days. The froglets resembled *C. ornata* froglets except for the large dense spotting on the dorsum. With age, Richard and one other sibling grew at a phenomenal rate, both reaching a snout-vent length of 12 cm in 6 months after hatching. The remaining froglets have grown to become rather stunted adult frogs with varying differences in pattern, head shape, hind limb proportions and in a couple of cases, neuromotor impairment.

An F2 breeding attempt using the two largest hybrids (both females) with hybrid males failed when tried 10 months after hatching. Though the males show clearly defined secondary sexual characteristics, they have failed to perform amplexus even when injected with twice the normal amount of LHRH. The large females failed to produce eggs. Future breeding attempts should determine whether the failure of the hybrids to breed was due to immaturity or sterility.

Breeding #3 *Ceratophrys cornuta* x *Ceratophrys cranwelli*

For this cross, we used a male *C. cornuta* and a female *C. cranwelli*. The standard breeding procedure was employed, except that the male was manually placed on top of the female approximately 3 hours after injection. The results of this hybridization were surprising, partly because we had believed that it would be successful suspecting the possible role of *C. cornuta* in the background of *C. aurita*. To our knowledge, we are the first to have attempted this interspecific cross. Fertility was approximately 80% with a high degree of egg clumping, which we dispersed manually to a single layer to increase the hatching rate.

Within 36 hours, about 300 tadpoles hatched, which we raised using standard *Ceratophrys* rearing procedures. About 190 of these eventually metamorphosed into froglets, which at first, vaguely resembled *C. cornuta* froglets. In addition, the froglets had a fine graininess to their skin that made them look almost velvety at times.

The most unusual feature of these froglets was their color. The majority had a bright green to yellow green background dorsal coloration with orangish and maroon along their sides. Some had salmon pink spots over the eyes and snout. Some had a pink background coloration with maroon or red or both. Others were green with bright pink or orange along the side. Some were brown with bright orange. In short, these were the most beautiful *Ceratophrys* we had seen to date. All the froglets also had tiny horns over the eyes which eventually grew to a size intermediate between *C. cornuta* and *C. cranwelli*.

Breeding was attempted at 10 months between the largest sexual pair. While the female failed to produce eggs, the male performed amplexus. We hope that a later breeding attempt will prove successful. For those who are concerned that these hybrids could one day be confused with pure *C. cornuta*, one feature of these frogs is a fail proof indicator of their hybrid origin - their throats are whitish or grayish with some dark mottling while the throats of *C. cornuta* is black in both males and females.

Breeding #4 *Ceratophrys cornuta* x *Ceratophrys ornata*

We attempted this cross a number of years ago using a *C. cornuta* male and a *C. ornata* female. Only 30 tadpoles hatched from this cross with 7 surviving to metamorphosis. The froglets resembled aberrant *C. ornata*; some with a bright, almost pure yellow background coloration. Four of the froglets survived until six months after hatching. We attempted to repeat this cross once with no success.

Breeding #5 *Ceratophrys cranwelli* x *Lepidobatrachus laevis*

This breeding was attempted in order to test the hypothesis of Lynch (1982) that *Chacophrys pierrotii* is in fact a natural occurring hybrid between *C. cranwelli* and *L. llanensis*. This has recently been refuted by Maxson et al. (1988).

In the first experiment, we used a male *L. laevis* and an adult female *C. cranwelli*. The problem we encountered was the impossibility for a male *L. laevis* to perform amplexus on a female *C. cranwelli*. The female is simply too large. The male *L. laevis* amplexes submerged while the dorsal area amplexed in *C. cranwelli* is usually above water. In a second experiment, the reverse was tried with a male *C. cranwelli* and a female *L. laevis*, but a similar problem occurred. The female *L. laevis* was too slippery for the male *C. cranwelli* to perform proper amplexus and she insisted on remaining submerged. On one occasion, we manually placed a male *C. cranwelli* on a female *L. laevis* and repeatedly replaced him until the female ejected a number of eggs. Some of these began to develop, but all tadpoles died at hatching. They looked similar to normal *L. laevis* tadpoles except for their small size.

On another occasion, the same experiment was repeated with the same problems. We decided to place the amplexing male *C. cranwelli* on a non-injected *C. cranwelli* female in close proximity to the laying female *L. laevis*. Again, we had signs of development in some of the eggs and the hatching of a few *L. laevis*-like tadpoles which all died within 24 hours.

Conclusion

Until we explore the possibilities of producing F2 offspring and until the genetics of the animals we have produced are uncovered we must conclude that any of the breeding experiments performed to date are preliminary in the strictest sense. The results of our *C. cornuta* x *C. cranwelli* cross are interesting and promising, particularly if the hybrid offspring turn out to be fertile. Our frog madness is far from over and we have some interesting intergeneric and even interfamilial hybridization experiments lined up.

For now, our emphasis will be on selectively line breeding *C. cranwelli* to determine some of the genetics underlying the various phenotypes and also to more closely study the genetics of some of our hybrids.

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Western New York Bog Turtles Perspectives on Captive Propagation

David Collins
Senior Keeper, Reptiles and Birds
Burnet Park Zoo
Syracuse, NY

Introduction

All too frequently, the connection between the species in our care and their wild counterparts becomes extremely tenuous. As these two parties become increasingly estranged, both the animals and our efforts to conserve them may suffer.

For many reasons, it is imperative that we understand the biology of wild populations when working with a species. Foremost, we must insure that the species are not exploited through over-collecting, through needless errors in our own husbandry, or through the conveyance of misinformation to the public or merely the lack of crucial information that could be conveyed to the public in our graphics.

Knowledge of a species' biology, habitat, and climate requirements is neccessary to establish a successful captive breeding program. Nonetheless, this information is frequently lacking or inadequate for many of the species with which we work.

Finally, we are beginning to more fully understand the importance of preserving habitats, rather than species; without the former, you cannot have the latter. Wild populations will only exist when sufficient habitat has been preserved. Obviously, we must understand the habitat requirements of a species and work to conserve these areas through direct conservation efforts or through the educational value of our zoological exhibits and graphics.

With these points in mind, I would like to stress the importance and advantages of working with a species within its native range. First, management problems are greatly simplified; the climate and photoperiod are appropriate. With many species, the option of seminatural outdoor enclosures is available. There is potential for field studies of wild populations to provide information needed for successful captive breeding. There is potential for bringing specimens into captivity through collection, and subsequent release of gravid wild females; perhaps in concert with a head-starting program so that captive stocks can be established without impacting wild populations. We all see how many wild caught adult animals are brought into the country every year, and how many of these die without reproducing. If these species were captive hatched or born in their native countries, and exported as established and acclimated juveniles, the drain on native wild populations could be reduced and the survival of the animals imported increased tremendously.

Finally, conservation should begin at home. While we are outraged at the destruction of the tropical rain forest, or the decimation of the fragile Malagasy ecosystem, a shopping mall down the road is filling in

another wetland. As we have all learned, the conservation war can never be won, so it is imperative that we understand the needs of our animals and be prepared to undertake conservation battles as they arise.

I would like to offer one example of a conservation program designed to address the needs of one species of a rare native reptile, the bog turtle (*Clemmys muhlenbergii*) in western New York which illustrates some direct applications of captive propagation.

Background Natural History

Through most of the bog turtles' range, its preferred habitat is an open canopy, wet meadow with soft muck substrate. It is generally associated with shallow water, 1-5 cm in depth, frequently in the form of cool running rivulets or shallow pools which are persistent throughout the year. Emergent tussock or hammock forming vegetation provides low elevation and seasonally dense cover over the aquatic environment. The low herbaceous canopy creates a micro-climate of very high relative humidity throughout the summer. Sedge tussocks or sphagnaceous hummocks also offer important nesting and basking sites. Bog turtles are adept burrowers and utilize this behavior for both defensive and thermoregulatory purposes.

The bog turtle occurs in a discontinuous range from northeastern Georgia to New York. Large gaps exist between the species core range (southeastern Pennsylvania, Maryland, New Jersey, and southeastern New York) and the southern Appalachian and western New York portions of its range. Surveys conducted over the past ten years suggest that the species is more cryptic than rare within its core and southern range. In western New York, however, the bog turtle has continued to be extremely elusive.

In 1977 the New York State Department of Environmental Conservation (NYSDEC) and the New York Zoological Society collaborated on a statewide survey of all historical sites and locality reports of the bog turtle. During these surveys, no bog turtles were found within the western New York range. During the following nine years, the NYSDEC received two apparently legitimate reports of bog turtles from the Western Tier; one from a historical site, the second from a new site.

The Burnet Park Zoo is located within the western New York bog turtle range. We felt it was incumbent upon us to develop a comprehensive program which would address both the unanswered questions regarding its distribution, as well as the conservation needs of the species in our region. In 1986 the zoo initiated the Bog Turtle Conservation Program.

Burnet Park Zoo Bog Turtle Conservation Program

The Burnet Park Zoo Bog Turtle Conservation Program is comprised of six components. Up to this point, the focus of our work has involved the first three components.

I have outlined the last three components in considerable detail previously (AAZPA 1987 Northeast Regional Conference) so I have only briefly touched on the more important aspects of these.

I. Field Surveys and Status Update

Our surveys focused on the disjunct western New York portion of the bog turtle's range. The species has been reported from eight sites in six counties of the Western Tier. One site, known only from a 1916 record in the literature, could not be located and a second, well-documented site in Tompkins County was destroyed

by a sand and gravel operation around 1950. Of the remaining six sites, only two are well-documented - Genesee and Seneca Counties. Bog turtles are known at the remaining four sites by only one or two reported specimens.

Bog turtles probably live up more to their name in western New York than they do in virtually any other portion of their range. Several of the sites surveyed are better known for their unique floral communities or the massasauga (*Sistrurus catenatus*) which shares a similar distribution as well as endangered status with the bog turtle in western New York. Some of the most striking members of these plant communities are the orchids which range from the large showy, yellow and pink ladyslippers to smaller species such as the fringed orchis, rose pogonia and arethusa. At some sites, such as Bergen Swamp in Genesee County, more bog turtles have probably been observed by botanists than herpetologists.

The six sites considered to be extant were surveyed a total of 57 times, representing 266.5 man-hours of search time during 1987 and 1988. During these surveys bog turtles were found at only one site, Seneca County. At this site only eight individuals, seven live and one dead were found in the course of 20 surveys of the site over a two year period. Despite the small number of animals, the population appears to be viable as it includes both juvenile and young adult animals, and one female was known to be gravid in 1988. This population became the subject of an ecological field study which I will discuss later.

Of the other five sites, only Bergen Swamp appears to offer good bog turtle habitat. This site is documented by a minimum of 18 specimens or reports; however, the last live bog turtle reported from Bergen was in 1972 and a shell only was reported in the late seventies. I will discuss this site more in my conclusion. Each of the four remaining sites lack critical components of good bog turtle habitat, such as flowing rivulets or open canopy. The individuals reported from these sites most likely represented relict populations or individuals displaced by either natural succession of their open wet meadow or bog habitat or alteration of the habitat by agriculture or other human activities.

In western New York, muck farming has been practiced extensively over the past century and has destroyed a tremendous amount of bog habitat. One Wayne County site, Zurich Bog, owned by the Bergen Swamp Preservation Society, is a poignant example of remnant bog habitat hemmed in by muck farming. Through the study of USGS Topographical maps and SCS soil survey maps, the distribution of muck soils and probable historic bog habitat is clear. At present, this entire drainage has been altered by muck farming.

Our field surveys have pointed out the critical status of the bog turtle in western New York. Hopefully, this research will aid in the management of this species by the NYSDEC as well as serve as an impetus for further studies. As I mentioned earlier, these surveys have also served to identify a population for more intensive study, which comprises the second component of our program.

II. Ecological Study

During the 1987 surveys, five bog turtles were captured, marked and released at the Seneca County site. The age and sex distribution of this group suggested that this was a viable, although apparently very small population. In 1988 the NYSDEC Endangered Species Unit offered the loan of radio telemetry equipment which was subsequently augmented by additional equipment funded by the Friends of the Burnet Park Zoo. This opportunity allowed us to intensify our studies of this population somewhat earlier than we had anticipated.

During early May, a male and female bog turtle were collected and fitted with radio transmitters. The transmitters were attached with waterproof epoxy and covered with silicon caulk shaped to conform to the shape of the shell. The entire package weighed 7-8 g, approximately 7% of the turtle's body weight. The turtles were

released at the point of capture and were relocated roughly twice a week. At each recapture, the turtle's location was mapped and data on habitat, environmental conditions and turtle activity were recorded.

Male #87.02 was followed from May 14-August 6, 1988 and female #87.04 was followed from May 17 - June 21. The female's signal was lost following the June 21 observation; the radio was later found on August 6, intact and sending a strong signal, in approximately one half meter of water at the same area where she had previously been observed. During the period in which this female was followed she moved from an area of contiguous shallow pools to a drier Juncus meadow with scattered sphagnum hummocks. Between June 11-14, she appparently nested on one of these hummocks. She had returned to a shallow spring rivulet near the pool habitat when found on June 21.

All observations of the male were in the same pool habitat or shallow rivulet where the female was observed. The male was not observed to move into the Juncus meadow during the female's nesting period, but was observed within several meters of her on June 21. Interestingly, the female was initially located in 1988 when she was found being mounted by the already telemetered male. During May and June, this pair was found in close proximity to one another on several occasions; not terribly surprising during the spring breeding season. If the post-nesting association observed on June 21 was not simply coincidence, it might suggest a more complex social behavior.

Our 1988 work at this site presents only the initial stage of this study. The significance of this first year was not so much the actual data that was collected, but the increased familiarity with the site. Hopefully, this familiarity will translate into a cohesive and effective study design which will give us some important information about the species at the northern extreme of its range.

III. Surrogate Species Recruitment Study

The practice of introduction or releasing mammal, bird, or fish game species has been a commonplace management tool for years. The application of this practice to non-game and especially reptile or amphibian species is considerably more recent. Currently, there are several herpetological head-start projects underway. These include the sea turtle work at Brownsville, the red-bellied turtle (*Pseudemys rubriventris*) work in Massachusetts, the Houston (*Bufo houstonensis*) and Puerto Rican toad (*Peltophryne lemur*) projects, and the Virgin Island boa (*Epicrates monensis*) project of the Toledo Zoo, to name only a few. To a large extent, however, there is still missing information regarding the effectiveness of these projects as recovery tools, and of the specific effects of introductions of captive produced progeny on the existing population. We are specifically interested in comparisons of recruitment rates of captive hatched and head-started juveniles versus their wild-hatched age cohorts, changes in the size of the reproductive population and changes in population density, movement patterns and home ranges.

We hope to illuminate some of these questions, and gain some insight into the feasibility of future bog turtle introductions by using spotted turtles (*Clemmys guttata*) as surrogate bog turtles in a head-start release project. These species are frequently sympatric and ecologically and biologically quite similar. Additionally, the spotted turtle is relatively common in western New York, enabling us to identify a reasonably convenient study population.

The spotted turtle study was initiated in 1985 with capture, marking, and release of three individuals at the Ira Marsh study site. In 1986 an additional 13 turtles were captured and in 1987 a total of 51 captures yielded an additional 10 unmarked animals. Based on the recapture data from 1987, we were able to estimate the population size, using the Lincoln Index, at 29 individuals. In 1988 a total of 25 captures yielded 17 previously marked and one new turtle. The population estimate remained unchanged at 29 with the 1988 data,

with 28 wild turtles actually marked. At present, this population consists of nine adult males, 10 adult females, and 10 juveniles.

The habitat of this population is tightly focused on a muskrat lodge hibernaculum. During spring emergence, late March through mid-April, as many as ten spotted turtles have been observed basking in the immediate vicinity of this lodge. In late April and early May, the spotted turtles disperse into adjacent wet meadow habitats where they remain quite active until early June. Most nesting takes place in the first two weeks of June, after which time the dense vegetation and greatly reduced activity of the turtles makes capture extremely difficult without telemetry equipment or other remote capture techniques such as drift fences.

Beginning in 1986, gravid females collected after mid-May were held at the zoo until oviposition. They were subsequently released at the point of capture and their eggs artificially incubated. Between 1986 and 1988, a total of 30 spotted turtles have hatched at the zoo. Clutch sizes have ranged from four to seven and we have experienced zero hatchling mortality. The first release took place on May 17, 1988. Four 1986 hatchlings were released at the hibernaculum. These turtles ranged from 66-77 mm in carapace length, roughly the size of a six to eight year old wild turtle from this population. Twenty-two youngsters will be released this May and a small group of four will be released in 1989.

IV. Development of Captive Populations

Captive populations should be developed within the framework of three categories:

(A) Non-releasable exhibit animals. Bog turtles of unknown origin and progeny of these animals should be held for educational exhibition and breeding research only.

(B) Regional population stocks. These captive populations should be established from several regions within the species' range. They should be derived from eggs collected from gravid wild females which are released following oviposition. These captive populations should then be monitored in the same manner as SSP (Species Survival Plan) species. Progeny of these populations may be used for reintroduction programs within their respective regions.

(C) Head-start programs. These programs are designed to bolster low population levels or enhance juvenile recruitment rates by the release of head-started juveniles, utilizing eggs from that population only. Where population levels are so low that reproductive females cannot be located, the site may be assessed as a candidate for introductions from Regional Population Stocks.

V. Reintroduction Programs

Introduction programs should be designed and introduction sites determined, following critical assessment of suitable habitats and current population dynamics resulting from field surveys and ecological studies. Potential sites for introductions may be placed in four categories:

(A) Verified populations. Head-start programs into existing populations with low recruitment or available, unoccupied suitable habitat.

(B) Verified sites. If a verified site cannot be upgraded to a verified population by locating more than one individual or evidence of reproduction, it may be considered as a candidate for introductions from Regional Population Stocks.

(C) Unverified historical sites with suitable habitat. With respect to introductions, these sites should be treated as lower priority verified sites. Particular attention must be paid to the identification and assessment of suitable habitat.

(D) Suitable habitat with no history of bog turtle occupation. Again, with respect to introductions, these sites should be treated as verified sites. The most stringent criteria of assessment of suitable habitat should be applied, and this category should receive the lowest priority of the four categories.

VI. Exhibit and Conservation Education

The bog turtle and the conservation program are excellent vehicles for a broad spectrum program of public conservation education. Turtles, in general, are well liked by the public and the diminutive size and endangered status of the bog turtle further enhance this species' ability to elicit strong public empathy.

The most important aspect in the conservation of the bog turtle is the recognition and preservation of appropriate habitat. The small, isolated habitats frequently used by rare species of reptiles and amphibians often lie on private property and are not identified until specific systematic surveys search them out. The process of increasing the public awareness about the importance of preserving these unique environments is paramount to broad scale environmental conservation.

The bog turtle's strong dependency on a specific type of wetland habitat affords an excellent opportunity to develop exhibits and presentations designed to illustrate the great variety and unique characteristics of wetland environments. Incorporated with exhibits of related turtle species which show similar specificity to different wetland habitats, the concepts of both endangered species and endangered habitats can be conveyed.

We have designed and this year will begin construction on an exhibit using the bog turtle to illustrate the concept that Endangered Habitat equals Endangered Species.

Conclusion

The purpose of this paper was to give one example of a project which incorporates the technology of captive propagation with a conservation effort for wild populations. We are hopeful that our preliminary surveys and studies will lead to a fruitful conservation program for the bog turtle in western New York.

One result from these surveys, and of previous studies I have conducted on spotted turtles in Ohio and wood turtles (*Clemmys insculpta*) in New York, is the realization of the extreme vulnerability of these populations. The eastern *Clemmys* are examples of species which show a high degree of habitat specificity. As such, they tend to occur in relatively small, discrete populations defined by the limits of their specific habitat. The Ira Marsh spotted turtle population appears to have only about ten breeding age females; the bog turtle population we are studying appears to be extremely small based on the recapture frequency seen this year; we do not have enough data yet to generate an estimate. A wood turtle population which I studied for eight years in Schoharie County, New York consisted of less than ninety individuals, less than a third of which were breeding females. The largest population of any of the *Clemmys* I studied occurred in northeastern Ohio. During a seven year study, 72 individuals were marked which generated a population estimate of about 200 animals; and estimated 75 of these were adult females. When viewed in these finite numbers, it is very easy to see the devastating effect that the removal of even a relatively small number of breeding aged adults would have. This is one possible explanation for the decline of the bog turtle at Bergen Swamp. This site is more heavily represented by preserved museum specimens than any other western New York site. Also, due to the unique vegetational and geological aspects of this site it has received a great deal of attention from naturalists and other

scientists over the past century. Undoubtedly, many bog turtles were removed from this population and never reported.

Successful captive breeding can certainly lessen the drain on wild populations once a species is established in captivity. However, it is extremely important that we are all cognizant of the heavy price that these wild populations pay while we are working the bugs out. I think it is incumbent on all of us to search out means by which this price can be lowered.

Captive Management of Exotic Tortoises

Richard J. Fife
Phoenix, AZ

Introduction

I have maintained various species of turtles and tortoises in my private collection and as Assistant Curator of Reptiles at the Gladys Porter Zoo (Brownsville Texas) for over fifteen years. After leaving the Zoo in 1978, I continued to procure various species for captive propagation.

The species I currently maintain include: African spur-thighed tortoise (*Geochelone sulcata*), leopard tortoise (*Geochelone pardalis babcocki*), red-foot tortoise (*Geochelone carbonaria*), Burmese mountain tortoise (*Manouria emys nutapundi*), radiated tortoise (*Geochelone radiata*), Hermann's tortoise (*Testudo hermanni*), marginated tortoise (*Testudo marginata*), and pancake tortoise (*Malocochersus tornieri*). The following husbandry techniques and management procedures are a result of my captive propagation endeavors.

Facilities

My tortoise facility is located in Phoenix, Arizona, which lies in the Sonoran Desert. Rain fall is 183 mm per year. I have recorded temperatures ranging from -6 to 47°C at my property. My property is flooded with irrigation water on a regular basis, which slightly increases the relative humidity. The tortoise yards are not irrigated.

Each enclosure is surrounded by a 2.0 m fence. The top 1.3 m is chain link and the bottom 0.7 m is plywood. The plywood is buried about 10 mm in the ground and has been painted with a nontoxic red barn paint. I have found that a solid barrier reduces animal pacing, retains hatchlings of undiscovered nests, and eliminates tortoises from breaking their beaks or tearing their necks on the chain link.

The substrate is native desert soil which is high in clay. The enclosures are planted with grasses, palms, cacti, and bamboo. I have found that fountain grass (*Pennisetum setaceam*) is essential as a retreat from the heat and cold for most species. The availability of grass for grazing tortoises is essential.

The tortoise enclosures measure 10.0 x 3.0 m. In most cases, each individual species has its own enclosure. I have provided an insulated house for tropical species. The house is 1.0 m tall with a floor of 1.5 x 1.0 m. A thermostat controls one 250 watt heat lamp. The heat lamp switches on when temperatures drop below 18°C.

Diet

All my tortoises are fed similar diets; grass or alfalfa hay is always available. Most of the tortoises are heavy grazers, excluding *M. emys nutapundi* and *G. carbonaria* which graze only occasionally. The tortoise diet is regularly supplemented with carrots, squash, cabbage, various greens, tomatoes, prickly pear cactus, and occasionally moistened monkey chow, melons and other fruits.

A variety of diets have been tried on neonates. Grasses promote steady even growth without shell deformities known as "hand-grenading" or "pyramiding". The grass must be a fine blade variety or a ground cover like dichondra (*Dichondra micrantha*). Hatchling tortoises do not have the biting power to eat coarse grass like bermuda (*Cynodon*). A disadvantage to grass is that most hatchlings cannot tolerate the high temperatures, dryness, or cold winters in Phoenix, so they cannot be put out to graze for most of the year.

A vegetable diet consisting of green vegetables, squash, carrots, tomatoes, and fruit is very time consuming to prepare and has been shown to promote unnatural shell growth. I now use vegetables as a supplement only.

For the past year I have used moistened monkey chow for all hatchling tortoises. The monkey chow is easy to use, inexpensive, and promotes excellent growth. Survival rates in neonates has greatly increased. Growth can be accelerated without affecting normal shell development. Straight line shell measurements of 125-140 mm can be expected at 8 to 10 months of age. The hatchling tortoises are bedded on alfalfa hay which they occasionally eat.

Sex Identification

In managing breeding groups of animals, and in distributing captive offspring it is very important to have accurate sexual identification. Unfortunately, sex identification in some species of tortoises is extremely difficult and almost impossible with neonates.

Sexing probes or forced hemipene eversion, common sexing techniques in snakes and lizards, cannot be used to sex tortoises because they have a single penis instead of a pair of inverted hemipenes. Furthermore, sexual behavior or activity can not always be relied on. I have observed female tortoises mounting other females and emitting audible grunting sounds in the species *M. emys nutapundi*.

Sexual dimorphism is evident in many species of tortoises. The most obvious differences are concavity of the plastron and larger tails in males. Another major difference is the configuration of the anal scutes. In males, the anal scutes are more elongated and have a wide angle of separation. In females the anal scutes are less elongated and are directed toward the rear of the shell. This difference is evident in most species of tortoises and can be seen in some neonates.

With some species of tortoises, the sex can be determined by size comparisons. This varies with species; in *G. carbonaria* the male is larger than the female, in *G. p. babcocki*, the female is larger than the male.

Gary Wenke of Phoenix, Arizona has noted that the nuchal scute in male *T. marginata* is narrower and longer than on females. This difference is noticeable to some extent on hatchling *T. marginata*. I continue to see other signs of sexual morphology as my tortoises mature, and as additional tortoises are examined.

Climatic Adaptability

I have found that many species of tortoises can adapt in some degree to the climate in Phoenix. I have used the book "World Climates" (Rudloff, 1981) to research the needs of my tortoises. I have included the climatic information of portions of the range of the leopard tortoise (*G. p. babcocki*), the Burmese mountain tortoise (*M. e. nutapundi*), and the African spur-thighed tortoise (*G. sulcata*).

The leopard tortoise is native to much of eastern and southeastern Africa. Due to the large range of this tortoise, it is difficult to describe its climatic needs.

Most of the captive leopard tortoises in this country come from Kenya and Tanzania, which is the tropical range of *G. p. babcocki*. The city of Tabora, Tanzania has the typical climate for the species' tropical range (see Figure 1). Tabora is located at latitude 5 degrees 05 minutes south, longitude 32 degrees 50 minutes east, and an elevation of 1190 meters. It should be noted that most of the tropical range is above 1000 meters.

In Tabora, January is wet with daily highs of 31°C, and daily lows of 15°C. July is dry with daily highs of 30°C, and lows of 13°C. Annual extreme temperatures are 12°C and 34°C. Annual precipitation is 882 mm.

	Jan	Feb	Mar	Apr	May	Jun	
High Temperature (°C)	31	31	31	30	30	29	
Low Temperature (°C)	15	16	16	16	14	12	
Precipitation (mm)	135	126	170	133	34	3	
	Jul	Aug	Sep	Oct	Nov	Dec	Year
High Temperature (°C)	30	32	33	34	34	32	34
Low Temperature (°C)	13	14	16	17	17	16	12
Precipitation (mm)	0	1	5	14	81	181	882

Figure 1 - Climate chart for Tabora, Tanzania

The typical subtropical range of the leopard tortoise has a climate similar to Salisbury, Zimbabwe (see Figure 2). Salisbury is located at latitude 17 degrees 56 minutes south, 31 degrees 06 minutes east, and an elevation of 1479 meters.

In Salisbury, January is wet with daily highs of 29°C, and daily lows of 13°C. July is dry with daily highs of 26°C, and lows of 2°C. Annual extreme temperatures are 2°C and 33°C. Annual precipitation is 863 mm. This climate is similar to San Diego, California with greater precipitation.

	Jan	Feb	Mar	Apr	May	Jun	
High Temperature (°C)	29	29	28	28	27	24	
Low Temperature (°C)	13	12	11	9	5	3	
Precipitation (mm)	216	172	99	36	11	4	
	Jul	Aug	Sep	Oct	Nov	Dec	Year
High Temperature (°C)	26	27	31	32	32	30	33
Low Temperature (°C)	2	3	6	10	12	12	2
Precipitation (mm)	1	3	5	30	100	186	863

Figure 2 - Climate chart for Salisbury, Zimbabwe

The typical (cool) subtropical range of the leopard tortoise has a climate similar to Bloemfontein, South Africa (see Figure 3). Bloemfontein is located at latitude 29 degrees 06 minutes south, longitude 26 degrees 18

minutes east, and an elevation of 1400 meters. Pritchard (1979) reported that leopard tortoises are found at altitudes above 6000 feet (2000 m) in the Graaff-Reinet area of South Africa.

In Bloemfontein, January is wet with daily highs of 35°C, and daily lows of 10°C. July receives about 10 mm of rain with daily highs of 21°C, and daily lows of -5°C. Annual extreme temperatures are -6°C and 36°C. Annual precipitation is 547 mm. This climate is very similar to Sacramento, California with one important difference. In South Africa winters are dry and summers wet. In California winters are wet and summers are dry.

	Jan	Feb	Mar	Apr	May	Jun	
High Temperature (°C)	35	32	31	28	24	21	
Low Temperature (°C)	10	9	7	2	-2	-4	
Precipitation (mm)	83	81	76	51	22	7	
	Jul	Aug	Sep	Oct	Nov	Dec	Year
High Temperature (°C)	21	25	29	33	33	34	36
Low Temperature (°C)	-5	-4	-2	3	6	7	-6
Precipitation (mm)	10	14	19	48	68	68	547

Figure 3 - Climate chart in Bloemfontein, South Africa

In observing my captive leopard tortoises, I have noticed that adults can tolerate cold temperatures (1°C) without any problems as long as it is of short duration and they can warm up soon afterwards.

My leopard tortoises will emerge from their heated house early in the morning when air temperatures are between 7-10°C. The tortoises orient their shells toward the sun to receive maximum radiation and soon have absorbed enough heat to begin grazing. This demonstrates the importance of South Africa's dry winters, enabling the tortoises to bask immediately after a cold night.

I would note that my leopard tortoises are from Kenya. They have only rarely been exposed to cold (near freezing temperatures). They are all long term captives and unstressed animals.

The African spur-thighed tortoise has become available in the United States recently due to importing and captive breeding. They have proven to be a very hardy tortoise, and I am sure they will become even more common in captivity.

G. sulcata is native to the southern fringes of the Sahara Desert, from inland Senegal to the Massaua coast on the Red Sea (Pritchard 1979). This is an area of extreme summer heat, only occasionally tempered by summer rains. The winters are dry (no rain from November through March) with cool nights (occasionally light frosts), and hot days. Tombouctou (Timbuktu), Mali has the typical climate for the range of *G. sulcata* (see Figure 4). Timbuktu is located at latitude 16 degrees 46 minutes north, longitude 3 degrees 01 minutes west, and an elevation of 273 meters.

In Timbuktu, January is dry with daily highs of 36°C, and daily lows of 8°C. July receives some rain. Daily highs are 44°C, and daily lows are 21°C. Annual extreme temperatures are 7°C and 47°C. Annual precipitation is 225 mm.

In the wild *G. sulcata* digs burrows to retreat from the heat and cold. My captive tortoises excavate burrows about 1.5 meters long. The tortoises have no problem with summers in Phoenix where high temperatures of 46°C can be expected. In winter the entrance to the tortoise burrows are covered with straw to keep out the cold. Seldom do the burrows drop below 5°C even though outside temperatures my dip to -2°C. As with the leopard tortoises the African spur-thighed tortoises emerge from their burrows in early morning, and bask in the sun until body temperature has increased and grazing begins. During extended periods of cold and overcast weather, a 250 watt heat lamp is set out for the tortoises to bask under.

	Jan	Feb	Mar	Apr	May	Jun	
High Temperature (°C)	36	39	43	46	47	47	
Low Temperature (°C)	8	9	13	17	22	23	
Precipitation (mm)	0	0	0	1	3	19	
	Jul	Aug	Sep	Oct	Nov	Dec	Year
High Temperature (°C)	44	41	44	43	41	36	47
Low Temperature (°C)	-5	-4	-2	3	6	7	-6
Precipitation (mm)	65	95	37	5	0	0	225

Figure 4 - Climate chart for Timbuktu, Mali

There are two subspecies of the Burmese mountain tortoise, *M. emys emys* and *M. emys nutapundi*. The two tortoises were confused for many years and were thought to be the same subspecies. They are in fact very different and may even be separate species. *M. e. emys* is the smaller of the two tortoises. It is from southern Burma, southern Thailand, south into the Malay Peninsula, and from the islands of Sumatra and Borneo. *M. e. nutapundi* grows to over 650 mm. It ranges from northern Thailand to northern Burma (Obst 1986).

Lashio, Burma is typical of the climate for the subspecies *M. e. nutapundi* (see Figure 5). Lashio is located at latitude 22 degrees 58 minutes north, longitude 97 degrees 51 minutes east, and an elevation of 855 meters. This climate is similar to that of Miami, Florida.

	Jan	Feb	Mar	Apr	May	Jun	
High Temperature (°C)	25	29	32	35	34	31	
Low Temperature (°C)	4	6	9	14	16	19	
Precipitation (mm)	8	8	15	56	175	249	
	Jul	Aug	Sep	Oct	Nov	Dec	Year
High Temperature (°C)	31	31	31	30	28	25	36
Low Temperature (°C)	20	19	18	14	9	6	4
Precipitation (mm)	305	325	198	145	69	23	1574

Figure 5 - Climate chart for Lashio, Burma

In Lashio, January is not as wet as other months of the year, with 8 mm of precipitation. Daily high temperatures are 25°C and daily lows are 4°C. July is wet with 305 mm of precipitation. Daily highs are 31°C

and daily lows are 20°C. Annual extreme temperatures are 4°C and 36°C. In the southern part of the range of *M. e. nutapundi*, temperatures are about 5°C warmer. In the mountains of Burma (above 1600 meters), temperatures of -3°C, and colder can be expected.

My *M. e. nutapundi* have hibernated every winter since 1980. They retreat to their turtle house or burrow under leaf litter when night time temperatures drop below 7°C, which occurs about mid October. They do not emerge until nights have warmed to about 10°C which usually occurs in March. The tortoise house is covered with a thick layer of straw to protect the tortoises from extreme cold and hot winter days.

Summers are a bit more of a problem. The tortoise enclosure is planted with giant reed (*Arundo donax*) which shades most of the yard. The reed is cut to the ground in winter to control its growth, and provide litter for burrowing and nesting. The yard is misted regularly and a water hole is provided.

Reproduction

Breeding behavior and egg laying have been described by other writers extensively and I concur with most of their observations. In addition, I would make the following generalizations:

My tortoises prefer to nest at the top of inclines or mounds, close to walls, and near bushes or trees. I have had no nesting during the hot months of summer (mid-June to mid-August).

My leopard tortoises and red-foot tortoises lay from two to five clutches of eggs per year. Eggs are laid from mid September to mid March. Leopard tortoises lay between 10-21 eggs. Red-foot tortoises lay between 3-6 eggs. Nesting begins in the late afternoon and is completed after dark.

My *Testudo sp.* nest in early spring or late fall. *T. hermanni* lay between 3-5 eggs. *T. marginata* lay between 6-9 eggs. The eggs are usually laid in the early morning.

My *M. e. nutapundi* lays her eggs the last week of May or the first week of June. Twenty to forty eggs are laid. Straw and leaf litter is provided for nesting material. A few weeks before egg laying she begins moving the nesting material into position for nest building. To date she has never completed her nest and infertile eggs are laid indiscriminatingly on the ground.

M. e. nutapundi is more difficult to sex than *M. e. emys*. It has taken over 13 years to locate a male tortoise. In 1986 a male was obtained and breeding was observed the next summer. The male did not mate with the female again until after eggs were laid in 1988. Two of the 1988 eggs were fertile but did not hatch. I am hopeful for success in 1989.

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Long Term Husbandry and Propagation of the California Desert Tortoise (Gopherus agassizi)

Kay Arneberg Booth
Orland, CA

Introduction

In 1935 I acquired my first two California desert tortoises (*Gopherus agassizi*). At this time, I was living in Pomona, California. In 1953 the family moved to Orland, California and it was here, in 1956, that the female laid her first clutch of eggs. These eggs were artificially incubated. According to herpetological records it was the first time that this had been successfully accomplished. The original pair of tortoises are still alive and produce eggs and hatchlings every year.

I kept several of the 1956 hatchlings (F1), which in due course had young of their own. One from their 1974 hatching and another from their 1975 hatching were retained and raised to sexual maturity (F2). In 1985 these tortoises laid eggs of which three hatched (F3). This makes four generations of tortoises in my collection and three generations of captive bred tortoises. As far as can be ascertained, this is a world first.

Reproduction

Captive raised desert tortoises mature between 10-12 years of age. In the wild it may take longer, because the amount and quality of food that they receive in captivity far exceeds that which they would naturally find. As a male tortoise reaches maturity, his plastron becomes slightly concave. The plastron of the female remains perfectly flat. This is the only reliable secondary sexual characteristic displayed by this sex. There are many theories on identifying the sex of hatchling desert tortoises. I suspect that the small indentation on the carapace just above the tail can be used as an indication of sex (see Figure 1). I think it is wider in females than in the males; however, I have only been able to verify this on two specimens. After about a year these indentations wear off. Sometimes, males can be determined within three months of age through their belligerent behavior.

Mature desert tortoises usually breed in April and May, with egg-laying occurring in June or sometimes as late as July. If you have only a single pair, you should ensure that the male's breeding activity does not interfere with the female's feeding. At times a lone female will become quite debilitated unless she is separated from the male during this period. It is much better to house two or three females with a single male. The male is amorous all year and it wise to keep a close watch on him. In view of his position he is very liable to get turned over on his carapace. Some tortoises cannot right themselves and will die very quickly if caught upside down in the hot sun.

Figure 1 - Indentation in carapace above tail

The desert tortoise looks like an armored tank, but this is definitely an optical illusion. Their shells are extremely thin. The skeleton and the scutes together are thinner than a dime. This means that desert tortoises can be injured very easily.

No tortoise likes to be handled too much and they definitely should not be handled too roughly or moved too quickly. If you startle a tortoise while you are handling it, they are likely to void their bladders of all of their liquid reserves. Because of this defensive behavior if you come across a desert tortoise in the wild, you should never handle it except to move it gently off of a road. A wild tortoise may only have one or two occasions in which to drink during a given year and this simple reflex can be life threatening, especially during drought years.

I provide my captive desert tortoises with a constant supply of water. A tortoise cannot drink out of an elevated container; therefore, all water should be provided at ground level especially for juveniles (see Figure 2). Water should be provided for females immediately after they lay their eggs and for all tortoises at all times at ground level.

Egg-laying

The female desert tortoise begins digging her nest with her front feet. After the hole is started, she turns around, anchors the front feet firmly and starts digging with the toe-nails of the hind feet. Each foot is used alternately, never the same foot twice. This continues until the tortoise can no longer reach the bottom of the nest with the toe-nails of the hind feet. The nest cavity is usually shaped somewhat like a shoe. The nest digging process can take from between two hours to two days, depending upon the individual tortoise and the hardness of the soil. About twenty minutes following the completion of the nest, the tortoise deposits from 3-15 eggs. The most common clutch sizes range from 5-9 eggs. The tortoise pulls its head deep into the shell while it is laying the eggs, which are white, hard-shelled and resemble ping pong balls in size and shape.

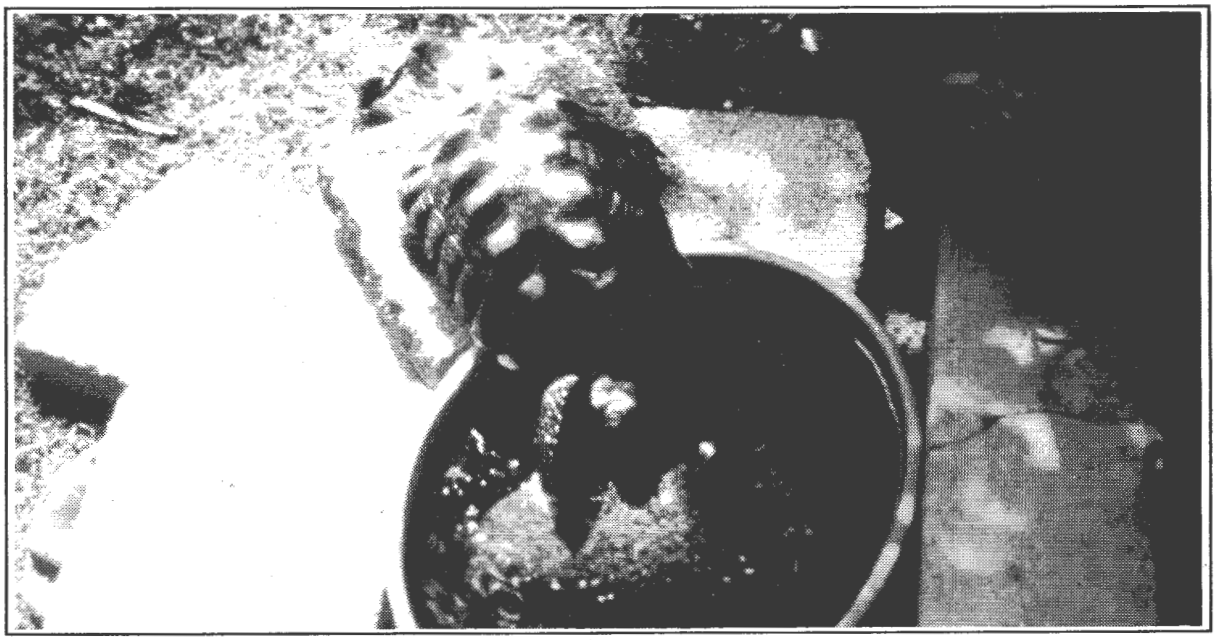

Figure 2 - Watering arrangement for captive tortoises.

After each egg is laid, one foot reaches down and very gently pushes the egg as far as possible into the hole. After the egg-laying is completed, the tortoise covers the nest. This is almost as difficult as the nest digging process because the loose dirt may be strewn as far as three or four feet from the nest site. When the nest is about half covered, the tortoise voids her liquid reserves onto the nest and continues to cover it with dirt, tamping the dirt down after each footful by placing all of her weight on that foot.

Covering the nest takes hours, but after the tortoise finishes it is very hard to see and the animal is visibly exhausted. Sometimes, they do such a good job covering their nests that I cannot find them until hatchlings appear. Each female lays once or sometimes twice a year. The females exhibit no further attention towards the nest once they have covered it. Incubation takes approximately three months. Hatchlings in outdoor nests have to dig their way out of the six inches of dry, packed earth.

Hatching

The developing tortoises are curled inside the egg with a yolk sac that is just about as large as the tortoise protruding from the outside of its plastron. After hatching this yolk sac takes anywhere from two days to two weeks to be completely absorbed. If the yolk sac is broken or dries out preventing its absorption, the hatchling will die. By the time the yolk sac is absorbed the hatchling has completely straightened out and weighs between 0.5-1.0 ounces. However, there are times when they remain wrinkled for weeks.

After hatching, the shells remain quite soft and the tortoises are particularly vulnerable to predation. The growth of these tortoises is directly proportional to the amount that they eat and this varies considerably with the individual tortoise.

In 1976 I had a number of albinistic or extremely light colored desert tortoises hatch. On these hatchlings, the blood vessels are visible quite close to the surface of the plastron. On the normally colored hatchlings, the blood vessels can only be seen through close inspection.

Feeding

The tortoises displayed a habit of defecating on top of their food following feeding, so we developed stall feeders made out of milk cartons that closely matched the size of the tortoise (see Figure 3). The stall feeders keep the food from becoming contaminated allowing the tortoises multiple opportunities to feed during the course of the day. These stalls also helped the slower eaters because they were less likely to be pushed away by more aggressive feeding cagemates. These stalls must be enlarged as the tortoises grow.

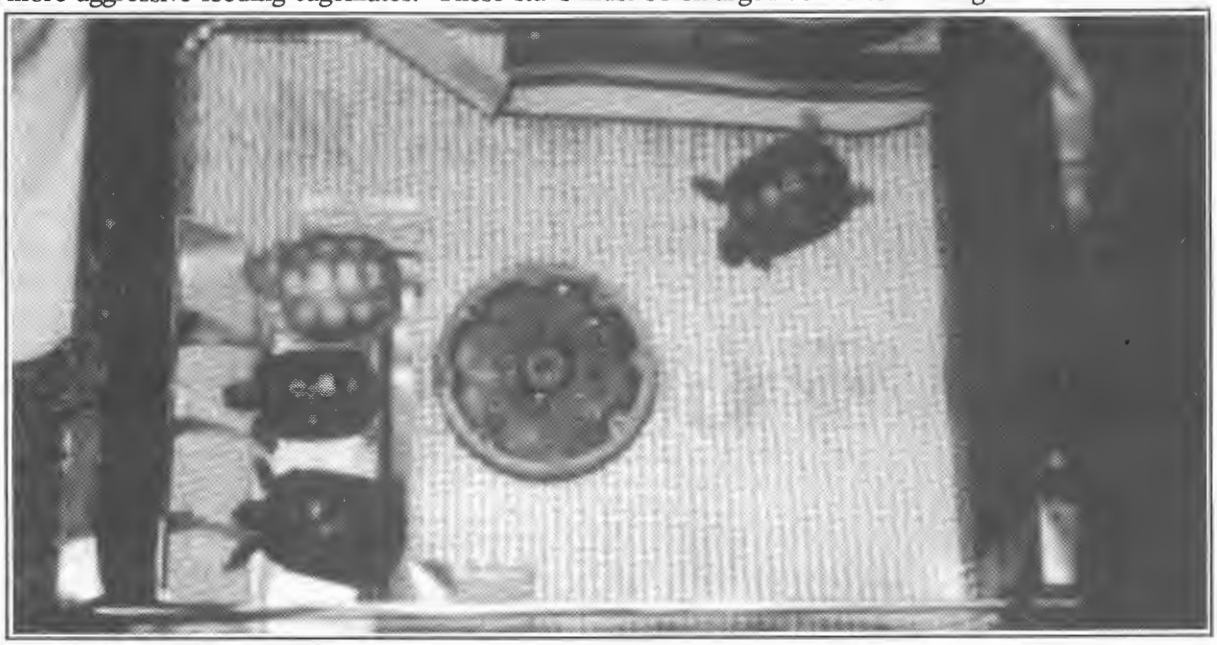

Figure 3 - Stall feeders for desert tortoises

Prior to 1976, the hatchlings were fed primarily on finely cut iceberg lettuce with dandelions and milkweed mixed in until they were large enough to be outside on the lawn or in pens planted with clover. The tortoises do not chew their food, instead they just bite it off and swallow. Since 1976 we have used chick starter as a supplemental food item for the hatchlings. The adult tortoises are also supplied with containers of the chick starter and eat a lot of it. Both juveniles and adults are also supplied with crushed oyster shell. For hatchlings it must be pulverized.

Enclosures

The outdoor pens are made of metal or painted boards slanted in at the top about two inches to keep the tortoises from climbing out. Hatchlings were maintained indoors in cardboard boxes lined with newspaper. In 1976 a number of albino or exceptionally light colored tortoises hatched. These tortoises became so dirty from the newsprint that we began using cardboard boxes with a wire-bottom (0.25 inch mesh) over a pull out tray for easy cleaning. A rolled up towel was placed across the front of the opening to keep drafts off of the hatchlings. Some people have informed me that this was not a natural footing, but it has worked much better than rabbit pellets or cat litter, both of which become soiled. Also, the wire mesh gives the hatchlings a better chance of getting a toe-hold to flip themselves over if they get turned onto their backs. This wire mesh must be checked and changed when needed. If it is too large the foot could slip entirely through. If too small, the toe nails could be caught. Either of these cases could cause injury.

Resting and night areas for the adult tortoises consist of a house much like a dog house. This house is placed so that the morning sun reaches the entrance and the house is in shade the rest of the day. Cloth strips are placed over the entrance to keep out flying insects, while still allowing the tortoises to enter and exit freely. A heating element is placed in the house for use during periods of inclement weather.

About the first of October, as the weather cools, the tortoises eat less and less, and stay in the houses much longer. After two weeks of this behavior, the tortoises stay in the houses all day and do not come out even to eat. At this time, I bring them in for winter hibernation, moving them as gently as possible, rub their shells with a soft cloth moistened with water with a dash of baby oil. This is just to ensure they are clean and nothing else is amiss. The I place them in boxes lined with layers of paper. Air holes are cut around the top of each box. Then I cover the tortoises loosely with crumpled up paper to be sure no drafts reach them. These boxes are then placed in an unused room which can be kept at a temperature of approximately 50°F.

Depending on the weather, but usually around the first of March, the tortoises begin to move around in the boxes and I bring them back outside. Just in case the weather gets too cold in the evenings, I leave the heating element on in their outdoor houses.

Conclusion

This paper provides a brief overview of how I have maintained the California desert tortoise (*Gopherus agassizi*). I have no desire to know about the inner workings of these tortoises except to keep them as healthy and comfortable as possible. The intriguing thing to me about these animals is the beautiful and intricate shell designs and colorings. The normal scute count on the carapace is five median, four costals on each side and eleven marginals. There is also one small scute just above the head and the tail. The tortoises produced in my collection display a tremendous variation in scute counts. The medians and costals range from 3-7 and the marginals from 10-13. The coloration ranges from the albino to almost completely black, and sometimes the entire range can be found in one clutch of eggs. One hatchling had an almost green cast to its shell.

Not only do the tortoises vary in coloration and morphology, but in their personalities as well. Some, especially the hatchlings, walk around with their heads fully extended, while others keep the head almost inside the shell. Some are very outgoing and do not seem to mind being handled, while others are very shy and dislike being disturbed. It seems as though they have idiosyncracies just like humans, but they are still tortoises and will remain just as they are and have been for so long.

Acknowledgements

Neither the tortoises nor myself would ever have known that three generations of captive bred tortoises were unusual if it had not been for Mr. James Buskirk of Oakland, California. Many thanks are extended to him for all the time and trouble he took to write their résumé. My thanks also go to my daughter, Kristi Douglas, and son-in-law, Russell Douglas, for preparing the slides for my talk and to my grandson, Kelvin, for his help.

Breeding the West African Dwarf Crocodile at Woodland Park Zoological Gardens

Dana Payne
Woodland Park Zoological Gardens
5500 Phinney Ave. N.
Seattle, WA 98103

Introduction

The West African dwarf crocodile (*Osteolaemus tetraspis tetraspis*) is a small, inoffensive crocodile that rarely reaches 2 m in length. Census work needs to be performed on this species. The crocodiles' status is listed by the International Union for the Conservation of Nature and Natural Resources (IUCN) as "Indeterminate", which includes the categories "Rare," "Vulnerable," or "Endangered," but is not specific due to a lack of current data on populations and their vulnerability. It is listed by the Convention on the International Trade in Endangered Species (CITES) as Appendix I, which contains endangered species (Groombridge, 1982).

There is a total of 33 collections holding 19 male, 10 female, and 13 undetermined sex *Osteolaemus t. tetraspis* and 14 male, 14 female, and 14 undetermined sex *Osteolaemus tetraspis ssp.*, the majority of which are probably *Osteolaemus t. tetraspis* (Slavens, 1988). These totals, according to Slavens, make the dwarf crocodile the most well-represented crocodile in captivity after the Nile crocodile (*Crocodylus niloticus*).

A few hundred baby dwarf crocodiles were brought in for the animal trade during the years prior to the enactment of the Endangered Species Act (Louis Porras, pers. comm.). The surviving animals and their progeny form the present captive population.

West African dwarf crocodiles were first bred in captivity at the Ueno Zoo in Japan in 1972 (Hara & Kikuchi, 1978). Subsequently, they have been bred at a number of institutions, sometimes repeatedly: Kuala Lumpur Zoo (Malaysia), Metro Toronto Zoo, Memphis Zoo, Fort Worth Zoo, Jacksonville Zoo, Los Angeles Zoo, Tel Aviv University, Tokyo Zoo, Noorder Dierenpark (the Netherlands), and five times since 1977 at Woodland Park Zoo in Seattle. The body of literature pertaining to the captive breeding of *Osteolaemus* is considerable, but Tryon's 1980 work is particularly valuable, detailing parental care and omitting little else.

On August 27, 1973 we received a pair of young dwarf crocodiles on loan from the Los Angeles Zoo. Their estimated age at that time was approximately 4 years. They were wild-caught, but had been raised at the Los Angeles Zoo.

The male crocodile, now 1.85 m in length, could hardly be more docile. He is very accommodating during cage cleaning, moving out of the way with little cueing, eating from the tongs at nearly every feeding. The female (1.3 m) is only slightly aggressive, hissing and advancing when crowded, but, as may be expected, she is much more aggressive during the nesting season.

Diet

These animals have had a unremarkable health history, and appear to be flexible and hardy specimens. They are fed twice a week on a diet of frozen smelt or herring, mice, and skinned adult rats. They are fed to satiation, and food is left in the pool overnight for the shyer female. Smelt or herring is supplemented with thiamine by inserting portions of tablets into the bodies of the fish. An attempt is also made to give each crocodile two 00 gelatin capsules of a multivitamin powder in a food item, but since only the male crocodile eats immediately, the supplementation of the female remains in doubt. Nonetheless, both specimens maintain very good weight and do not seem to suffer from any nutritional problems.

Housing

For the first twelve years here, they were maintained in an irregularly shaped grotto (see Figure 1) containing a 8500 l pool, which is less than 0.55 m deep and slopes up to a small land area (2 x 7 m) at the back. The enclosure also contains a number of water turtles, mostly Amazonian river turtles (*Podocnemis sp.*), but also giant hill turtles (*Heosemys grandis*), red-eared sliders (*Trachemys scripta*), mata matas (*Chelus fimbriatus*) and map turtles (*Graptemys geographica*) (the turtle population has varied over the years). The enclosure is surrounded by planters and narrows at the end away from the land area where a recirculating waterfall provides a dark, sheltered overhang for turtles and crocodiles seeking a hiding place. The pool is cleaned 2-4 times weekly, and is refilled with 28°C water. Water temperature is maintained by a recirculating heater system, which distributes the reheated water along the length of the pool.

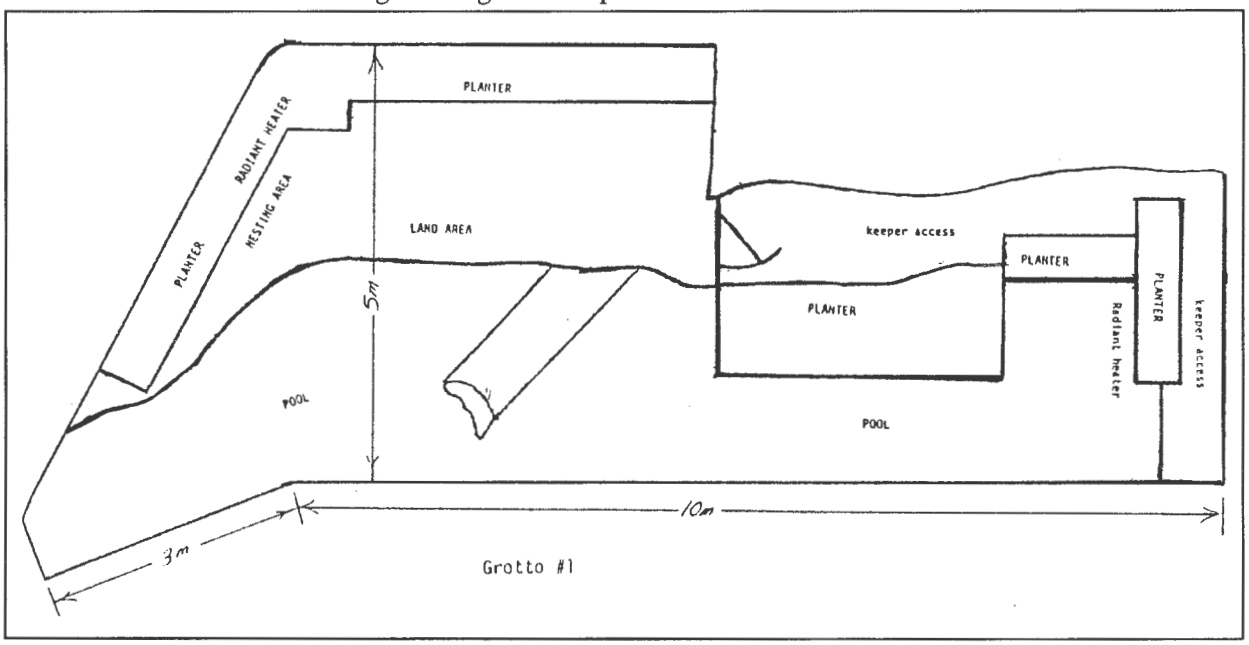

Figure 1 - Main Enclosure for Dwarf Crocodiles

Over one end of the land area, a 2000 watt radiant heater provides a basking spot and heats the nesting area substrate for turtles and crocodiles alike. An identical unit is suspended over the water at the opposite end of the enclosure.

After a bout of harassment of the turtles by the female crocodile in 1985, the crocodiles were transferred to a similar, but smaller grotto (see Figure 2) containing a 3500 l pool, sloping from all sides to a total depth of 0.75 m at the center. A single radiant heater is suspended over the water at the front center of the enclosure. Two 250 watt heatlamps and a large hot rock (a 0.45 x 0.9 m concrete pad which is electrically heated to 38-43°C) provide the necessary basking spots on the land portion of the enclosure.

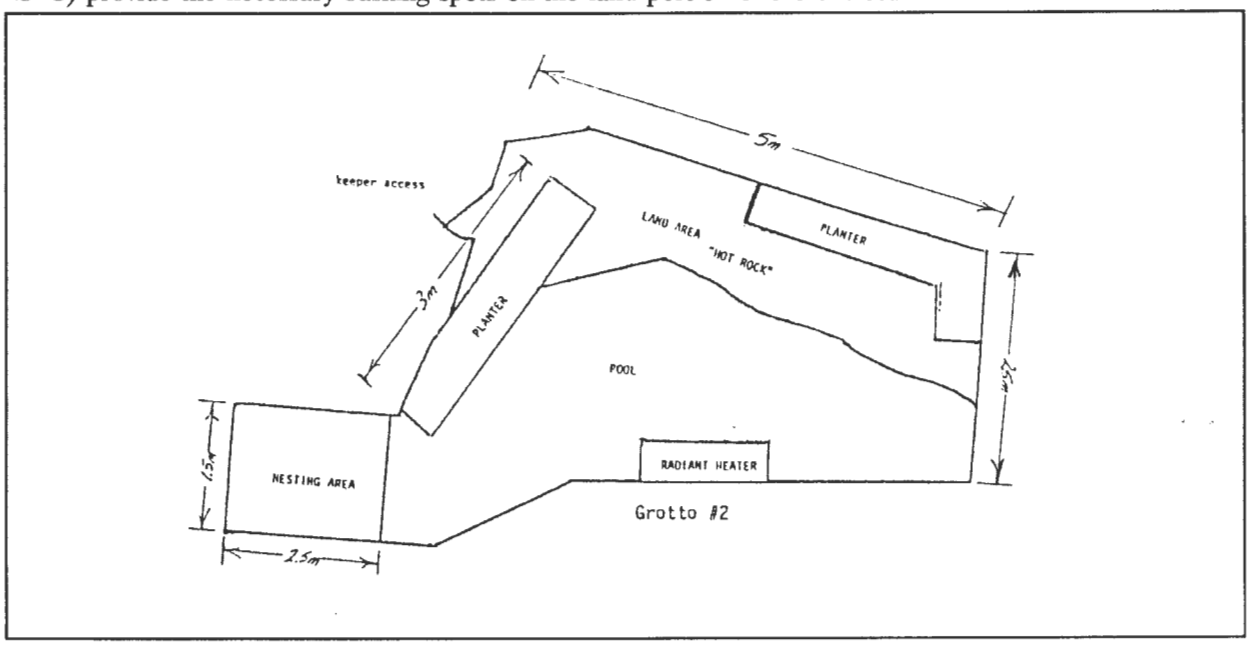

Figure 2 - Second enclosure for Dwarf Crocodiles

This second enclosure is cleaned twice a week on the days after feedings. Again, 28°C water is used for cleaning and filling the pool.

Clerestories above both enclosures admit natural light. This is supplemented by artificial lighting, which over time, has been changed from fluorescent and incandescent, to fluorescent and sodium lighting.

Vagaries in physical plant equipment have caused temperatures in this enclosure to vary greatly over time, but were generally in the range of 24-29°C air temperature, and 24-29°C water temperature.

Reproduction

Our dwarf crocodiles were first observed copulating on May 2, 1975, and have been observed copulating in each of the following years: 1976, 1979, 1981, and 1985-87. Observations of copulation were fortuitous, and many copulations were undoubtedly not observed. Many of the copulations observed were early in the morning or late in the afternoon, when the public was absent from the building, suggesting that the crocodiles prefer quiet and minimal disturbance for this activity. Copulation has been observed in every month from January to July, and in September, with some courtship behavior observed in August and December. Copulation is performed as described by Tryon(1980).

Egg-laying has occurred in each of the following years: 1977-79, 1981, 1982, 1984, and 1986-88, and has occurred in May once, in June four times, in July three times, and in August once. In spite of the female taking

an obvious proprietary interest in a small area of each grotto, and in spite of her interest in the nesting materials provided, oviposition has always occurred in the water. The eggs are found during the morning check, and are immediately rescued and placed in artificial incubation. The amount of time they were immersed may have been from just a few minutes to up to 14 hours. The longer immersions may have been a factor in the poor hatch rate of some clutches.

Clutch sizes have dropped from 12-17 during 1977-1982, to 2-6 during 1984-88. The reason for this is not known, and was not apparent on ultrasound and radiographic examinations of the female following these small clutches. These examinations were made because of our concern that eggs might have been retained and might have caused egg peritonitis and death.

Although the eggs have not been measured, they seem to be without much variation in size or appearance within each clutch. An infertile egg, which was blown and saved, is larger (71.7 mm x 44.6 mm) than any in six clutches reported by Tryon (1980) or in four clutches reported by Hara and Kikuchi (1978). However, this egg is very similar in size to those reported by Beck (1978). The eggs were found covered with a clear jelly-like mucus (also noted by Hara and Kikuchi, 1978), which has not been wiped off on recent clutches.

Egg Incubation

Eggs are set up in plastic shoeboxes on a mixture of 1:1 sifted beach sand:peat moss (by volume). This is moistened to a consistency well short of mud (moist, but not wet), and the eggs are half-buried in this mixture. The shoeboxes have small holes in the lid for ventilation, and are checked daily and remoistened as needed. The incubator is very basic: a wooden box with a thermostat controlling a heat lamp's on/off function. A thermometer is kept inside each shoebox to insure that the temperature being monitored is the temperature that the eggs are experiencing, and it is checked daily at the same time as the moisture measurements.

Eggs were incubated at 31-32°C through 1987, but recent work on temperature-related sex determination (TSD) in crocodilians (Webb et al, 1987) it was decided that we should adjust our incubation temperatures somewhat in an effort to avoid producing young crocodiles all of the same sex. The three crocodiles hatched in 1987 were all females. 1988 eggs were incubated at 30.5°C, but this may not be low enough to give us a better proportion of females. TSD is very complex, and varies from species to species.

This phenomenon bears additional scrutiny, especially when the relative incompatability of adult males and the finite amount of space for adult crocodilians is considered. I have made inquiries to a number of institutions which have bred dwarf crocodiles to try to accumulate more information on TSD in this species.

Neonates

Hatching occurred in 1977 (3 of 16), 1978 (2 of 12), 1979 (3 of 17), 1986 (3 of 6),and 1988 (2 of 3). Incubation length varied from 75-87 days at 32°C, to 95 days at 30.5°C.

Although many of the neonates made it out of the eggs on their own, recent clutches have been opened on the day after pipping, and the vocalizing youngsters released, as they might have been by their mother if they had been incubated naturally as suggested by Tryon (1980). Recent neonates have had no retained yolks, and it is not possible to determine from the records why the first clutch showed this and other problems. Hatchling weights for recent clutches have been in the range of 60-66 g, and neonates appeared as described by Sims and Singh (1978), but were substantially larger than any reported by others (Tryon, 1980, Hara and Kikuchi, 1978, or Teichner, 1978).

Until 1988, neonates were started on crickets dusted with a variety of vitamin/mineral preparations and fed progressively larger mice as they grew and were able to swallow the larger meals. In 1988, feeder goldfish were added to this regime. For the first few months hatchlings were fed nearly every day, and growth was rapid (see Figure 3). The crocodiles hatched in 1986 reached 1 kg within their first year.

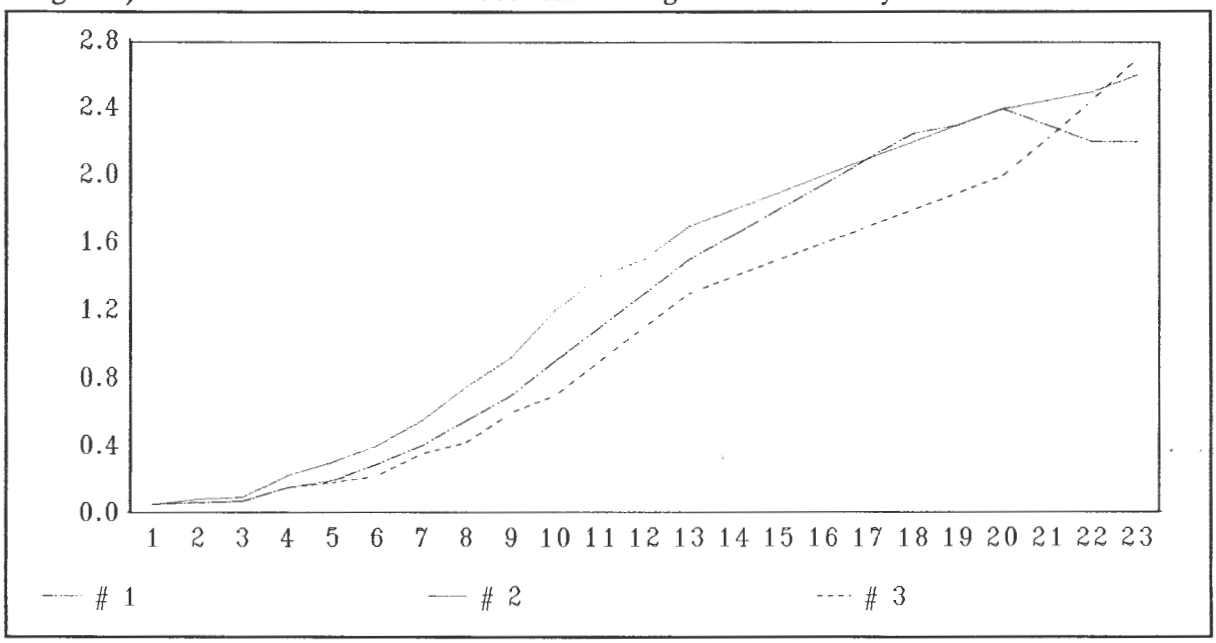

Figure 3 - Weight gain in *Osteolaemus t. tetraspis* hatchlings (kg vertical axis/age in months horizontal axis)

Problems with neonates in less recent clutches included calcium deficiencies (probably due to feeding excessive numbers of crickets, which lost their vitamin coating before they were consumed), and occasional conjunctivitis (possibly due to frequent exposure to chlorinated water). Incompatability between 1-2 year old female crocodiles was more problematic than we would have anticipated, and one crocodile made life impossible for its two siblings in the very large enclosure which was the first home for the adult pair. The two subordinate animals were removed to holding cages.

Finally, it is worth mentioning that the small clutches of recent years were a relief of sorts. Trying to find homes for small but growing crocodiles is a problem, as zoos develop more rigorous animal disposal policies. Fortunately, the AAZPA Crocodilian Advisory Group has recently begun to recommend that approved alligator farms be allowed to help carry the load of maintaining captive crocodilian populations.

Acknowledgements

Nearly the entire keeper staff at Woodland Park Zoological Gardens has at one time or another helped care for the dwarf crocodiles over the years, but two individuals deserve special mention: Jack Simmons, who recorded hatchling growth; and Frank Slavens, while he was unit keeper of the reptile house the crocodiles first reproduced, and under his direction as a curator the crocodiles continued to do so.

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Geckos of the U.S.S.R. in the Collection of the Reptile Breeding Foundation

Thomas A. Huff, Director
Reptile Breeding Foundation
P.O. Box 1450
Picton, Ontario
K0K 2T0, Canada

Introduction

When the Reptile Breeding Foundation was founded in 1973, our main focus was on the Boidae, and more specifically, the insular forms of the genus *Epicrates*. Although we continue to work with several species of the genus and a number of other insular boids, we have now diversified into other taxa. At that time, the thought that we might ultimately be working with a number of Soviet geckos never entered my head.

Our fascination with geckos began innocently enough: I was attracted to a pair of leopard geckos (*Eublepharis macularis*) and decided to purchase a pair in March of 1981. This actually was also the first species of gecko from the U.S.S.R. to enter our collection. As most herpetoculturists know, leopard geckos reproduce rather easily in captivity. Within five years we had no less than sixty individuals from this original pair. About the same time, we acquired a pair of flying geckos (*Ptychozoon lionatum*). They were almost as easy to propagate in captivity as *Eublepharis*, and we soon had some forty individuals of this species in our collection.

In 1982, I was program chairman for the 6th Annual Reptile Symposium on Captive Propagation and Husbandry held in Washington, D.C. In response to my call for papers, I had submissions from four people who wished to present papers on geckos. Papers by several individuals, notably Mike Miller, Tim Tytle, and Tom Digney, perked my interest in the day geckos (*Phelsuma*) and I was off into that world. This genus, unlike some of the other geckos we work with, fits our criteria of "a concentration on endangered species." Ultimately we were breeding Round Island day geckos (*Phelsuma guentheri*), the Ladigue Island day gecko (*P. sundbergi ladiguensis*) and other potentially endangered or threatened members of this genus.

Our entry into the herpetoculture of frog-eyed sand geckos (*Teratoscincus sp.*) came about for no other reason than I had always thought them to be cute and I acquired a pair of Asian frog-eyed sand geckos (*T. scincus*) in October 1982. Success with this species led to a greater interest in the genus, and a search for other species. In October 1983 we were able to obtain a trio (1.2) of the Mongolian frog-eyed sand gecko (*T. przewalskii*) and nine months later we purchased a second trio of this species. Based on our success with *T. scincus*, we established the husbandry routines and caging for the Mongolian species in a similar manner. Our efforts were rewarded when on September 16, 1985 we hatched our first *T. przewalskii*. I will not go into detail on the husbandry and captive propagation of these two species as that has been most adequately presented by Kellough (1987).

We have produced in excess of 100 *T. scincus* since that first pair and are presently into the third generation of captive hatched individuals. We have successfully hatched 10 *T. przewalskii* to date and believe that we are still the only institution successfully reproducing this species in captivity.

While attempting to obtain the Mongolian species, I had contacted a number of herpetoculturists in West Germany, East Germany, Czechoslovakia, Poland and the Soviet Union. Often when making an offer to purchase or trade for these animals, I was offered other species. Ultimately, we received two interesting and, at that time unique to North America, species of geckos from the Soviet Union. The first was *Crossobamon eversmanni*, one of a genus of two species (*C. orientalis* has just been recognized) which we simply call the Russian gecko. The second species we received was called the Russian spider gecko (*Tenuidactylus fedtschenkoi*). Originally, this species was placed in the genus *Cyrtodactylus* with which it has close affinities, then moved to the genus *Gymnodactylus* and now placed in a new genus altogether.

Russian Gecko (*Crossobamon eversmanni*)

Crossobamon eversmanni is found in the deserts of the central Asian Republics of the U.S.S.R., eastern Iran, and Afghanistan. It feeds on a variety of insects and reaches a maximum snout-vent length (SVL) of 14 cm. This gecko is nocturnal and spends the daylight hours in burrows which it digs in sandy hills and dunes. These burrows are shallow and rarely exceed 70 cm in length. At sundown, the geckos become active and appear on the surface. When hunting, they can often be found on desert shrubs.

Russian geckos are brownish-yellow or rose, and covered with small dark dots. A narrow dark stripe can be found along the sides of the neck to the middle of the body were it separates into spots. The legs and the lower side of the tail are lemon-yellow, while the belly is white. The entire body and head appears to be somewhat flattened. The eyes are quite large and bulbous in appearance.

Females lay one or two eggs per clutch, beginning at the end of May or the beginning of June in the wild. This generally holds true in captivity, although on several occasions we have had fertile eggs laid from September through December. These eggs are oval in shape with a diameter between 9-12 mm. A female may lay two or three clutches per year.

We maintain a group of six, sexually mature individuals at the Reptile Breeding Foundation. Adults are paired for reproduction and no special egg depositing chambers are provided. Eggs are laid on the sand substrate of the enclosure, then removed to an incubator where they are kept at a temperature of 30°C for the 55-70 day incubation period. The hatchlings are extremely small (3.0-3.5 cm total length), but feed well on pinhead crickets. They reach sexual maturity within 10-12 months. Although this species hibernates in its natural environment, we have never allowed ours to hibernate in captivity. There is a minimal mean cage temperature drop during the winter, but I do not believe any special conditions must be met for this species.

Russian Spider Gecko (*Tenuidactylus fedtschenkoi*)

Tenuidactylus fedtschenkoi ranges through western Turkmenia, Uzbekistan and Tajikistan in the U.S.S.R., northern Afghanistan, and northeastern Iran. The gecko is found in varied habitats including rock out-croppings, desert rodent burrows, houses, and outbuildings. It occurs at relatively high elevations; 2200-2300 m above sea level in some parts of its range. In the wild, its diet consists primarily of scorpions, millipedes, insects and their larvae. It reaches a SVL of 15 cm.

The Russian spider gecko is brownish with a yellow or grey tinge. It has five indistinct stripes on its neck and body, and nine stripes on the tail. The lower side of its body is white. The body and especially the head of this lizard appear flattened. Males have femoral and anal pores.

The Russian spider gecko hibernates from late fall through early March in its native habitat. Clutches of two eggs are laid beginning at the end of May, and two more clutches are usually laid by the end of the summer. We have found this to be the same in captivity. Two or three females will often share communal laying sites. Eggs are oval and approximately 10 to 11 mm in diameter. Incubation is about 50-60 days. The young hatch at the beginning of July and attain sexual maturity in nine to twelve months.

We presently have twenty individuals in our collection and they reproduce on a regular basis. As with *Crossobamon eversmanni*, we do not artificially hibernate this gecko in captivity. Its egg-laying habits and our incubation criteria are the same as for the former species. An interesting note, we have allowed eggs to remain and hatch in the cage with the adults. These geckos appear to be much more social and less aggressive than the other species mentioned here and can be kept in large groups.

Iranian Frog-eyed Sand Gecko (*Teratoscincus scincus keyzerlingii*)

Never having lost our desire to work with other species and subspecies of *Teratoscincus*, we were able to obtain a pair of *T. scincus keyzerlingii* in May 1988. Then in August 1988, we finally made contact with someone who could provide the Pakistan small-scaled frog-eyed sand gecko (*T. microlepis*) and we shortly thereafter received five individuals. Two months later we were able to obtain an additional five individuals. These arrived in terrible condition, but they are now feeding well, putting on weight and we are optimistic that they will reproduce this year.

T. scincus keyzerlingii ranges from north central and southeastern Iran, western Afghanistan, northwestern Pakistan and the eastern Arabian peninsula. It has been found within a few kilometers of the Soviet border and most likely does range into the U.S.S.R. Its range is fairly well restricted to desert regions with sparse plant cover, where it feeds on a variety of insects and spiders.

Like the other members of the genus, this gecko is nocturnal. It varies between yellow, orange and different shades of brown, with areas of light-grey. Normally there are two wide, oblong, dark-brown lines on the back. The sides and belly are light pink to white. Young specimens are dark yellow to light orange.

When confronted by an enemy, the Iranian frog-eyed sand gecko will attempt to intimidate it by producing a vocalization that sounds like a snarl. They also produce noises by rubbing the fingernail-shaped scales of the tail against each other. This behavior is consistent with other members of the genus.

We have not yet reproduced this subspecies in captivity, but as with *T. microlepis*, we are optimistic of success this year. The female has just recently laid her first egg, which unfortunately was infertile.

Pakistan Small-scaled Frog-eyed Gecko (*Teratoscincus microlepis*)

T. microlepis ranges from Baluchistan in Pakistan, westward into Dasht-i-Lut in Iran. The gecko has also been found very close to the Russian border, but not actually within the Soviet Union. It lives in desert areas consisting of fine, wind-blown sand, feeding almost exclusively on beetles and their larva. It reaches a total length of 12 cm.

The Pakistan small-scaled frog-eyed sand gecko is yellow to light brown in color, and patterned with six dark transverse bands which can be either V-shaped or straight-edged. These bands are usually a dark brown or gray in color in adults, while young geckos are patterned with reddish bands. There are also five or six cross-bands on the tail.

There is no reproductive data available for *T. microlepis*; however, we have just introduced a pair in our first reproductive attempts with the species and hopefully we will have some data in the near future.

Diet

All of the above mentioned species of geckos are fed primarily crickets and wax moth larvae at the Reptile Breedings Foundation. These insects are dusted with AVIA® vitamin powder and are offered to the geckos three times per week. No standing water is provided, but rock surfaces are misted lightly once every 7 to 10 days. Calcium is supplied ad libitum in the form of crushed cuttlebone. We believe this is mandatory to prevent impaction of the gut through consumption of sand and is certainly required for egg production.

Each group or pair is housed in either a 48 l or 68 l terrarium. There is a temperature gradient ranging from 25-34°C within the enclosures. Lighting consists of two 40 watt Vita lite® fluorescent tubes on a 12 hour cycle. The substrate of all enclosures is sand to a depth of 5 cm. Rock piles, pieces of bark and split plastic logs are provided for cover and basking. Although nocturnal, all of these species show some propensity for basking, usually for short periods of time in the morning.

Conclusion

The literature on Soviet reptiles is scant or unknown to westerners. There are three or four standard references which are well known, but quite outdated for which there have been translations. In 1986, a small book appeared entitled "The Gekkonid Fauna of the Soviet Union and Surrounding Countries". I was excited about this publication, but being unable to read Russian, it was of limited value to me. The scientific names were in Latin, and could be recognized. The limited photographs in this publication were of some value, and weights and measurements were pretty straight forward. Thanks to my colleague, Bert Langerwerf and his generosity in translating the section of this book dealing with *Teratoscincus*, we have increased our knowledge of these animals ten-fold. These translations will be published in upcoming issues of the Reptile Breeding Foundation's Journal, "The Herpetoculturist."

Working with and having reproductive success with any reptile can be both gratifying and frustrating. The lack of information on the geckos and, for that matter, all the reptiles of the Soviet Union has certainly caused us frustration, but our ultimate success with these species has likewise been gratifying. Our knowledge and success with similar species helped pave the way for success with these animals. This paper is simply an attempt to further our collective, but limited knowledge of the Soviet herpetofauna and encourage more herpetoculturists to work with these species.

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Captive Maintenance of Green Tree Monitors (Varanus prasinus) and Their Kin

Robert George Sprackland, PhD
Dept. of Biological Sciences
San Jose State University
San Jose, CA 95192

Introduction

The tree monitors represent a small group of medium-sized varanid lizards endemic to New Guinea, its offshore islands, and Australia's Cape York Peninsula. The most widespread taxon is the green tree monitor, or emerald monitor (*Varanus prasinus*) of New Guinea, an unusual varanid because of its brilliant green coloration. This animal is a particular prize in live animal collections, especially as exports of this lizard have declined sharply since 1978. However, shipping conditions and acclimation to captivity are extremely stressful to these lizards, and the mortality rate can be high in freshly imported lizards. This study presents findings based on husbandry of tree monitors from 1977-1989 and offers findings on successful maintenance of these lizards.

Though four subspecies have been listed for *V. prasinus*, a revision of the group has been proposed (Sprackland, 1989b); three taxa are unknown from captive observations, and one is presently known only from the holotype. This report deals only with the green monitor and the Aru Island monitor (*V. beccarii*)

Information on live tree monitors is scanty. Sprackland (1982) provides information on gut morphology and diet based on freshly imported lizards. Losos and Greene (1988) provide analysis of stomach contents from museum specimens. Greene (1986) reviews diet and arboreal adaptations of *V. prasinus*. General sources (i.e., Cogger, 1975; Neugebauer, 1975) indicate that the lizards are arboreal and insectivorous. A general account of captive maintenance is given in Sprackland (1990), and a description of treatment of an individual *V. prasinus* received in poor condition is given by Mann (1976). Most other data published have been systematic in nature (see Sprackland, 1989b).

Until 1978 *Varanus prasinus* was frequently imported from Indonesian or Thai sources. At that time, restrictions in Thailand reduced the exportation of the lizards, and they were rarely seen on the commercial market. Half of New Guinea (=Irian Jaya) belongs to Indonesia, and consequently a limited trade in *V. prasinus* and *V. beccarii* has recently resumed.

Husbandry

Observations were made on twenty adult tree monitors, beginning in 1977. Four were *V. beccarii*, the remainder *V. prasinus*. All but seven were kept in the author's collection; two were in a private collection, and five in a municipal zoological park. Behavioral observations were made on all specimens.

Cage size and construction varied, but all were provided with heat lamps and full-spectrum fluorescent lamps. A thermal gradient was usually provided so that daily temperature range was 28-35°C and humidity kept in excess of 70%. The zoo animals had a pool with running water; other terraria had water dishes which were changed daily.

Activity Patterns

Tree monitors tend to be hyperactive. Freshly caught animals may race about the cage wildly at the slightest disturbance in the room, and it may be necessary to provide a visual barrier in front of their cages while they acclimate (Murphy, pers. comm; pers. obs.). While exploring their surroundings, they may easily injure their snout by running into glass, or rubbing against screen or sharp objects. Such injuries may permanently disfigure the animal, and frequently lead to infection.

Arboreal animals are typically active, alert, and wary. Tree monitors will need cover before they can adjust to captive conditions. This should include stout branches, hide boxes, hollowed logs, and large inverted flower pots. Though plants fare poorly in a varanid terrarium, the use of a variety of large, leafy plants during the acclimation period may be beneficial. It not only provides a better approximation of natural surroundings than would a more sterile cage, it also provides more cover, especially for a lizard patrolling its new surroundings. The plants may need to be replaced periodically, but after the lizards adjust to captivity, they are not necessary so long as alternate cover is provided.

Complications from Transit

The stress of transit often promotes bacterial infection in hardier species. In imported tree monitors a disproportionate number, including fifteen of the twenty used in this study, is found with trauma, stomatitis, pneumonia, or some combination of these. Gentocin (2.5 mg/kg every 72 hrs) and chloramphenicol (12 mg/kg daily) have been the drugs of choice for these infections, the former largely superceding the latter in recent years. The only published report on veterinary care seems to be Mann (1976), which reports on treatment of a single specimen for transit induced stress.

Amoebiasis is also common in monitors shipped from southeast Asia. Tree monitors diagnosed with this disease were given oral doses of chloramphenicol (7 mg/kg) three times a day for four days, or ampicillin trihydrate (4 mg/kg, t.i.d.) for the same period. In both cases, the temperature was raised to 40°C for the duration of treatment (Jacobson, pers. comm). Heat is effective in killing amoebae in the gastrointestinal tract of lizards, and occasionally raising the terrarium temperature may be prophylactic in controlling this illness.

Whenever treating bacterial infections, a reliable heat source is required. Many bacterial agents are effectively neutralized by heat, and raising the terrarium temperature may facilitate healing. Best results while treating eight lizards for stomatitis/pneumonia were obtained when the animals were kept at a daytime temperature of 33-35°C, and a nighttime low of 28-30°C. In contrast, terraria are usually set up to provide a thermal gradient, with a daytime range of 28-35°C, and nighttime low of 19-26° C. In five animals treated with intramuscular injections of chloramphenicol, treatment took 3-4 days for three lizards kept at the warmer temperatures and 7-12 days for the two lizards kept under the normal gradient regime.

Humidity requirements for monitors have not been established, but tree monitors inhabit humid, lowland forests (Allison, 1982). Cages are routinely kept in excess of 70% humidity. Good ventilation is necessary in order to prevent animals and props from becoming too moist, which could lead to fungal and bacterial growths in the terrarium.

Feeding

The diet of tree monitors varies. Based on regurgitated material and stomach analyses of freshly imported animals, Sprackland (1982) concluded that the diet of *V. prasinus* consists primarily of hylid frogs (40%), geckos (17%), unidentified anurans (15%), vegetable matter (12%) and a variety of insects, small birds and eggs. Percentages were based on mass, and most likely reflected an artificial diet provided by the animal collectors prior to shipment (Greene, pers. comm). Losos and Greene (1988) examined 29 museum specimens of *V. prasinus* and concluded that orthopteran insects make up 68.1% of the natural diet. Other prey identified by them included insects and larvae, a centipede, a spider, and a rodent.

Captives are typically fed a diet high in rodents, though these do not seem to constitute a major natural food item. The analyses made by Sprackland (1982) and Losos and Greene (1988) indicate that wild *V. prasinus* consume a large number of small, soft-bodied organisms that are themselves nocturnal. The monitors are diurnal foragers, and, like woodpeckers, search out sleeping prey species. Alternately, they consume diurnal prey, such as stick insects, that offer little resistance when seized by the lizard. The implications are important in the husbandry of tree monitors. Many freshly imported animals have little experience with a prey item, such as a live mouse, which can bite and claw enough to seriously injure the lizard. This added stress, of overpowering a large, fighting prey animal, is probably linked to trauma and added stress reactions of acclimating monitors. In time, the lizards learn to seize the rodents by the nape and to avoid claws and teeth, but early trials often result in bitten and bleeding monitors.

Alternately, freshly killed mice can be offered for food. Some monitors will take these readily. For problem feeders, a diet of crickets and young mice should be offered. The lizards respond to the movement and to the size of the prey; given a choice, monitors I have observed will almost always take the smaller prey instead of the larger. In 70 feeding trials, insects were taken more quickly than adult mice, and in 40 trials where both crickets and adult mice were offered simultaneously, insects were taken first on 28 occasions. Rodents were chosen first on six occasions, and food was ignored on four trials. On the remaining two occasions, the lizard took the first item that moved directly in front of it (both times, crickets)

Tree monitors that I have managed which were fed only on mice invariably became constipated. Specimens given a diet of mice, insects, lizards, and fruit did not develop this symptom. I now feed my tree monitors pieces of steak, chicken, crickets, live anoles, young mice (fuzzy or pink), bananas, and cantaloupe. I alternately sprinkle all non-living food items with calcium-phosphorus or vitamin supplements, and feed the lizards from twice weekly (winter) to four times weekly (early summer). The reasoning behind these seasonal feeding changes is to simulate pre-mating boon periods with leaner post-mating periods.

Neugebauer (1975) has noted that the hyoid apparatus of varanids allows them to expand the throat to swallow prey items of considerable bulk. This observation has traditionally been held to imply close affinities between varanids and snakes. However, small varanids (subgenus *Odatria*) typically swallow small prey items intact, while larger monitors (*Varanus salvator*, *V. komodoensis*, *V. indicus*) tend to render large prey into smaller chunks for easier swallowing. In this regard, *V. prasinus* and *V. beccarii* resemble the latter group. Large prey items, including mice, are clawed or twisted until smaller pieces can be removed. In cases where such dismemberment is not successful, swallowing can be a long and laborious process, and it is not uncommon for one lizard to try to take a partially swallowed rodent away from another monitor. The implications for husbandry are (1) feed tree monitors small food items that are quickly swallowed (2) provide enough food at each feeding so one lizard will not take food from another, or (3) separate lizards during feeding (or offer dishes of food at opposite sides of the enclosure.

Figure 1 - The author and a 2.0 m water monitor (*Varanus salvator*). This monitor is certainly acclimated to human presence, and may be properly called tame. However, if a rat is within view, this lumbering goliath becomes uncharacteristically adroit and swift. It is still an open question whether such behavior implies intelligence or is merely a simple reaction to the regular interaction with people. Photo by Teri Sprackland.

Reproduction

Data from museum specimens suggest that egg-laying occurs in August-October, with hatchlings emerging in December-February. Only one report observing wild *V. prasinus* hatching is known (Sprackland, 1989), and the young were emerging from a rotting log. One breeder reports that a wild-mated female laid two eggs that hatched after 142 and 145 days. The eggs were incubated at 90°F. Dallas Zoo had a female lay three eggs; one which was infertile. The two fertile eggs hatched and one of the juveniles escaped and the other died after a few months (Murphy, pers. comm.). The preserved juvenile is housed in the University of Kansas Museum of Natural History, and to date represents the only known voucher specimen of a captive bred *V. prasinus*.

On two occasions, females in my collection exhibited what may have been pre-laying behavior. In each case, the lizard would excavate soil from a large planter in the terrarium, using the hind limbs. Prior to this, both females had fed little during the preceding three weeks, and refused to feed during the week of digging. Normal feeding resumed shortly after digging behavior ceased.

Behavior and Growth

Varanid intelligence is well known anecdotally, though the literature rarely addresses the subject. Zurich Zoo director H. Hediger has noted that mangrove monitors become tame, and one individual would go swimming in the ocean with him (Neugebauer, 1975). In his classic text, Ditmars (1933) reports that water monitors became very tame, and would allow keepers to embrace them. He further asserted that the lizards would recognize the keepers. My own experience has shown that some large varanids do, indeed become tame (see Figure 1), but smaller varanids are less likely to acclimate to human handling. Numerous private keepers have relayed that *V. prasinus* is a hyperactive lizard, rarely prone to handling; and *V. beccarii* is reported (Murphy, pers. comm) to be even more highly strung.

Since my initial experience with *V. prasinus* involved a specimen quite traumatized by transit, considerable handling was required from the outset (force feeding, injections, general examination, cleaning). The animal was a large (308 mm) male, and became quite tame, in that it regularly allowed handling without clawing, defecating, or biting. On many occasions, it would perch atop the author's head as he did paperwork in the office (there are those who frown at such domestication of wild animals, to whom I say that domestication was not the aim; I cite this example to show the extreme docility evinced from a species normally considered hyperactive and intractable).

Since that specimen adjusted, we have tried to acclimate all tree monitors to some degree of handling. This reduces stress when animals must be moved for cleaning or examination, and helps insure that observation by humans in close proximity will not cause an animal to stop feeding. I rarely handle my tree monitors and I consider them to be sufficiently acclimated if they allow me to stroke their dorsum without them running away.

I have measured the growth of adult tree monitors. A male measuring 280 mm snout-vent length (SVL) on arrival measured 308 mm six months later. A female was measured at 254 mm SVL upon acquisition and 270 mm six months later. The growth rate for adults seems to be about 3-4 mm per month, though this probably is reduced drastically at some critical point. Only one subadult was available for measurement and it grew from 171 mm to 213 mm SVL after 100 days, a rate of 11.9 mm per month.

Activity is largely crepuscular, with activity peaking in late afternoon, and continuing until shortly before sundown. During the active period, lizards forage, drink, and remain fairly mobile. In contrast, midday is a period of basking and peripheral foraging. Given a tall enough cage with adequate branches, tree monitors are

almost wholly restricted to the arboreal environment, rarely coming to the ground except to drink or eat from a dish. They seem equally comfortable perching horizontally and vertically, though they rarely do so in a head-down posture. While climbing, they employ the fully prehensile tail as a fifth limb, and may dangle from a branch, suspended by only a few centimeters of tightly coiled tail. No varanid has an autotomous tail, but most, including the dwarf *Odatria* species, use this organ as a weapon. Not so in tree monitors. When threatened, they coil the essential tail close to the body, and will maneuver the body to keep the tail away from an opponent. I have seen a prasinid use its tail as a whip only once, when trying to induce a live mouse to move away from the lizard.

Threat behavior is rarely seen in captive tree monitors and is far less elaborate than that reported for terrestrial varanids. Given the nature of being arboreal, where flight is the easiest and most efficacious response to a threat, it is not surprising that tree monitors would have a reduced agonistic repertoire. A typical display involves raising the forebody, turning the head, and raising the head and neck into a tight S-coil, with gular region distended. The effect is to present an apparently much enlarged head to a potential predator.

Further display is rarely seen unless the monitor is on the ground or on a broad perching site. In that case, it will angle the dorsum to face the opponent, depressing the body and tilting it at the same time. In doing this, the monitor may increase its width by 100-125%, and by tilting the body, raise its height to twice normal size. This display is similar to that described for *V. gilleni* (Murphy and Mitchell, 1974) and *V. mertensi* (Murphy and Lamoreaux, 1978). The primary distinction between this posture in *V. prasinus* and in *V. mertensi* is that in the former, the tail remains tightly coiled, and is kept away from the opponent. Hissing is usually inaudible, though the lizards do expel air forcefully through the mouth when displaying.

One bout between two male *V. prasinus* was observed when both tried to occupy the same perch. One monitor was a long-term resident, the other a new arrival, both approximately equal in size. The resident responded to the approach of the new male by assuming the S-coiled neck posture. The new male neared, eliciting a stiff-legged stance from the resident. When the new male was within 200 mm of the other, the resident assumed the body-tilting orientation, slowly weaving back and forth on the stiff limbs. The new lizard continued to advance, and as the lizards made contact, they slowly assumed tripod stances. They rocked each other until the new lizard lost its grip and began to fall. The bout was repeated three times, and ended when the new arrival finally fell from the branch.

Many monitors are excellent swimmers and only one, *Varanus griseus*, is a non-swimming species. *Varanus prasinus* is not regularly aquatic, but it can swim. Unlike water monitors that have compressed tails and propel themselves with slow undulations of that organ, tree monitors undulate the entire body. This is energetically more costly to the animal, implying that swimming is employed only when needed, and that foraging in or near water is unlikely. Tree monitors that are provided with large water dishes will occasionally immerse themselves on very warm days, but this is not a regular means of behavioral thermoregulation. More typically, the lizard will retreat to shade or cover to avoid heat.

Thermoregulation by tree monitors in captivity is not unusual. The lizards emerge from shelter and position themselves under a heat lamp. The dorsum is distended, revealing most of the black skin between the green scales. As the lizards warm, they gradually reduce the degree of distention. The black monitors do the same posturing, and the time spent in the distended state is similar for both lizards. The glossiness of the scales in both taxa may contribute to reflecting light waves, while the rough, flat-textured skin between the scales may may contain a greater capillary bed allowing for more rapid absorption of heat. When temperature becomes too warm, lizards may retreat to the water (rarely), seek shade, shelter, or burrow.

Conclusion

The tree monitors are highly active lizards requiring a large terrarium with numerous above-ground perches. During the early phases of captivity, physical injury may exacerbate travel-induced stress to produce trauma and other illnesses. Acclimation should include an isolation period in a warm (38-42°C) terrarium, to help eliminate enteroparasites and to relieve stress. Clean water should be provided as needed during this period, and a dish large enough to allow the lizard to soak in is recommended.

Though not classified as threatened or endangered, tree monitors are restricted in range. At present, their natural habitat is secure, but lowland rain forests rarely remain secure. The demand for these lizards by collectors will probably not contribute greatly to their decline in nature, but in general, shipping conditions must be improved if transit related illnesses and deaths are to be reduced. Though the wholesale price in Indonesia has remained fairly constant ($90-125) since 1976, the U.S. retail price has risen from $200 in 1976 to $450 or more in 1988. Consequently, collectors obtaining specimens will most likely be better prepared and willing to take necessary veterinary precautions with new arrivals.

Breeding information is scanty, and captive reproduction is documented for only two cases. A primary goal of husbandry of these lizards should be captive propagation. Their size makes them available for more herpetoculturists to work with than the larger varanids, and once acclimated to captivity they are not much more demanding than many other lizards.

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Tennessee Blind Salamander (*Gyrinophilus palleucus*)
Adult. Photo by Edward Maruska

Tennessee Cave Salamander (*Gyrinophilus palleucus*)
larva. Photo by Edward Maruska

Slimy Salamander (*Plethodon glutinosus*)
Photo by Edward Maruska

Japanese Giant Salamander (*Andrias japonicus japonicus*)
with egg mass. Photo by Edward Maruska

Yellow Monitor (*Varanus flavescens*)
Photo by Robert Sprackland

Black Tree Monitor (*Varanus prasinus beccari*)
Photo by Robert Sprackland

Leopard Tortoise (*Geochelone pardalis*)
Photo by Richard Fife

Burmese Mountain Tortoise (*Manouria emys*)
Photo by Richard Fife

Desert Tortoises (*Gopherus agassizi*) showing variation in coloration and scutulation. Photo by Russell Douglas

African Spurred Tortoise (*Geochelone sulcata*)
Photo by Richard Fife

Bog Turtle (*Clemmy muhlenbergii*)
Photo by David Collins

Spotted Turtle (*Clemmys guttata*)
Photo by David Collins

Black-lined Plated Lizard (*Gerrhosaurus nigrolineatus*)
Photo by Tom Huff

Smith's Plated Lizard (*Gerrhosaurus validus*)
Photo by Tom Huff

Russian Spider Gecko (*Tenuidactylus fedtschenkoi*)
Photo by Tom Huff

Pakistan Small-scaled Frog-eyed Gecko (*Teratoscincus microlepis*) Photo by Tom Huff

Russian Gecko (*Crossobamon eversmanni*)
Photo by Tom Huff

Iranian Frog-eyed Sand Gecko (*Teratoscincus scincus keyzerlingii*) Photo by Tom Huff

Ruthven's Kingsnake (*Lampropeltis ruthveni*)
Photo by Robert Applegate

Horned Frog hybrid *Ceratophrys cornuta* **x** *Ceratophrys cranwelli*. Photo by Philippe de Vosjoli

Madagascar Ground Boa (*Acrantophis madagascariensis*)
Note large size of neonate. Photo by Sean McKeown

Madagascar Ground Boa (*Acrantophis madagascariensis*)
adult. Photo by Sean McKeown

Mandarin Ratsnake (*Elaphe mandarina*) with eggs
Photo by Bill Gillingham

Mandarin Ratsnakes (*Elaphe mandarina*) hatching
Photo by Bill Gillingham

Mating and Waiting: A Status Report on Reproduction in Captive Monitor Lizards (Sauria: Varanidae)

Robert George Sprackland
Department of Biological Sciences,
San Jose State University,
San Jose, CA 95192

Introduction

Reproduction of monitor lizards under natural conditions has been thoroughly studied in only a few species (Cowles, 1930; Auffenberg, 1981, 1988). Data for captive propagation are scarce and widely scattered through the literature. Such data are usually published by zoo personnel, with a minor representation by private breeders. The latter have probably had success beyond that reported in this paper, but lack of published material or publication in regional society news letters with limited distribution makes that avenue difficult to assess. An overview of available information on varanid reproduction may allow the proposal of baseline data that can be used to successfully breed other species. A summary of incubation information is given in Figure 1. Figure 2 provides a relationship curve between adult size and reproductive data.

To help make these data most useful to a large audience of breeders, some anecdotal data has been included, but only when I have personally made observations on captives or had data verified by a qualified second source. Unless otherwise credited, observations are my own. I apologize for the departure from rigid scientific formality, but the nature of this subject is such that leads must be publicized so that experienced herpetoculturists may test them. In the course of researching a compendium volume on giant lizards (Sprackland, 1990), these data on varanid reproduction were compiled. Detailed information on husbandry and care of juveniles will be available in that volume. Where possible, all literature pertinent to each taxon is given. Natural history data are also presented for those species whose reproduction has been studied in the wild.

Bengal monitor (*Varanus bengalensis*). These animals have bred repeatedly in captivity, though their large size (1.2 m) at maturity limits the number of facilities that have done so. Mating takes place from December to early March. Between 6-30 eggs are laid from January to April. In the wild, females may deposit their eggs in termitaria or, more typically, in long, deep burrows specially excavated by the mother. Incubation ranges from 80-154 days (Smith, 1931; Deraniyagala, 1957; Auffenberg, 1988). Young take insects, small eggs, and small mammals, and may double in length from 31-60 cm during the first year.

Short-tailed monitor (*Varanus brevicauda*). According to Pianka (1970), this species lays two eggs. Schmida (1974, 1985) states that this species has rarely been bred in captivity, and I have been unable to locate any other published accounts for *V. brevicauda*. According to Schmida, this smallest of monitors mates after a month-long hibernation period, which is induced by turning off terrarium heating. Eight eggs laid in three batches over a six-week period hatched in 6-12 weeks. Hatchlings averaged 7.8 cm in total length.

Species	Clutch Size	Incubation (Days)	Source
V. bengalensis	6-30	80-154	Auffenberg (1988)
V. brevicauda	8	42-84	Schmida (1974)
V. dumerili	12-16	203-215	Paine et al. (1988)
V. exanthematicus	5-50	120-360	Branch (1988)
V. flavescens	11	150	Visser (1985)
V. giganteus	11	228-235	Bredl and Horn (1987)
V. gilleni	3	87-95	Horn (1978)
V. gouldii	5-8	240	Barnett (1979), Roberts (1988)
V. komodoensis	2-30	224-238	Auffenberg (1981)
V. mertensi	1-14	180-270	Brotzler (1965), Zimmermann (1986)
V. niloticus	--	129-175	Cowles (1930), Branch (1988)
V. prasinus	1-5	--	Pers. Obs.
V. rudicollis	1-14	180-184	Horn and Peters (1982)
V. salvator	9-25	180-327	Kratzer (1973)
V. spenceri	11-18	120-130	Peters (1969)
V. storri	1-7	80-112	Mudrack (1969), Stirnberg and Horn (1981)
V. timorensis	6-9	140	Behrmann (1981)
V. varius	8-12	--	Hoser (Pers. Comm.)

Figure 1 - List of varanid species bred in captivity with clutch size, incubation time and source of data.

Dumeril's monitor (*Varanus dumerili*). Rarely bred in captivity, with little known about wild biology. Mating observed in July and August (pers. obs.), when males become very active, day and night. Males will frequently evert hemipenes while lifting the posterior portion of their body high off the ground. Mating activity may span 3-4 weeks, copulation taking 3-45 minutes. Twelve to sixteen eggs are laid in late September through October, which hatch in 203-215 days when incubated at 28°C (Zimmermann, 1986). The first recorded captive reproduction was at the Buffalo Zoo in 1987; incubation of 14 eggs took 215 days at 27-30°C. The hatchlings measured 83 mm snout vent length (SVL) (Paine et al, 1988).

Savannah monitor (*Varanus exanthematicus*). Numerous captive breedings and wild observations are on record for savannah monitors. Presently, this is the most commonly imported species of varanid imported live into the United States, and captive breeding can be expected to become a regular occurance in the forseeable future.

Mating occurs in August through mid-October, and eggs are laid in November through January. Females usually dig a shallow nest for egg-deposition, but may employ large termitaria. In nature, the 5-50 eggs hatch in 170-360 days, but Branch (1988) reports that captive eggs may hatch in 120 days. Incubation should be at 32-33°C. The first captive breeding may have been at the Rotterdam Zoo (Visser, 1981)

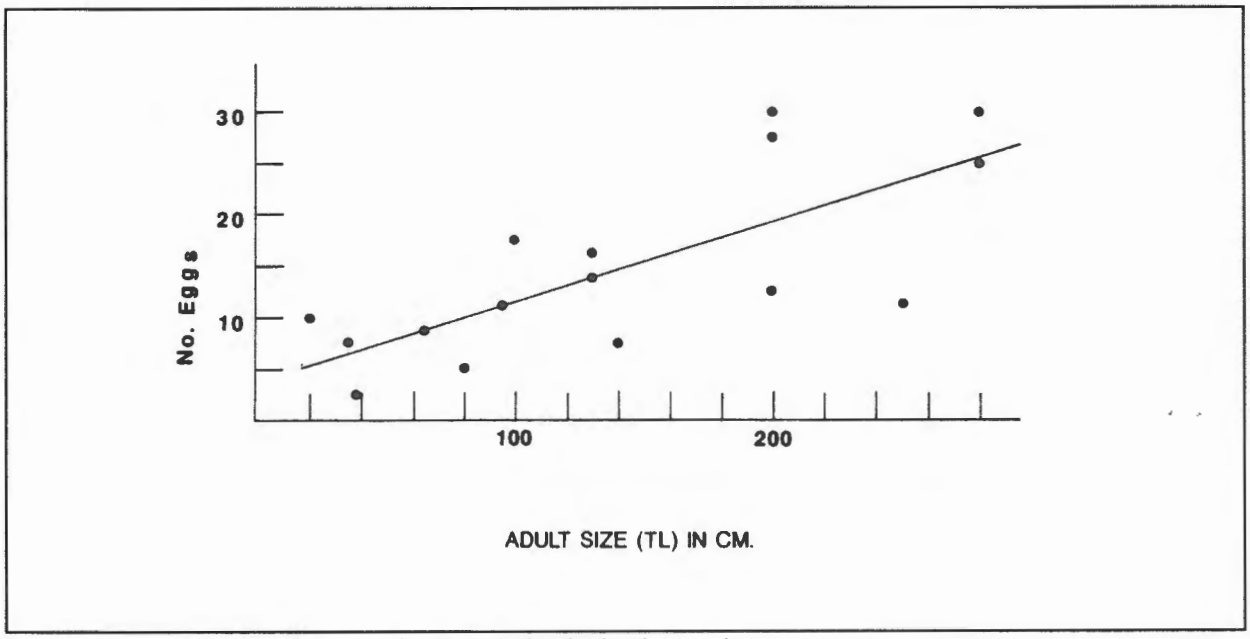

Figure 2 - Relationships between body and clutch size in monitors.

Yellow monitor (*Varanus flavescens*). Very little reproductive data are available. Rotterdam Zoo (1983) probably had the first captive breeding. Mating took place in June-July, and eggs were laid a few weeks later. They were incubated at 30°C, and hatched in about 150 days.

Perentie (*Varanus giganteus*). Limited captive breeding information exists, except that the Melbourne Zoo and a reptile zoo in South Australia have had some success (J. Murphy, pers. comm.). In the latter, perenties housed outdoors mated in early summer (December-January) and 11 eggs were laid soon after. Six of these eggs hatched after 228-235 days, and the hatchlings had a SVL ranging from 144-155 mm. (Bredl and Horn, 1987).

Pygmy mulga monitor (*Varanus gilleni*). Has bred in captivity on rare occassions (Horn, 1978; Zimmermann, 1986). Territorial, and male-male combat has been well documented (Murphy & Mitchell, 1974). Similar in breeding behavior to *V. brevicauda* with mating following a period of hibernation. Some three weeks later, the female digs a long burrow and deposits 3 eggs, which incubate in 87-95 days at 29-30°C.

Sand monitor (*Varanus gouldii*). Mating takes place in January and February, with 5-8 eggs laid soon thereafter. Females may dig a shallow nest, or deposit the eggs in logs, tree stumps or termite nests. Incubation takes about 240 days. Juveniles are active insectivores, and will feed within hours of emerging from the egg. The Dallas Zoo may have the record for first captive breeding (Roberts, 1988). Details on incubation of eggs is given by Barnett (1979).

Komodo dragon (*Varanus komodoensis*). Limited data are available regarding captive reproduction, though success has been obtained by Indonesian zoos (Auffenberg, 1981). Mating activity takes place from July through late August or early October. Between 2-30 eggs are typically laid in August through May. The eggs hatch in 8.0-8.5 months (see Busono, 1974; De Jong, 1944)

Merten's water monitor (*Varanus mertensi*). Information is based on Zimmermann (1986) and field observations from the literature. Gravid females are known from late summer (February-March), and June (Shine, 1986) and contain 1-14 eggs. In captivity, incubation takes 180-217 days at 29-30°C. Eggs require a relative humidity above 90%.

Nile monitor (*Varanus niloticus*). Most of the wild reproductive data was reported by Cowles (1931), who gave a detailed report on the use of termitaria as incubators for large varanids. Eggs are laid after the rainy season (dependant upon locality), and may take as long as one year to hatch (Branch, 1986). Eggs incubated in captivity at 26-31°C may hatch in 129-175 days. Humidity for eggs should be 65-75%.

Green tree monitor (*Varanus prasinus*). The Dallas Zoo bred this species in 1978 (Roberts, 1988), but the juveniles did not survive long. The only nest observed in nature was seen by a University of California ornithologist in the 1960s, who watched two juveniles hatch and preserved them for the museum collection at Berkeley (H. Greene, pers. comm.). Females may lay up to 5 eggs in September or October. Nest-digging behavior has been observed in captives in my care, but no eggs were laid.

Rough-necked monitor (*Varanus rudicollis*). Limited captive breedings, recorded by Horn and Peters (1982) and Zimmermann (1986); the latter seems to have based her data on the former. Up to 14 eggs are laid, and incubate in 180-184 days at 29°C.

Water monitor (*Varanus salvator*). Captive breedings are recorded from several sources around the world, but few breeders seem to have regular success. Most breedings are cited by zoos (i.e., San Antonio Zoo, 1980), and a superior account of reproduction is given by Kratzer (1973). Eggs are laid over a broad range of dates (typical in species with large geographic ranges). Clutches ranging from 9-25 eggs have hatched following 180-200 days incubation at 32°C.

Spencer's monitor (*Varanus spenceri*). Bred at the Taronga Zoo, Sydney (Peters, 1969, 1970). Females lay 11-18 eggs in November. They hatch in 120-127 days when incubated at 29°C. Hatchlings average 220 mm SVL and may increase to 340 mm by the first year.

Pygmy monitor (*Varanus storri*). Small size, captive hardiness, and availability to a wide range of herpetoculturists has made this perhaps the most frequently bred monitor in captivity (Bartlett, 1981; Eidenmuller and Horn, 1985; Mudrack, 1969; Stirnberg and Horn, 1981; Zimmermann, 1986). Captive mating may occur at any time of year, with 1-7 eggs being laid shortly afterwards. When incubated at 27-29°C, the eggs hatch in 80-112 days.

Spotted tree monitor (*Varanus timorensis*). According to Zimmermann (1986), this monitor has been bred in captivity. Females lay 6-9 eggs some 30-40 days after mating. These hatch in 140 days at 28-31°C. Belcher (1981) reports mating taking place from mid May until late July, with sporadic activity through September. Six eggs were discovered on June 18, and hatched in 182-186 days at 27°C. See also Anonymous (1981), Behrmann (1981) and Eidenmuller (1986).

Ruegg (1974) has bred the subspecies *V. t. similis*. It lays 6-8 eggs which hatch after 139-140 days at 30°C.

Lace monitor (*Varanus varius*). This species is apparently bred regularly in captivity (Hoser, 1980, pers. comm.; Horn, 1980). Between 8-12 eggs are laid, with no apparent set reproductive season. I have no references citing incubation times. In the wild, this species often deposits eggs in termitaria.

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Author's Note: In the nearly two years since this paper was written, two particularly useful references on varanid breedings have been published. The first is a major review of the subject, "Review of Reproduction of Monitor Lizards, *Varanus spp.*, in Captivity," by H. G. Horn and G. Visser, International Zoo Yearbook 28, 1989:14-151. That same volume contains "The Reproduction and Management of the Dumeril's Monitor, *Varanus dumerilii*, at the Buffalo Zoo," by L. Radford and F. Paine, pp. 153-155. There is also a report by Bernd Eidenmuller on successful breeding and rearing of *Varanus mertensi* in Salamandra, 1990, 26(2/3):132-139.

I should also like to add that during the International Symposium on Varanids held in Bonn, Germany in 1989 I met with Hans-Georg Horn to discuss his successful varanid husbandry. He informed me that he has bred *Varanus varius* through seven generations, perhaps an unparalleled feat in varanid husbandry. This report confirms that the task is not impossible, but it does take considerable effort -- and space -- on the part of the herpetoculturist.

An Update on Plated Lizard Reproduction at the Reptile Breeding Foundation

Thomas A. Huff, Director
Reptile Breeding Foundation
P.O. Box 1450
Picton, Ontario, K0K 2T0, Canada

Introduction

Plated lizards are a group of robust African lizards found south of the Sahara. They are ground-dwellers with short legs, an elongated body, and a long tail, which is stout, especially at the base. As their name suggests, these lizards are covered with closely fitting plate-like scales. An underlying bony sheath gives the body added protection, while the ventral surface is covered in scales which are smooth and polished.

Along the sides of these lizards, a deep groove extends from below the eye to the hind limbs. This is formed from an upfolding of the integument and divides the bony casing into two portions. The groove appears to allow the plated lizard to vary its girth during respiration, feeding, and breeding.

Although some species of plated lizards live in crevices in rocks, others live in burrows constructed in the sun-baked soil. It has been suggested that this construction takes place during the rainy season when the ground is much softer. Most species can run at a fair pace even though their limbs are short. The tail, which is also covered with rings of plates, is often used in defense and can be regenerated if broken.

Reproduction at the Reptile Breeding Foundation

At the Reptile Breeding Foundation, we successfully reproduced the tawny plated lizard (*Gerrhosaurus major*) and Smith's plated lizard (*G. validus*) in 1987 (Kellough, 1989). In that year, we also reproduced the yellow-throated plated lizard (*G. flavigularis*) albeit unsuccessfully.

In 1988 we had success with the first two species again and another failure with the third species. However, during this year we had two clutches of *G. validus* eggs (six in the first clutch and five in the second). All but one of these successfully hatched. We also obtained two additional species in the genus, the black-lined plated lizard (*G. nigrolineata*) and an unidentified species of *Gerrhosaurus*. We have yet to reproduce these two species and unfortunately only have a single individual of the second remaining.

Black-lined Plated Lizard (*Gerrhosaurus nigrolineata*)

Gerrhosaurus nigrolineata ranges from Central Africa to northern Southwest Africa, Namibia, Botswana, the Transvaal, and into southern Mozambique. It inhabits savannah areas, where it feeds on insects and some vegetable matter. It reaches a total length of 50 cm, more than half of which is tail.

The black-lined plated lizard is light brown to russet, with scales that may have brown spots. A yellow, dark-edged streak runs along each side of the body. Its sides are paler than the upper body, and are scattered with white, yellow, reddish-brown or dark brown spots. The ventral surface of the lizard is creamy to yellowish-white.

This species, as are all members of the genus, is quite shy and seeks retreat in burrows or under rock piles at the slightest disturbance. These lizards are agile and difficult to capture and will bite vigorously when caught. During the breeding season, females lay between 4-6 oval eggs, which are buried in the ground where they hatch after a period ranging from 50-90 days. The eggs measure approximately 21 x 14 mm.

Husbandry

The herpetoculture of the *Gerrhosaurus* is fairly straight forward. We house these animals in groups in fairly large enclosures (211 x 133 cm). They are provided with rock piles for cover, basking sites, water, crushed cuttlebone (as a calcium source) and a nest box. They are fed a variety of foods, including live crickets, wax moth larvae, pink mice and rats, and earthworms three times a week, and they are offered a vegetarian plate with canned dog food twice a week. There is a temperature gradient within the enclosures ranging from 26-30°C during the day (10-14 hours), and 22-25°C during the night. The substrate of the cages consists of a mixture of soil, sand, and peat moss to a depth of 10 cm.

Strange Happenings

We obtained three, believed to be adult Smith's plated lizards in May 1983 from an individual in Ottawa. He had purchased one of these reptiles from a pet shop in Canada, and the other two from a dealer in Florida in 1980. They were adults when he received them and he had assumed they were all males, based on several characteristics normally indicative of a male lizard - wide, robust heads; noticeable femoral pores; and their large size. We made a concerted effort to obtain some females, without success. These three individuals lived quite peacefully in an enclosure measuring 211 x 133 cm for four years. We never experienced aggression, or anything that could be construed as mating behavior. Examination of these animals on a regular basis, showed enlarged femoral pores with heavy exudate, in all three animals during the months of April and May. This confirmed our assumption that all three were males.

In 1986, while attempting to extract one of these individuals from under a rock, I pulled it by the tail and ended up with the tail in my hand. Although not prone to drop their tails like some of the fragile geckos, when you pull on a *Gerrhosaurus*, its tail does come off. After the tail regenerated, I began to notice some differences in this particular individual. Its head seemed to be narrower. Upon capturing this animal (by the body this time) for a closer examination, I noticed that the femoral pores were not nearly so noticeable. This animal now had the appearance of a female.

Now I went through all the things you might ask: Had I been drinking? -- Well perhaps a bit, but not constantly over four years. Was I on drugs? -- Yes, but nothing non-prescriptive, and none of these hallucinatory. Was I crazy? -- That one is still up for debate. And, Had we moved into the Twilight Zone? or the Far Side? -- You be the judge. The only other possible answer I had was that this lizard had changed sex.

That immediately brought up another series of questions, not the least of which was: "Can you change the sex of lizards by tearing their tails off?" I laid off the booze completely and continued to observe these lizards. The following Spring, the two larger, more robust, wider-headed, more noticeably femoral pored individuals had heavy exudate from their pores, and the smaller, less-robust, narrower-header, less-defined

femoral pored individual had none. Our sex ratio had suddenly gone from three males and no females to two males and 1 female.

The Smith's plated lizards bred in 1987 and the female produced six eggs, two of which were infertile. We hatched the remaining four eggs. Those juveniles at 19 months of age have a snout-vent length (SVL) of 23-24 cm and a tail length of 32-33 cm and, I suspect, are approaching sexual maturity. They exhibit neither sexual dimorphism nor any differences in growth patterns. I am not going to guess at their sex.

In the spring of 1988, while looking at these adults, I noticed that two individuals exhibited female characteristics, and only one individual looked like a male. Upon examination, I was convinced that we now had one male and two females (No, I did not pull the tail off this one). In 1988, we had two clutches of eggs from these animals (six in the first and five in the second). Now, it is possible that our one known (?) female, double-clutched, and produced all of the eggs. But, I suspect that we had single clutches from two different females. The first clutch was laid on May 27 and hatched after an incubation period of 95-100 days. The second clutch was laid on July 5 and hatched after 115-120 days (both at 30°C).

It frightens me to consider what might happen this year. Are we going to end up with three females and no eggs? Only time will tell. I can tell you that I am going to keep a close watch on our 14 youngsters. I have not decided whether or not to break the tails on some of them.

Conclusion

I have no concrete evidence for these observations. I think that *Gerrhosaurus validus* may be able to change sex. This may come about as a result of a stressful situation and as an effect of such, an effort to insure the survival of the species. This has been documented in fish and there are some situations in parthenogenic lizards where in an all female population, a few individuals will exhibit male coloration at times when the population is in decline. These three individuals had been together for seven years, during which time they had shown no appreciable growth. They were aging, there had been no reproduction and there were no new animals introduced into the group. If they were indeed all males initially, was some physiological and gonadal change brought on in a "last ditch effort to secure the future of this group" or "do they do this all the time on a whim?". I do not know. Only further study will answer this question.

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The First Captive Breeding of the Madagascar Ground Boa (Acrantophis madagascariensis) in North America from Long Term Captive Adults

Sean McKeown, Curator of Reptiles
Fresno Zoo
894 W. Belmont Ave.
Fresno, CA 93728

Introduction

On August 17, 1985, four Madagascar ground boas (*Acrantophis madagascariensis*) were born at the Fresno Zoo after a gestation period of between 226-234 days. This is the first time this Convention on International Trade in Endangered Species (CITES) Appendix I snake has been captive bred in North America from long term captive parents. According to the International Zoo Yearbook (Volume 25) only 27 (13 males and 14 females) Madagascar ground boas existed in six collections during 1984.

Breeding Program

In the early 1980's the Fresno Zoo began to develop breeding programs for Endangered, Threatened and CITES Appendix I and II herpetofauna. A major area of emphasis within that theme was the Indian Ocean islands of Madagascar, Mauritius, Reunion, and the Seychelles. This region was selected because of its severe and continuing habitat destruction, the high degree of endemism and the uniqueness of the herpetofauna.

One of the targeted species was the Madagascar ground boa. On September 25, 1980 one pair of adults was received on breeding loan from the San Diego Zoo where they had resided since 1973. These snakes had originally been purchased on July 1973 by the San Diego Zoo from Leon Leopard of Vivo Animals. Leopard, an animal dealer, had collected both as adults.

After a brief quarantine the pair of Madagascar ground boas was moved to a "C" sized display chamber at the Fresno Zoo. This model chamber has an interior dimension size of 130 cm high x 132 cm wide x 103 cm deep. Wood chips were selected for use as a substrate and a large calimyrna fig tree skeleton was placed in the enclosure to allow for climbing.

Management of the Madagascar Ground Boas at the Fresno Zoo Between September 25, 1980 - August 1, 1983

Initially the ground boas were kept at 28.9/25.0°C day/night with 13 hours of light per day, roughly matching the longest daylight period in Madagascar. Both cool white and natural spectrum (Vitalites® by Duro-Test) lighting were provided.

June 4, 1981	The temperature was dropped to 27.2/20.0°C with 10.5 hours of light per day.
June 7	During the evening the pair was very active and a large amount of seminal fluid was found on the substrate at 08:00 the following morning.
June 23	The chamber was warmed to 29.4/23.9°C and feeding was resumed.
October 15	Feeding was halted.
November 20	The male was moved to a reserve enclosure and housed at 24.4°C. The female remained on exhibit and the temperature was dropped to 22.2/20.0°C.
December 21	The female was warmed to 28.9/24.4°C and feeding was resumed.
January 11, 1982	The male was introduced into the female's enclosure. No courtship was observed.
January 12	The temperature was reset at 27.8/22.2°C and the feeding regime was continued.
February 16	Courtship by the male was observed at 16:45 before the staff left the building for the evening.
February 17	Intense courtship was in progress when the staff arrived at 08:00. The male was spurring the female continuously and she was making no attempt to escape his advances. The snakes had their vents aligned at 13:30. The male spurred the female and she lifted her tail higher. The male was riding the female's back at 17:00 but actual penetration was not observed. The following morning, the snakes were in separate corners and no activity was occurring. The possibility of mating the previous night was believed likely.
February 23	The female looked heavier, however, offspring were not forthcoming in 1982.

Although the pair were chilled to 22.2/20.0°C during the winter of 1982-83 and separated, no courtship was observed when they were reintroduced folowing the cooling period.

1983-84 Breeding Season

Preparing for the 1983-84 breeding season, the total program was reviewed on 1 August 1983. The diet was changed from birds to adult rats. The photoperiod was reprogrammed to a year-round 12 hours of sunlight. Based on observations made by the Reptile Curator while doing field work in the Indian Ocean and a review of Branch and Erasmus (1977), it was decided that lower hibernation temperatures would be utilized in hopes of stimulating additional courtship and mating. During the winter of 1983-84, the pair was hibernated together on display.

December 28, 1983	The temperature was dropped to 22.2/20.6°C.
February 22, 1984	The chamber was further chilled to 20.0/17.8°C
February 23	The temperature was brought down to 16.7/15.6°C and maintained at that level until February 28.
February 25 and 26	Courtship was observed at 08:00, but mating was not observed.
March 1	Temperature in the chambers was raised to 29.4/25.6°C. Both snakes fed normally. As the spring progressed the female showed no signs of swelling to indicate she was gravid.

Preparing for the 1984-85 Breeding Season

In June 1984 we once again reviewed our Madagascar ground boa program. In order to stimulate courtship and mating we had tried a number of variables during the past four years. We had used a variety of low temperatures at night with warmer daytime temperatures. We had employed both low day and night temperatures during this period. We had left the pair in together and had also separated them before, during, and after hibernation. We had tried increasing the humidity and heavy misting following warmup. We had exchanged information with other knowledgeable zoo and private boid breeders. We reviewed the existing literature. Courtship and mating had occurred, but no young had been produced. We felt we could increase our success significantly if we could work in the one remaining variable - a second male to stimulate male to male combat and, perhaps additional courtship, and mating.

Since only a limited number of adult male Madagascar ground boas were in American collections, we were initially unsuccessful in our efforts. At this point we began exploring the possibility of bringing in a male of the closely related species, the Dumeril's ground boa (*Acrantophis dumerili*) in hopes of at least stimulating male to male combat between these congenerics. However, that option was never implemented as on November 8, 1984 the Fresno Zoo was able to obtain a second male *A. madagascariensis*. Like our pair on loan from the San Diego Zoo, this male had been collected as an adult during 1973 by Leon Leopard.

Sold to the Gladys Porter Zoo on 9 July 1973 along with an adult female, this male was believed to be the male parent of offspring born at the Gladys Porter Zoo on 24 March 1974 which represented the first documented birth of this species in captivity.

Upon acquisition of this second male from the Gladys Porter Zoo via the Houston Zoo, the animal went directly into quarantine. Two reserve holding boxes were built for each of the males measuring 86 x 45 x 33 cm high. In preparation for the seasonal cooling, feeding was discontinued the second week in November for all three snakes.

Events Leading to Successful Breeding

November 29, 1984	The three boas were separated for hibernation. The cold room housing the two males was set initially at 17.2°C. The display chamber, housing the female, was programmed to 21.1/20.0°C and the hot rock was unplugged.

December 3	The temperature in the cold room was lowered to 15.6°C and the display chamber housing the female was programmed to 15.0°C. This chamber has a fluxuation rate of +/- 1°C. The water crocks were left in the enclosures throughout the winter cool down. The water level in the crocks was reduce to half the normal level to prevent spillage. The substrate was checked twice daily to ensure it remained both clean and dry.
December 21	The temperature in the display chamber was brought up to 26.7/23.9°C and the hot rock was plugged in.
December 28	The display chamber was brought up to 28.0/26.1°C and the SDZ male was returned to the display enclosure at 08:00. Within 8 hours intense courtship was taking place. Afterwards, the GPZ male was put on display with the other two adults.
December 29	At 07:00, the Reptile Curator found all three snakes intertwined and penetration was observed. The snakes remained intertwined until 09:45. At about 10:30 the female was unusually active, crawling around the perimeter of the enclosure and up into the branches of the large fig tree in the enclosure. This unusual diurnal activity continued on and off throughout the day.
December 30	The female was entwined with the GPZ male at 08:00.
December 31	The female was observed copulating with the GPZ male for two hours, again at 08:00.
January 1, 1985	The female was observed copulating with the SDZ male, again at 08:00.
January 2-3	The female was observed copulating with the GPZ male on January 2 and 3, both times at 08:00. No sexual activity was observed after the morning of January 3. The female fed twice after this date, but began refusing food the last week in January.
February	The female began to swell, looking more and more like she might be gravid as the month progressed.
March	The female continued to refuse food and looked very round. She stayed tightly coiled, often with both males coiled against her or partially over her.
April	The female began using the hot rock for long periods of time. On April 28, she was observed to be unusually active and moved throughout her enclosure and into the fig tree.
May	The female used her hot rock off and on. The pronounced swelling over a large portion of her body moved to the posterior 40% of her body. The swelling became more evident ventrally.
May 24	The two male Madagascar ground boas, which had been on display with the female, were moved to their respective holding boxes. The males were moved so that if a birth did occur, there would be less risk of the young being crawled over and possibly injured.

The removal of the males may have triggered a behavioral change in the female. She began spending large periods of time coiled directly over the hot rock or virtually burying herself beneath the wood chip bedding in her display enclosure. She was most secretive during daylight hours when the public was in the zoo.

June 3 — When the staff arrived at 08:00, the program controlling the temperature of the environmental chamber was found to be scrambled and the temperature readout was at 18.9°C. The chamber was immediately reprogrammed to 28.9/26.1°C. Fortunately, the female was coiled over the hot rock.

June 20 — The female spent large portions of time coiled directly over the hot rock. We felt this behavior might indicate that she preferred a warmer air temperature, so the chamber was reprogrammed to be 30.6°C during the day and 28.9°C at night. The female immediately began to use the hot rock for shorter periods during the day, although she still continued to burrow under the substrate on a frequent basis during daylight hours.

Another behavioral change after the temperature increase was that when the female did use the hot rock, she would only place the rear portion of her body or upper portion of her tail over the hot rock instead of coiling the main portion of her body directly over it.

July 3 — The female passed a small amount of uric acid.

July 15 — The female shed her skin in many small pieces.

July 29 — The female continued to use the hot rock, but for shorter periods.

August 17 — The reptile keeper arrived at 09:00 and noticed birth debris on the surface of the chamber. When the enclosure was opened, one healthy offspring was found behind the water bowl and three more live, healthy young were found buried in the wood chips. Two large undeveloped follicles were found with the birth debris on the surface.

Hatchling Growth

The neonates were given identification letters "A", "B", "C", and "D" and the distinctive head and neck markings of each were recorded. The length and weight of the individual offspring were also recorded on August 17 (see Figure 1) before the four were collectively put on display in their own chamber. Pine wood shavings were used as the substrate.

On August 20 three of the neonates were moved to individual five (5) gallon terraria in a reserve room. One was left on display. The substrate for all four was changed to newspaper when one of the of offspring was found to have wood shavings lodged in its mouth.

After five days, each of the offspring was offered a dead mouse and as expected, all refused, although one struck defensively at the mouse. Feeding response of the offspring varied initially (see Figure 2), however, after several months, all were feeding without coaxing on dead adult mice.

	A	B	C	D
Total Length at Birth (cm)	68.6	71.1	66.0	61.0
Weight at Birth (g)	282.5	285.9	280.6	226.9
Total Length at One Year (cm)	112.4	108.0	94.0	97.8
Snout Vent Length at One Year (cm)	104.2	99.5	86.5	90.3
Weight at One Year (g)	1035.0	1080.0	720.0	675.0

Figure 1 - Weights and lengths of *Acrantophis madagascariensis* at birth and one year

	A	B	C	D
19 Aug. 1985	Refused	Refused	Refused	Refused
30 Aug. 1985	1 adult mouse	Refused	Refused	1 adult mouse
7 Sep. 1985	1 adult mouse	Refused	Refused	1 adult mouse
12 Sep. 1985	Opaque - refused	Opaque - refused	Opaque - refused	2 adult mice
19 Sep. 1985	2 adult mice	2 adult mice	1 two-week old mouse	2 adult mice

Figure 2 - Initial feeding records of hatchling *Acrantophis madagascariensis* at the Fresno Zoo

Discussion

Acrantophis madagascariensis is a generalized species and therefore is a taxon that can be bred using a variety of techniques. The Transvaal Snake Park in South Africa has had the greatest reproductive success with this species, obtaining five different clutches from two different females between 1977-1987. Transvaal Snake Park houses a total of five (3.2) adult Madagascar ground boas in a large outdoor, west-facing, glass fronted exhibit with a natural highveld photoperiod supplemented with natural spectrum lighting (Morgan, 1985). Interior air temperatures range from a low of 10.0-24.5°C during June/July to a high of 23-36°C during November/December. Humidity is not regulated or monitored. No food is offered during the winter and the snakes are not separated to induce breeding (Morgan, 1985). Precopulatory behavior and copulation usually occurs during March and April.

One of their two females fasts while she is gravid and cycles in every other year. She feeds voraciously after giving birth and may be storing up fat for the following year. The second female takes rodent prey during the lengthy pregnancy and cycles in on a yearly basis (Branch and Morgan, pers. comm.).

Larry Black, a private breeder in Southern California, has successfully bred his single pair of *Acrantophis madagascariensis* twice. His male was wild caught as an adult and is on loan from the Los Angeles Zoo. The animal was purchased by the Los Angeles Zoo on September 4, 1969. His female was captive born at the Transvaal Snake Park in February, 1979. In contrast to the management regime used by the Transvaal Snake

Park, Black does not cool his snakes during the winter, but keeps them at 27.8°C during the day and 25.6°C at night. Black uses a Southern California light cycle with lighting provided through high windows. Black (pers. comm.) supplements a drop of Avitron® liquid vitamins on each rat prior to feeding and believes that vitamin supplementation is a key to his general success with breeding boids.

Huff (1984) presents an excellent summary of husbandry and propagation techniques for Malagasy boids in captivity. Huff notes increased humidity and misting are useful stimili to trigger courtship in Malagasy boids. Huff also believes that copulation in *Acrantophis* must occur either during or very close to the time the female is ovulating for successful mating to occur. He is unaware of any documented case of sperm storage by this genus.

Future Management

The Fresno Zoo will work closely with the San Diego Zoo, Gladys Porter Zoo, Houston Zoo and other institutions with Madagascar ground boas to insure proper genetic management and disposition of offspring for captive breeding. We have corresponded with the Transvaal Snake Park about the need to develop an international studbook for the species. The Fresno Zoo has since acquired a 1983 captive bred female from the Transvaal Snake Park to increase the genetic diversity in our collection. Two (1.1) Fresno Zoo, 1985 captive bred offspring assigned to the San Diego Zoo, have been transferred to the Fort Worth Zoological Park. Next fall an additional 1985 captive born female assigned to the Gladys Porter Zoo, will be exchanged on breeding loan with the San Antonio Zoo for an unrelated wild-caught specimen.

Conclusion

The Madagascar ground boa (*Acrantophis madagascariensis*) is relatively uncommon in American collections. Unlike its congeneric relative *A. dumerili*, it has proven difficult to breed in captivity with live births in the United States occurring at just three facilities. Although a variety of management techniques may be utilized, the author recommends separating adults before and during hibernation, chilling each snake during hibernation down to 15.5°C or lower, and using at least two males to stimulate male to male combat and courtship. Once they are out of brumation (winter cooling), misting may prove useful during daytime periods when courtship behavior has been noted. Primary courtship and mating activity takes place at night. Gestation is lengthy, varying between 222-285 days. Small litters of 2-8 neonates are typically produced, but the neonates are notably larger than those of *A. dumerili*. Neonate *A. madagascariensis* vary in size ranging from 55-74 cm and 156-286 g based on data from six different sets of captive births in four collections. Adults are long-lived and can reproduce throughout their lives. Successful mating during the 1980's in American collections appears to correspond with the December-February rainy season in northern Madagascar.

The young undergo a postpartum shed within the first 24 hours after birth. Their second shed occurs 10 to 28 days later. Although juveniles may initially refuse food, they are not typically problem feeders. If a neonate does not accept food during the first three weeks of life, a two week old "fuzzie" mouse can be placed into its mouth and the snake will typically swallow it.

A very positive note is the high degree of cooperation and sharing of information by institutions and private individuals keeping *Acrantophis madagascariensis*. It is now critical, especially with the importation of South African captive bred specimens, that a studbook be established for this species to insure proper genetic management of individuals currently in captivity.

Acknowledgments

I would like to express my appreciation to the following individuals and their respective institutions for the exchange of information on captive management/reproduction of Madagascar ground boas; the late James P. Bacon, San Diego Zoo; Patrick M. Burchfield, Gladys Porter Zoo; Rick Hudson, Fort Worth Zoo; John McLain, San Antonio Zoo; Andrew Odum, Houston Zoo; Ron Tremper, and Larry Black. I am grateful to Mary Morgan and Dana Knepper, of the Fresno Zoo Reptile staff, for reviewing the manuscript.

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Captive Propagation of the Emerald Tree Boa (Corallus caninus)

Kamuran Tepedelen
1818 Pine St.
Boulder, CO 80302

Introduction

This paper reports successful breeding of the emerald tree boa (*Corallus caninus)* in two successive years. The project began in the summer of 1985, with parturition occurring in 1987 and 1988.

The male *C. caninus* was obtained from an animal dealer in the spring of 1984. The animal was approximately 122 cm in length, and posed no feeding problems accepting small rats from forceps. In June of 1985, I acquired two females from Ernie Wagner. They had been collected in Surinam during 1984. These animals were well acclimated and accepted dead rats from forceps. One of the females lacked any of the typical white vertebral stripes, and was uniformly green. This animal (female #1) was 167 cm. The other female (female #2) was 180 cm in length and was typical in coloration.

Housing

The male was housed in a 492 l aquarium, 183 x 46 x 56 cm. The females were housed in a 61 cm diameter x 76 cm high hexagonal aquarium. In the 492 l aquarium, branches were affixed to the side of the aquarium using a clear silicon sealant. The hexagonal aquarium had PVC pipes 5 cm in diameter mounted at various heights.

Thermal gradients were made available to all three snakes by using 2 incandescent bulbs (red 25 watts/110v) to provide hot spots that reached 27-31°C. Room windows provided a natural photoperiod. Fluorescent lights (Vita-Lites®, 30 watt/110v) were used to provide additional illumination for the females.

Air temperature in the cages varied from 22-28°C depending on the time of day. Pine shavings were used as a substrate the majority of the time, but gravid females near parturition were housed on blank newsprint. Water was offered in several locations in both cages. The animals would frequently drink from bowls on the cage floor, even though water was available in bowls suspended from the branches.

Breeding

On September 9, 1986 a climate change was initiated. At dusk the snakes and the cages were misted for approximately four to five minutes. The heat source was then turned off. Over a period of several hours the cage temperatures were allowed to drop to 22°C (as suggested by Walsh, 1978). Each morning the heat source was turned on and cage temperatures returned to 27°C. This was continued until November 15. The snakes' activity significantly increased during the early evening hours. Although no records were kept of snake activity,

it is my clear impression that the male was more active than either female. The snakes were misted briefly in the morning with water that was cooled in the refrigerator (as suggested by Laszlo, 1983).

The male shed on September 24. Food was offered on September 25. Two medium-to-small rats were consumed. Female #1 went opaque and then shed on October 2. That evening, after their normal mistings, female #1 was placed in the male's cage, and she remained there for five days. The male commenced courtship almost immediately, as indicated by the male flicking his tongue faster and more frequently than normal. He used his spurs to rub and scratch along the female sides. This differs from that reported by Groves (1978) for *C. caninus*, but coincides with observations made by Murphy (1981) on Fiji island boa (*Candoia bibroni*). The female seemed very receptive to the male. Courtship lasted from 1 to 3 hours during several episodes between October 2 and October 7. The male positioned himself along one side of the female, until their cloacas were aligned. When this happened, the female's vent opened even before the males hemipenes were observed (also noted by Gillingham et al, 1977). Once the males hemipenes were inserted, he would wrap his tail in a tight coil around hers. Her tail hung down, but did not wrap around his. Courtship and copulation only occured on the branches. Once copulation had started, there was very little movement. Copulation would last several hours, but by morning they were always separated, and coiled in their typical fashion. Cage temperatures during copulation were between 22-23°C. Female #1 was removed from the males cage on October 7.

The male remained alone until the evening of October 9, when female #2 was introduced to his cage. Female #2 had gone through ecdysis on October 6, as with female #1, male courtship began almost immediately. Copulation was observed with #2 at 9:55 P.M. Again, by morning they had separated. Although females were left with the male for several days, the most active breeding activity occurred within the first 24 hours of introduction. Only one female at a time was introduced into the males cage (Murphy and Campbell, 1987), and the females were alternated between October 2 and November 12. Copulation was observed with female #1 on October 2, 5, 12, and 13. Copulation was observed with female #2 on October 9, 18, and 19.

During the breeding period the male refused to feed, while the females continued to feed regularly. No further copulations were observed, until November 11, 1986, which involved female #1. This was the last observed copulation. Females accepted food every eight days. Mistings were discontinued, and cage temperatures were returned to 24-28°C, at which time the male began feeding again.

Gestation

By the end of December 1986, there was mid-body swelling in both females (also noted in Walsh, 1978). Both females became very passive. Once it was determined that the females were gravid, they were housed together for the duration of gestation in the 492 l aquarium. This aquarium provided the thermal gradients I suspect to be necessary for successful gestation. At this time, the male was removed from the 492 l aquarium and housed in the hexagonal aquarium.

Cage temperature during gestation was maintained at 24-28°C, with "hot spots" of 27-31°C. Both females chose to remain in the hottest spot offered in the cage. Occasionally, during the night they would become active and roam about the cage for short periods of time. Food was still offered every 8 to 9 days. Both females continued to feed throughout December, 1986 and on into January, 1987. Female #1 refused her first meal on January 10. She also refused food on January 15, 22 and 26. On February 1 she became opaque, completing ecdysis on February 22. This was to be her last shed before giving birth. Female #2 fed until the first week in February. She then refused on February 5 and 11. She shed what was to be her last shed (before giving birth) on March 1. Food was offered to both females after their sheds, but was refused on all occasions. Water was placed in bowls situated on the branches next to the gravid females. Both females were observed drinking water frequently.

Females became very passive during gestation, and when disturbed would hide their heads in their coils. Towards the end of May, female #1 became more active, and was observed spending more time in the slightly cooler (26-27°C) area. Her resting coil was more relaxed than usual and she appeared to be very uncomfortable. By the second week in June, the mass in her body had shifted noticeably towards the cloaca. She became more restless during the night, but by morning would rest in one place.

Parturition

At 8:30 A.M. on June 21, 259 days after the initial copulation, female #1 became increasingly more active, moving about the branches of the cage. Just before giving birth, she passed a pellet of uric acid. At 9:15 A.M. an unfertilized egg was passed followed by 10 neonates and one more unfertilized egg. By 9:45 A.M. parturition was completed. Female #2 was undisturbed by female #1's parturition activity. Female #2 was not observed during parturition. On June 27 at some time between 10:15 P.M. and 1:30 A.M. female #2 also gave birth to 10 neonates and 2 infertile eggs. Female #1 had one neonate that was born prematurely (i.e., the yolk sac was not fully absorbed). The yolk sac became infected, and this neonate died. Both females resumed feeding the day following parturition. Females were again offered medium-sized rats every 8-10 days. In 1988 both females were bred again under conditions identical to those described above. Female #1 gave birth on June 21 to 8 neonates and 8 infertile eggs. Female #2 showed all the signs of pregnancy, but resumed feeding in late July, with no resultant neonates.

Neonates

Neonates were maintained individually in one gallon jars (as suggested by Murphy and Campbell, 1987), with plastic dowels for perches, and 6 mm of water on the bottom. Jar temperatures were maintained at 26-28°C. During the first few days, several neonates (1987 litters) inadvertently became over heated, when jar temperatures reached 32°C as a consequence of a faulty thermostat. Two neonates everted their hemipenes. Similar hemipenal eversions due to high neonatal temperatures were observed by T. Walsh (pers. comm.). Unfortunately, the present cases went undetected for several days, and by the time they were discovered, the hemipenes had become swollen.

The neonates were soaked in cool water, and sugar was applied directly to the hemipenes to reduce swelling. The hemipenes had been everted too long, and this was not successful. These two males ultimately lost their hemipenes, but otherwise continued to thrive. A similar incident happened again in 1988, but was detected within hours. The same procedure was used, and proved successful. No problems with neonates were encountered at temperatures of 26-27°C. The neonates first ecdysis occurred 16-18 days after birth. No shedding difficulties occurred. In 1987 no attempts were made to feed the neonates before their first shed. In 1988, two neonates accepted pink mice before their first shed.

Pink mice were offered from forceps, but only a few neonates accepted food in this manner. Live pink mice were left in the jars over night and most neonates accepted these prey. A few had to be assisted by placing the pink mouse into their mouth (as suggested by Groves, 1978). Generally, these neonates would constrict the pink mouse and swallow it. After several assisted feedings these neonates began to feed on their own.

Conclusion

Successful breeding of *Corallus caninus* is made much more feasible by using healthy, well-acclimated specimens, preferably captive-born, as breeding stock. Animals should be housed in cages that can be easily serviced with minimal disturbance. A climatic cycle involving temperature fluctuation appears to stimulate

females to ovulate and males to copulate. The importance of temperature fluctuations to induce copulation cannot be over emphasized. Indeed, it is likely that *C. caninus* can be induced to breed any time during the year by providing a climatic change (Murphy and Campbell 1987; Laszlo 1983).

Gravid females showed a strong preference for the warmer areas in the cage. The gravid females should be kept in cages that afford a thermal gradient with local hot spots of 31°C.

Neonates are sensitive to high temperatures and should be maintained at 26 - 28°C. Temperatures above 32°C can cause eversion of the hemipenes in male neonates, a condition which is correctable if detected and treated immediately.

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Products Mentioned in Text

Vita-lite: fluorescent tubes manufactured by Duro-Test Corporation

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Captive Propagation and Husbandry of the Western Green Rat Snake (Senticolis triaspis intermedia): The Untold Story

Thurgess Cranston
Camino, CA

Introduction

Procedures for successfully breeding colubrid snakes under captive conditions have been described in detail for the last fifteen years (Wagner, 1976; Scheidt, 1984; Applegate, 1985). Most colubrid snakes can be bred following these proven methodologies: (1) proper diet, (2) a winter cooling period, (3) introduction of adult pairs, (4) providing gravid females with the correct conditions for gestation and oviposition, and (5) correct incubation of eggs. In my collection, I have applied these tried and true techniques on several species of colubrids. Under captive conditions, there has been one animal that has been most difficult to propagate, the western green rat snake (*Senticolis triaspis intermedia*). The purpose of the present paper is to: (1) present the techniques I have used to breed these snakes (albeit with a low fertility rate) and (2) report courtship and reproductive behaviors in these snakes under captive conditions.

Maintenance

In the present study, four green rat snakes from Cave Creek Canyon in the Chiricahua Mountains of Cochise County, Arizona were utilized to observe courtship and reproduction. Information about the animals used in this study is listed in Figure 1. Animals were maintained in either 10 gallon glass aquaria (1984) or in Herpatat® modular cages (1985 - present) in a room with large windows which provided a natural photoperiod.

Specimen	Date Captured	Weight (1987)	Length (1987)
Female A	Unknown	556.2 g	1.54 m
Female B	May 24, 1978	243.1 g	1.15 m
Male A	May 26, 1978	124.4 g	1.00 m
Male B	August 8, 1985	135.1 g	1.00 m

Figure 1 - Capture dates, weights and lengths of the western green ratsnakes utilized in this study

Feeding occurred during spring, summer and fall on a weekly basis. Water was kept with the animals at all times. A more detailed description of captive maintenance of the western green rat snake can be found in Cranston (1990). In the present study, these snakes were provided with a brumation period which began in the middle of November and continued until the middle of February (approximately 90 days). The animals were kept at a temperature range of 9-13°C during this time. The animals were allowed access to a warmer region in the cage to alleviate any ataxia problems (Cranston, 1990). The animals tended to keep their heads in the warmer regions of the cage and their posteriors in the cooler areas.

At the end of this cooling period, the snake room was warmed up to approximately 20°C. The temperature regime during the spring, summer, and fall months ranged from 20-27°C. Heat tapes were used to provide a thermal gradient of 20-30°C in the cage, taking into account the preferred body temperature of 25°C (Cranston, 1990). Within two weeks of the spring warming, all animals started to feed.

Breeding

Courtship and reproductive behavior were observed a total of ten times over a four year period. The breeding season began as early as March 16 (or 20 days after the initial spring warming); the latest I have observed breeding behaviors was May 11, or almost two months after the spring warming. Most observed copulations took place during the afternoon and early evening. Females were always introduced into the male's cage. After her introduction, the male would immediately inspect the female. Within fifteen minutes, courtship would ensue.

The courtship of the western green rat snake follows typical colubrid patterns outlined elsewhere (Murphy et al., 1978; Brecke, et al., 1976; Gillingham et al., 1977). Males exhibit the tactile-chase phase (Gillingham, et al., 1977) where they press their chin on the dorsum of the females in jerking motions and move towards the anterior part of her body. The females, immediately following this jerking by the males, respond with similar body jerks. This phase lasts from 20 to 70 minutes. This phase is followed by the much shorter tactile-alignment (Gillingham et al., 1977) where the males attempt to copulate. Intromission and coitus (Gillingham et al., 1977) is the final phase and can last up to 45 minutes. After the male separates from the female, the female's cloacal region often appears swollen, a condition which soon subsides. A similar phenomenon has been noted for the common rat snake (*Elaphe obsoleta*) (Johnson, 1950). Neck biting, as occurs in other colubrids (Gillingham, 1974; Tryon, 1978; Lewke, 1979), has never been observed in green rat snakes. In my colony, neither adult male has ever bred the same female twice in one breeding season despite numerous reintroductions. However, the adult males have bred a female previously bred by another male.

Egg formation took approximately 70 days (see Figure 2). In the red rat snake (*Elaphe guttata*), egg formation was found to take only 35 days (Holman, 1960). A shed would occur 14-17 days before oviposition. I provided my females with two different options for oviposition. The first was a simple crock or plastic container with a substrate of damp sand placed outside the den area. The second was damp sphagnum moss placed inside the den area. When given these choices, the females always laid their eggs in the den region. Usually, the females oviposited at night.

One difference I have noted between *S. t. intermedia* in comparison to other colubrids in my collection is the relatively low fertility of their eggs (29%). This compares to a fertility of 50% for the Trans-Pecos rat snake (*Elaphe subocularis*) in my collection. Kingsnakes of the genus *Lampropeltis* have even higher percentages of egg fertility: gray banded kingsnakes (*L. alterna*) 72%, Sonoran mountain kingsnakes (*L. pyromelana*) 81%, and common kingsnakes (*L. getulus*) 94%.

Difficulties

I believe the reasons for the low fertility of green rat snake eggs are manyfold. The foremost is that males will only breed each female once during the breeding season. That means the female must be at the peak of her receptivity if she is to have a high percentage of fertility.

	Gestation Period	Clutch Size	Fertility	Incubation
Female A				
1984	68 Days	6	33% (2/6)	77-78 Days
1985	84 Days	7	14% (1/7)	79 Days
1986	70 Days	7	57% (4/7)	82-84 Days
1987	58 Days	4	0% (0/4)	---
Female B				
1984	---	---	---	---
1985	48 Days	3	0% (0/3)	---
1986	62 Days	3	0% (0/3)	---
1987	73 Days	4	75% (3/4)	86-88 Days

Figure 2 - Gestation lengths (first breeding to oviposition), clutch sizes (with fertility percentages), and incubation lengths for the western green rat snake (*Senticolis triaspis intermedia*)

Secondly, these snakes are extremely sensitive to any disturbance. Even with the drawer-type cages, these snakes may be disrupted just by the keeper walking into the room. I have observed rejection of a food item which was halfway down the esophagus apparently as a result of my entering the snake room.

Egg Incubation

Figures 2 and 3 list the clutch size, egg weights, and neonate data. Females generally invested about 25-30% of their biomass in eggs (egg weight divided by females weight plus egg weight). This is slightly less than egg investments found in other colubrid species (Merker, pers. obs.). Eggs were incubated in glass gallon jars with a substrate of 50% peat moss and 50% sand which was moistened until it had the consistency of damp soil.

The eggs hatched in approximately 82 days (see Figure 3) at an incubation temperature of 26°C. *E. subocularis* had an incubation period of 105 days at an incubation temperature of 24-30°C (Campbell, 1972). The neonates were all similar in appearance. They averaged 18.5 g in weight (range 11-22.5 g) and 34 cm in length (32-26 cm). Tryon (1978) and Campbell (1972) found captive hatched *E. subocularis* weighed approximately 14 g and measured 28-35 cm upon hatching.

Neonates

Captive bred *S. t. intermedia* have not presented the husbandry difficulties exhibited by wild-caught adults as described by Cranston (1990). Most hatchlings fed readily on small, pink domestic mice after their first shed which occurred approximately 10 days after hatching. On a regular feeding schedule of 3 pink mice per week, the neonates doubled their weight in 6 months. A young male engaged actively in courtship and breeding at 31 months.

	Length (cm)	Width (cm)	Weight (cm)	Neonate Weight (g)	Neonate Length (cm)
Clutch 1					
Egg 1	---	---	---	12.4	---
Egg 2	---	---	---	22.1	---
Clutch 2					
Egg 1	---	---	---	18.3	---
Clutch 3					
Egg 1	---	---	---	17.8	32.6
Egg 2	---	---	---	19.6	33.1
Egg 3	---	---	---	20.7	34.5
Egg 4	---	---	---	21.6	35.0
Clutch 4					
Egg 1	6.0	2.8	21.1	19.2	36.0
Egg 2	5.9	2.7	23.2	22.5	35.1
Egg 3	5.8	2.6	20.0	11.0	32.0

Figure 3 - Data on fertile eggs and hatchling western green rat snakes (*Senticolis triaspis intermedia*)

Occasionally, one of the hatchlings refused to feed on domestic mice. These animals would usually accept appropriately sized deer mice (*Peromyscus*). Once feeding regularly on deer mice, the neonates were tricked into feeding on domestic mice using scenting techniques described by Applegate (1984).

Caging for neonates consisted of plastic shoe-boxes with a piece of paper towel for substrate and a small water container. At one year of age, when the animals weighed 60-70 g, they are placed in plastic sweater boxes with pine shavings substrate and a water container.

Conclusion

Much of what is known about reproduction of colubrid snakes under captive conditions applies to *Senticolis triaspis intermedia*. However, difficulties encountered in inducing *S. t. intermedia* to reproduce in

captivity indicate that these animals may have specific needs or requirements that are not being met. This is evident by their relatively low fertility rate. I feel that acclimation is the most important obstacle to the successful captive propagation of this species. Once the snakes have been allowed to acclimate to captive conditions and a seasonality is provided for them, captive breeding will occur. In my collections, the time period needed for acclimation appears to be from three to nine years.

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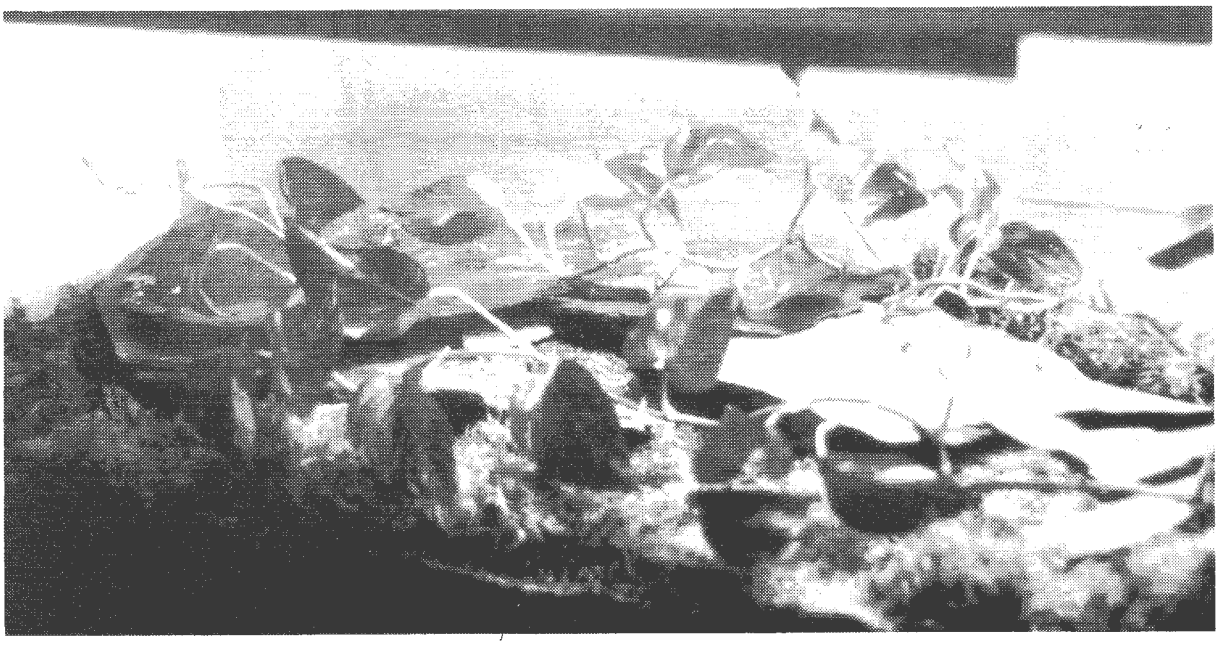

Semi-naturalistic cage set-up used with Mandarin ratsnakes

The First North American Captive Breeding of the Mandarin Ratsnake (Elaphe mandarina)

William B. Gillingham
555 E. Vista Rio Ct.
Woodbridge, CA 95258

Introduction

The Mandarin ratsnake (*Elaphe mandarina*) is a very beautiful and enchanting ratsnake from the mountain regions of southern China. Until recently this ratsnake has eluded captive husbandry and propagation success stories. The first known captive breeding in North America was successfully accomplished with the hatching of six eggs in 1988. The captive breeding and husbandry techniques used are described, including the rearing of the offspring.

Adults

The imported wild Mandarin ratsnake has been an extremely difficult ratsnake to maintain in captivity. High mortality of this snake in captivity is usually caused by a combination of factors, all of which seem to aggravate each other. The most common factors are stress, internal parasites (lung worms and nematodes), bacterial infections, anorexia, and improper environmental conditions. In spite of this, a few hardy specimens do survive, slowly acclimating to their new environment.

I purchased two pairs of wild caught, long term captive Mandarin ratsnakes in May of 1987 from a reputable Michigan snake breeder, Tom Lamont. He had purchased these snakes from another reputable breeder, Ernie Wagner, who obtained the snakes in 1983. The snakes were housed in separate cages for the first month. One of the females arrived with a respiratory infection and eventually died. In June, I placed the snakes in a hundred gallon glass terrarium containing a natural habitat setting composed of damp bark mulch, spaghnum moss, living indoor plants, and large thin slabs of slate rock. The terrarium was periodically sprayed with water. I used a four foot flourescent light fixture with two wide spectrum Gro Lux® fluorescent tubes placed twelve inches above the terrarium. The daytime room temperature averaged about 26°C. The temperature taken in the primary hiding area in the terrarium was 22°C. Since my reptile facility is located in the basement of my home, there is only a small 4-5°C temperature variation between the day and night temperature.

Behavior

The snakes ate most frequently at night. An occasional feeding was observed during the day, if the observer remained hidden from the snake's view. Large pinkie and small fuzzy mice were usually accepted but the snakes generally shied away from larger mice. The food items were usually scattered throughout the

terrarium with most of the food items gone by morning. The snakes are light feeders, rarely eating more than three or four fuzzy mice.

One snake was usually observed out and about in the morning, lying motionless when observers were detected, then disappearing quickly into a shelter. Most activity occurred during the night. Tail vibration was often observed when the snake was confronted or excited. One of the more aggressive males would occasionally strike when disturbed. All three snakes shared the primary hide area.

Hibernation

With the approach of winter, I began preparing the room for hibernation by gradually cooling it down. By mid-November hibernation had begun. The room temperature dropped to about 15°C. The temperature inside the room was cooled by using the cold outside air. Cooling was achieved with a fan system which was controlled by a thermostat. Colder outside air is drawn into the room as the warmer air is exhausted from the room. During the coldest part of winter, the room temperature dropped to about 12°C for six to ten weeks.

Breeding

I began warming the room in the third week of February. The Mandarin ratsnakes were not disturbed during the entire winter. At the beginning of March, I began introducing food and they began feeding. By late March, the female was looking somewhat heavier than normal. At the time, I thought she might be constipated. It had not occurred to me that she may have been ovulating. I also noticed that one of the males kept the other male away from the primary hide area. The subordinate male occupied another hide area on the opposite side of the terrarium. I observed the dominant male jerking as he entered a tunnel into the primary hide area. I could not tell which of the other snakes, the male or female, was occupying the primary hide area at the time. For the greater part of that spring, both the dominant male and female stayed together in the primary hide area.

Egg Incubation

By April, the posterior of the female continued swelling indicating that she was, indeed, gravid. Late May she became opaque and shed several days later, May 27. I placed her in a plastic sweater box with damp vermiculite and a hide box. She laid six eggs, all of which appeared to be good, on June 7 (11 days after ecdysis). The female stayed curled around her eggs. I removed the eggs and placed them in a plastic shoe box filled with damp vermiculite and place this box inside of a large sweater box which was placed on a shelf. The average daytime temperature in the shoe box containing the eggs was 27°C and the average nighttime temperature dropped to 24°C. I felt this might be a more appropriate temperature range than my incubator (28°C) since these snakes prefer the cooler temperatures. They have been recorded in elevations ranging from 700-2300 m (2,200'-7,500') in the high-lying mountain woods of southern China (Fleck 1985).

I expected the eggs to have a longer incubation period because of the lower temperature. When checking the eggs on July 26, I noticed one egg was slit. It had only been 49 days since the eggs were laid. I thought perhaps the egg slit from too much moisture, but later noticed a nose protruding through the slit. They all hatched within the next 36 hours. The neonates weighed 10-12 g, their average length was 30 cm. The neonates shed for the first time on August 4-5. One neonate ate a pinkie mouse before its first shed. The sex ratio was even, with 3 males and 3 females. The neonates looked identical to the adults in color and pattern.

Another wild Mandarin ratsnake imported that same summer laid two fertile eggs on July 14 which hatched 54 days later on September 7. These eggs were incubated at a slightly higher temperature, daytime 27°C and nighttime of 25.5°C. Both of these hatchlings were females.

Neonates

The hatchlings were kept in individual plastic sweater boxes with a high level of damp bark mulch (later switched to aspen bedding), a large piece of bark for hiding and a water bowl. All of the hatchlings began feeding on a regular basis after their first shed accepting new-born mice. Rarely was more than one newborn mouse taken at a time. The hatchlings were fed approximately every four to six days. Occasionally the food was not accepted because either the food item was too large or the snake was preparing to shed. After six months, the largest hatchlings have reached a length of 49.5 cm. They also show the same shy characteristics as the adults, spending most of their time hiding and burrowing tunnels in the substrate.

Conclusion

The captive hatched Mandarin ratsnakes have been relatively easy to raise. They were large neonates that started feeding directly on pinkie mice. They have spent their first six months at a room temperature range of 23-26°C and without any special lighting. As adults they will probably do very well in captivity as has been the case with other European and Asian *Elaphe*. The key to this first captive breeding is contributed to the natural setting in a large terrarium with ample and secure hiding areas, a relatively cool temperature and adult snakes which have had the time to acclimate themselves to captivity.

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Reproduction and Husbandry in the Red-tailed Rat Snake of South-east Asia

Dale J. Bakken
2739 12 Ave. S.E.
Calgary, Alberta, Canada
T2A 0G3

Introduction

The red-tailed ratsnake (*Gonyosoma oxycephala*) is a relatively common arboreal snake found in mangrove swamps and riverine forests of Southeastern Asia and the Philippines. In recent years, many of these snakes were imported from Thailand and Malaysia.

This snake can reach an adult length of 2.0 m or more, but most specimens typically measure 1.5 m. It has an elongated head and large eyes with round pupils. The tongue is dark with blue sides. The head and body are green and the tail is rusty brown. The scales are smooth. The ventrum is light green or greenish yellow. A sharply defined line, running through the eye separates the darker green of the top of the head from the lighter color of its sides and lower parts. This species is a strong, active, and powerful constrictor. *G. oxycephala* often inflate their throat pouch vertically when excited or provoked. It has a wild diet consisting of birds, nestlings, eggs, rats, squirrels and other small mammals, while neonates may feed more on frogs, lizards and smaller birds and mammals.

Husbandry

I currently house a group of two male and one female wild caught adults. These animals arrived in my collection June 13, 1985 and were imported directly from Malaysia. They were part of a larger shipment containing four male and two female *G. oxycephala*. One pair of *G. oxycephala* died within the first three months of their arrival and one other male was later sold.

As wild caught animals they generally arrive in a dehydrated state with heavy internal and external parasites. The first step is to rehydrate the animal with fluids occasionally giving electrolytes such as Lactated Ringers and water mixed at 1:1 by volume. Avitron®, an oral vitamin supplement, was also added.

Many times the *G. oxycephala* were infested with internal parasites of the genus *Strongyloides*, which were treated with Fenbendazole at a dose of 75 mg/kg administered at 2 week intervals.

Ticks were the major external parasite which were either manually removed or killed using an appropriately sized piece of Vapona pest-strip placed in the snake's enclosure.

All individuals are housed separately in glass aquariums measuring 60 x 30 x 35 cm high. Each aquarium is equipped with a plexiglass lid with numerous 3 mm holes, newspaper substrate and a 15 cm diameter water dish placed below a rack made of wood doweling upon which the snakes rest. The doweling rack is 20 cm high with the actual dowels being 1.6 cm in diameter and placed 3 cm apart. No hide boxes are provided. Temperature varies for adults from 21-29°C.

The dietary preferences of imported individuals varies from specimen to specimen. Most prefer fresh killed mice; however, one individual would only accept birds like freshly killed sparrows or chicks. At present one male still prefers chicks or juvenile rats to mice.

G. oxycephala have a high metabolism and digestion is rapid. I currently feed my female three mice at 10 day intervals. The males average one food item per 10 days.

Reproduction

Breeding can occur at any time throughout the year and this is supported by work done at the Bronx Zoo. I house all the *G. oxycephala* in separate enclosures except when a breeding is planned. Then at that time I introduce a male into the female's enclosure. The male is introduced to the female just prior to or on the day of her ecdysis. The male is housed with the female for approximately one week and the pair is misted for a few minutes a day with an ordinary plant spray bottle.

The first clutch was laid in August 1987. The female shed on July 25 and the eggs were laid 13 days later on August 7. A total of eight eggs were laid which were incubated in a vermiculite:water mix at 2:1 by weight. The eggs were buried in the substrate and incubated at a temperature of 27-30°C. All the eggs were opened at 96 days and contained dead full-term embryos. Some of the embryos had spinal and eye deformities.

Our next and successful breeding took place on October 12, 1987. Breeding was observed throughout that day. The female was given a supplement of Nutriderm and Calcium Sandoz with her November 11 feeding. The female shed on December 30. Sterile potting soil was added to the female's enclosure on January 6, 1988 and she laid eight eggs on January 16. These eggs weighed 200 g collectively and were incubated in a vermiculite:water mix at 2:1 by weight. The eggs were not buried, but rested on the damp substrate. It should be noted that high humidity was maintained throughout the incubation period. These eggs were incubated at 28.0-29.5°C.

The eggs began to hatch April 26 and continued to hatch until April 28, 1988. Incubation ranged from 101-103 days. All eggs hatched and the sex of the hatchlings was determined using reptile sexing probes to be five males and three females. One male was discovered to have a slightly kinked spine located anterior of the cloaca. All neonates were housed in individual plastic containers (17 x 31 x 9 cm high). Each container had numerous 3 mm holes drilled in the lid, and contained a substrate of paper toweling and plastic plants. Each container had a plastic water dish 9 cm in diameter and 3 cm in depth. Neonate housing containers were all placed on an adjustable heat tape at one end of the container to provide a thermal gradient.

All neonates shed 11-16 days after hatching and were initially force fed pre-killed small pink mice. After about four such feedings (approximately two months after hatching), the neonates then started feeding voluntarily out of my hand. Growth was rapid. These neonates are arboreal so they were kept slightly hungry and thin.

Clutch number three had its share of problems. The female was fed on May 2, 1988, supplemented this time with Avitron®. Breeding was observed on May 14. The female's pre-oviposition shed occurred on July 10, 21 days prior to laying nine eggs (July 31). The eggs averaged 4.6 cm by 2.8 cm. These eggs were incubated in

the same manner as clutch number two, however, the incubation temperature was decreased slightly to 26-28°C. The eggs hatched between 96-98 days later on November 4-6. All but one of the neonates pipped their eggs on their own. As in the hatching of the eggs from clutch number two, it seemed normal for the neonates to take 48 hours from initial pipping to full emergence from the egg. However this time, we had a major problem. Eight of the nine embryos had pipped on their own, but only three males successfully hatched.

The six dead embryos were removed from their pipped eggs. Average total body length of the dead neonates was 42 cm, of which tail length averaged 10 cm. No neonates showed any signs of external deformities. The sex of the neonates was determined via probing and was 6 males and 3 females of which only 3 of the males survived. The growth of these neonates has been equivalent to that of the second clutch.

Conclusions and Discussions

G. oxycephala are fairly difficult to maintain in captivity, especially if they are newly imported wild-caught individuals. Upon stabilizing the animals in captivity, they seem relatively easy to breed. I have had no problems attaining fertile eggs or raising the newly hatched neonates. However, I have experienced problems in incubating eggs of this species, having produced full term dead neonates with deformities and neonates that appeared healthy, but failed to successfully hatch on their own.

Further study is needed on the cause or causes of my problems with egg incubation and hatching. Temperature, humidity and vitamin supplement may play a major role in any future success. I have an ongoing breeding program with this particular species and find them a delight to work with.

Acknowledgements

I wish to take this time to thank all the zoos and individuals who have corresponded over the past six years with me on this species. I would like to specially thank the Bronx Zoo and its staff for sharing valuable breeding and incubation information. Also a very special thank-you to Sherri Nordin for her valuable work and input into this paper.

Products Mentioned in Text

1. Avitron liquid vitamin supplement, Lambert Kay, Div. of Carter Wallace Inc., Cranbury, New Jersey. 08512
2. Calcium Sandoz oral supplement syrup, Sandoz Canada Inc., Dorval, Quebec. H9R 4P5
3. Nutriderm, Norden Laboratories, Calgary, Alberta, Canada. T2H 2K4
4. Panacur (fenbendazole) 100 mg/ml, Hoechst, Hoechst Canada Inc., Montreal, Quebec, Canada.
5. Vapona Pest Strip, Shell Canada.

Methodology for Obtaining Multiple Clutches of Eggs in One Season from Colubrid Snakes

Robert Applegate
1762 Pepper Villa Drive
El Cajon, CA 92021

Introduction

Only a few years ago, breeding a pair of snakes and obtaining a single clutch of good eggs was considered a major accomplishment. Today we can consistantly produce eggs each year and now have even branched out into techniques that will increase production. It is now possible to get two, three, and sometimes even four clutches of eggs from certain colubrid species. I am currently working with ten colubrid snake species, comprising nineteen subspecies. I have successfully obtained two clutches of eggs in a single breeding season from all nineteen subspecies. One subspecies has even consistantly laid three clutches each season.

Records

The single most important indicator and review source are records -- keep detailed records. Records are vital for future guidance and problem solving. Record the females' weights just after hibernation before their first meal of the season. This weight will give you a good measure of your starting point each breeding season. After you have compiled a small data base, you can begin making educated predictions of what you can expect from snakes at certain base weights.

First Clutch

Most of the snakes I began working with were young, and each year for several years, including 1988, my average egg production from many of the females has exceeded the previous year's production. My data suggests that for the colubrids I work with, the females produce well from 2-3 through 9-10 years of age. However, this is based on a very limited number of snakes for which I have complete life records. The techniques I use are pretty much the same for all my colubrids. Some respond readily and regularly produce multiple clutches; others only rarely produce a second clutch. I will not try to speculate why, there is still a lot to learn. Before we can attempt to produce multiple clutches, obviously we must produce a first clutch. To produce a first clutch our snakes must be properly managed and conditioned. A short review of some of the techniques that contribute towards proper conditioning will follow, but for complete details I suggest you review Applegate (1985, 1987) and Scheidt (1984).

My adults are hibernated from November 1 through March 1 of each year. Four months may be excessive for some subspecies, but does no apparent harm, and the overall results are good. Review Applegate (1987) for a more detailed discussion on the effects of hibernation temperatures.

We will start with an adult female, just out of hibernation, as a beginning point for breeding. If there is a real secret to be shared here, it is the feeding of the snake. Feed her small to medium sized meals frequently as often as three times per week. When she is opaque and refuses her regular food items, offer her a delicacy item. If her normal meals are mice, offer her a pinkie rat. Keep food in the digestive tract at all times, if she will accept it.

Using your data base of weights and your past experience, you can decide if your adult female or your two year old female is large enough to breed, or if you might be better advised to defer breeding until the following year. I have had some female colubrids that were low in weight, so I kept them warm and feeding over their second winter. They developed follicles anyway, so I assumed that if they could develop follicles, they were in fact large enough to breed. I quickly introduced a male to each, which promptly copulated with its respective mate. Good sperm counts, wrong assumption. All three in this example laid infertile eggs and died of complications soon after. This was a costly, but valuable lesson. I will defer breeding future underweight females until the following year, even if they develop follicles.

The actual determination of when a snake is ready to mate is well covered in past articles, but there are a couple techniques that can be used to check for copulation and fertility. I watch the sand substrate of their cages for hemipene plugs and use a microscope to search for sperm in a cloacal smear taken from a female suspected of or observed copulating. Palpating a suspected female's abdomen for follicles will sometimes help you decide if she will be receptive. Some snakes will mate before their first shed, some just after. On some of my snakes, the first shed of the season will be the pre-egg-laying shed. Many individual snakes are remarkably consistent in their behavior patterns from year to year and you learn to expect certain things at certain times. Here again your records will show these patterns. This information is particularly useful when you have to share males with several females and you need to be able to expect a pattern to set the order in which the females should be placed with the male.

Multiple Clutches

Keep feeding the snakes, even when gravid. When she swells with eggs, feed small sized meals. I have had female snakes feed in the morning and lay eggs later that afternoon. If she refuses a meal, do not assume she is off feed for the duration, try her again later that day, or the next. Offer a delicacy item. Keep trying, these difficult meals may make the difference between a single clutch and multiple clutches. Extra feedings may also increase the size of subsequent clutches. You do not want to over-feed to the point where you have an obese snake, but you want to maintain prime condition status, which can be severely compromised in egg production.

After the eggs are laid, feed the female snake. If you determine the female is in good condition, immediately put a male in her cage. I have had second clutches of eggs that hatched some neonates without a second mating, but I feel it increases the odds of fertilization and a good hatch rate if they breed again. The same procedure is used for third clutches. With my hibernation time of four months, I feel I just run out of time for a fourth clutch. If one wanted to experiment with shorter and perhaps cooler hibernation times I am sure some colubrids could produce four clutches of eggs per year, maybe even more.

Males

Do not neglect the males. In some species of snakes, some males will refuse to feed when around females. While busy with all this female management, it is easy to overlook the males. I have had to take thin males completely out of the breeding rooms and house them in a plastic shoe or sweater box to get them to resume feeding. I now feel that on some species, when the males have successfully copulated with the females, I should

put them in single occupant cages. Here, I keep them a little cooler and feed them frequently, so they will also be in prime condition and still produce viable sperm for second clutch matings.

Risk

What is the risk factor in multiple clutches versus a single clutch for the female? For now, my data suggests that for certain under weight and stressed snakes, it is riskier to try for multiple clutches. However, there is always risk involved even for only one clutch. Also, one would expect the risk to be at least double that for one clutch, if the female lays two clutches in a season. Some of my snakes have double clutched their second year, then gone on to double clutch each year for many years. Some got through their first clutch, then died of complications after their second clutch. The few triple clutch animals have all done well, and consistantly produced multiple clutches for many years. I feel that if the female is still in prime condition after laying eggs, she could safely have another clutch, no matter how many clutches she has had up to that time.

Figure 1 contains a listing of the snakes I am currently working with, followed by the largest first, second, and third egg clutches for the year. All the eggs may not have hatched, the record size clutches may not have been laid by the same female (i.e. the largest first and second clutches may have been laid by different females). Some records come from a single female, others from dozens.

Conclusion

Many species of colubrid snakes will lay multiple clutches of eggs in a season if they are properly managed. Feeding is the key. A healthy female kept in prime condition from continuous feedings will respond by laying multiple clutches and probably larger and healthier clutches of eggs. Detailed record keeping allows the culturist decide which females are healthy enough to breed as two year olds or to breed for a second or third clutch of eggs. Again, a female colubrid snake kept in prime condition can safely produce multiple clutches of eggs in a season for many seasons.

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Species/Subspecies	1st	2nd	3rd
Elaphe guttata guttata	23	16	--
Elaphe obsoleta obsoleta	21	11	--
Lampropeltis alterna	16	10	--
Lampropeltis calligaster calligaster	10	14	--
Lampropeltis getulus californiae	15	12	--
Lampropeltis getulus holbrooki	17	15	--
Lampropeltis getulus nigritus	13	10	--
Lampropeltis mexicana greeri	12	11	--
Lampropeltis mexicana mexicana	14	7	--
Lampropeltis mexicana thayeri	14	12	--
Lampropeltis pyromelana	7	5	--
Lampropeltis ruthveni	11	10	--
Lampropeltis triangulum abnorma	7	6	--
Lampropeltis triangulum annulata	11	9	--
Lampropeltis triangulum campbelli	12	12	9
Lampropeltis triangulum hondurensis	13	8	--
Lampropeltis triangulum nelsoni	10	4	--
Lampropeltis triangulum sinaloae	14	9	--
Pituophis melanoleucas annectans	14	12	--

Figure 1 - Maximum number of eggs laid in clutches within the author's collection for 18 forms of snakes.

Techniques for Sex Identification in Reptiles

James S. Stewart, MS, DVM
Zoological Medicine Service
Veterinary Medical Teaching Hospital
University of California
Davis, CA 95616

Introduction

For any reptile captive propagation program, the value of proper sex identification of the specimens is self evident. All too often, a breeding group is established by acquiring several individuals of a given species, housing them together, hoping that they are not all of the same sex, and waiting for reproduction to occur. Such a system is clearly inefficient in terms of space, time, effort, and money. The sex of any reptile can be determined in one manner or another, and fortunately, for most species the techniques employed can be quite simple. This report cannot be a species by species account of sex identification methods. Such an undertaking would be excessively extensive and very repetitive. Rather, a summary of the techniques for sex identification is presented. Various taxa will be mentioned to simply serve as examples to illustrate a particular point.

Observations of Reproductive Behavior

Sex identification by observation of reproductive behavior is still a commonly employed practice in herpetoculture. This method requires a good deal of time and effort combined with a dose of good luck. Interpretation of the behavior is also fraught with potential error. In order for a behavior to be indicative of gender, it must have been previously known to occur exclusively in one sex of a given species. The sex of the animals performing the behavior must, therefore, have been identified and verified using another technique. Assigning a sex to an individual for performing a behavior that "should" be a sex-specific behavior is pure conjecture.

Delivery of Eggs or Offspring

This is the definitive behavior for females. This does not necessarily indicate the sex of cagemates, however. Some reptiles, chelonians in particular, may lay eggs without being bred by males. The production of viable offspring by a female maintained long term with a single cagemate does not necessarily mean that the cagemate is a male. Many female reptiles have the capability of prolonged sperm storage (e.g., up to four years in the box turtle (*Terrapene carolina*) and six years in the cat-eyed snake (*Leptodeira annulata*)).

Copulation

True copulation with observed penetration of the phallus or hemipene into the partner's cloaca is a clear indicator of sex. True homosexual copulation has not been observed in reptiles. The partner thus far can be safely be assumed to be female. Copulation must be distinguished from mounting.

Mounting

Mounting is both a reproductive and dominance establishing behavior. It is performed by members of both sexes. During courtship in American alligators (*Alligator mississippiensis*), females routinely mount males in an apparent evaluation of the strength of perspective mates. Female tortoises often mount other females and may even vocalize in a manner similar to breeding males. In tortoises in particular, the individual being mounted may be either sex, and may even be another species. Mounting is a common aggressive behavior in lizards of both sexes. The simple assumption that males mount females is invalid.

Courtship Behavior

Specific behaviors involved in courtship and territoriality have been demonstrated to be species and sex-specific. The head bobbing patterns of iguanid lizards and tortoises, the combat of male pit vipers and the water dance of male alligators are a few examples. Again, it must be emphasized that the behavior needs to have been studied in a population of individuals of known sex and demonstrated to be truly sex-specific.

Sexual Dimorphism

Fortunately for herpetoculturists, a great many reptiles show sex-specific variation in external morphology. Here again, the external morphological trait needs to have been correlated with specimens of proven sex. This is readily accomplished through examination of preserved specimens in museums and other zoological collections. The following listing serves to illustrate some of the types of morphologic traits that are dimorphic among some various members of the reptile groups.

Rhynchocephalia

Tuataras (*Sphenodon punctatus*) become dimorphic with sexual maturity at about 20 years of age. The male is more heavily bodied than the female and develops large jowls around his throat.

Crocodilia

As a general, crocodilians are not sexually dimorphic. Males achieve greater size than females, so very large individuals of a species are most probably male. Mature male gharials (*Gavialis gangeticus*) develop large bulbous nasal flaps on the tip of the snout.

Chelonia

Most chelonians are sexually dimorphic at maturity, but are apparently monomorphic when immature. Some examples of dimorphic traits include:

Size. Mature males are larger than females in the alligator snapping turtle (*Macroclemmys temmincki*) and giant tortoises. Conversely, mature females are larger in map turtles (*Graptemys sp.*) and some sliders (*Chrysemys sp.*).

Color. Color dimorphism is uncommon, but when it occurs is usually around the head. Male eastern box turtles (*Terrapene carolina carolina*) have a red iris while that of the female is brown. The male spotted turtle (*Clemmys guttata*) has brown eyes and a tan chin while the female has orange eyes and a yellow chin.

Head Size. The female map turtle (*Graptemys geographica*) has an enlarged head relative to that of the male.

Nails. The nails on the front limbs of some members of several genera (e.g., *Chrysemys*, *Pseudemys*, *Trachemys*, and *Graptemys*) are markedly elongated in the male. The male green sea turtle (*Chelonia mydas*) has an enlarged hook-like claw on the front flipper to grasp the female's shell, while the male ornate box turtle (*Terrapene ornata*) has a hooked nail on the inside of the hind foot for the same purpose.

Shell Shape. The concavity of the plastron in males is found in many species of both turtles and tortoises. In most tortoises, the shape of the shell surrounding the tail space is dimorphic. In males the opening is short and broad, and the anal scutes are also short, broad and point caudolaterally. In females the opening is more rounded, that anal scutes are longer and narrower and tend to point directly caudally. In male tortoises such as the California desert tortoise (*Gopherus agassizi*), the gular projection of mature males may be markedly enlarged.

Tail Size. Dimorphism of tail size is also seen in many species of both turtles and tortoises. This is well exemplified in softshell turtles (*Trionyx sp.*) in which the males has a large fleshy tail with the cloaca situated near the tip, and the female has a small tail with the cloaca located near the base.

Sauria

Sexual dimorphism is quite marked in a number of lizards, particularly the visually oriented diurnal species. A few examples of dimorphic traits include:

Color. The blue abdominal patches of male fence lizards (*Sceloporus sp.*) are striking. Color dimorphism is common among iguanids, agamids, lacertids, small teiids, and day geckos (*Phelsuma sp.*).

Head Size. The male broad-headed skink (*Eumeces laticeps*) has a markedly enlarge head and jaw musculature.

Adornments. The male Jackson's chameleon (*Chameleo jacksoni*) has three prominent horns that are lacking in the female. The dorsal crest of the basilisk (*Basiliscus plumifrons*) is well-developed in the male. The dewlap of several anoles (*Anolis sp.*) is larger in the male and more colorful.

Tail Shape. The male shingleback skink (*Trachydosaurus rugosus*) has an elongated pointed tail relative to the stubbier, rounder tail of the female. Many of the smaller species of iguanids and geckos show prominent swellings on the ventral tail base indicative of the male hemipenes.

Femoral and Pre-anal Pores. The femoral pores of iguanids (e.g., the green iguana (*Iguana iguana*)) are enlarged in mature males. The size and pattern of pre-anal pores in geckos are dimorphic and vary with species. The male Komodo dragon (*Varanus komodoensis*) has two pre-anal pores that are lacking in the female.

Post-Cloacal Bones. Some geckos (e.g., *Coleonyx sp.*) possess post-cloacal sacs with prominent spurs formed by post-cloacal bones in the male.

Serpentes

Snakes for the most part are sexually monomorphic. Color dimorphism is uncommon. The male common adder (*Vipera berus*) has a red iris while that of the female is brown. The tail base of some snakes is visibly broader in males due to the presence of the hemipenes. This is marked in some pit vipers (e.g., *Crotalus sp.*) and more subtle in colubrids. The hemipenes may be seen through the skin of some albino snakes. The boas and pythons retain vestigial hind limbs seen externally as spurs that are usually more prominent in males.

Internal Examination of Monomorphic Species

Sex identification of monomorphic reptiles involves examination for the presence or absence of the male copulatory organ, visualization of the gonad to distinguish testis from ovary, or testing for the presence of gonadal products (e.g., sperm, ova and hormones). Any of these methods can be applied to any reptile species (except that the male tuatara has no copulatory organ). Only the techniques that have proven to be most clinically useful for each reptile group are described.

Crocodilia

Crocodilians are perhaps the easiest of reptiles to sex. The male possesses a single phallus that has a rigid fibroelastic shaft and an erectile tip. It is normally positioned in the ventral aspect of the cloaca, cranial to the cloacal slit, and is directed caudally. It can be identified in any crocodilian of any size. The phallus is easily palpable in any animal large enough to pass a lubricated finger or hand into the cloaca or by manipulation of the organ with a lubricated cotton tip swab passed into the cloaca. The phallus may also be visualized by passing an otoscope cone into the cloaca, but this is usually not necessary.

Chelonia

Male chelonians possess a single phallus that is composed primarily of erectile tissue. The organ is quite large and usually has a prominent dorsal groove. Although the phallus may be visualized during mounting and copulation, it cannot be manually externalized. The phallus is easily palpated in mature males of sufficient size for passage of a lubricated finger deep into the cloaca. In small specimens, the phallus may be visualized by passing an otoscope cone into the cloaca. The use of a fiberoptic endoscope for direct visualization of the testis or ovary is a safe and relatively simple technique in chelonians and may prove to be of value in sex identification of immature specimens.

Sauria

Male lizards have paired hemipenes situated in the tail base caudal to cloaca. These are sac-like extensions of the cloaca that may be everted with vascular pressure. Females also possess these sac-like extensions, but they do not evert. Sexing probes may be passed into the sacs in a manner as described below for snakes. However, in lizards the depth of probing has no consistent pattern with sex identification: males may probe to a greater, lesser, or most often, to the same depth as females depending on the species. The hemipenes may be manually everted in some of the smaller lizards such as geckos using a technique commonly referred to as "popping". The thumb is placed along the ventrolateral aspect of the tail over the hemipene and pressure is applied from caudal to cranial using a rolling motion.

A very reliable method for hemipene eversion is the tail injection technique. This has proven to be a useful method in most monomorphic lizards including heloderms, skinks, cordylids, small monitors, and other

species that have traditionally been difficult to sex using other methods. With this technique, a sterile isotonic solution such as physiologic saline or lactated ringer's solution is injected so as to surround the hemipene and simulate the vascular pressure causing eversion. Using sterile technique and a ventral approach, the needle is inserted intramuscularly to a point that approximates the caudal extent of the inverted hemipene. The volume injected varies with the size of the lizard: approximately 1 ml for the crocodile lizard (*Shinisaurus crocodilurus*), 10 ml for the blue tongue skink (*Tiliqua scincoides*) or 20 ml for the Gila monster (*Heloderma suspectum*). In the female, the cloacal margins become engorged and the openings of the post-cloacal sacs are apparent. In the male, the hemipene everts usually before the cloaca is markedly engorged. It is not necessary to completely evert the hemipene for sex identification purposes, but it can be accomplished. Using moistened or lubricated fingers, gentle pressure is applied to the hemipene and the organ is slowly manipulated back into the inverted position. The lizard is placed in an enclosure with a small, clean non-absorbent surface, such as an empty aquarium or fiberglass snake cage, for a few hours after the procedure to prevent damage to the hemipene in the event of re-eversion. The author has used this method numerous times on many species of lizards with no negative effects. The technique is ineffective in the larger lizards such as green iguanas and large monitors. Apparently, the hemipene retractor muscles are of sufficient strength to over-power the injection pressure and prohibit hemipene eversion.

Alternative methods for sex identification of lizards include examination of the gonads. This may be accomplished with a fiberoptic endoscope, by the use of a sterile otoscope cone as a laparoscope, or by exploratory surgery. Ultrasonography can be of some benefit, especially in identifying the developing ova in females. Cloacal swabs of mature males will often reveal spermatozoa on microscopic evaluation. Recently bred females may also show viable spermatozoa and the lack of spermatozoa could be found in both sexes. Blood hormone analysis has been used to identify the sex of lizards. This method requires specialized laboratory techniques and is subject to a great deal of variation with the season of the year, animal age, and species.

Serpentes

Male snakes have paired hemipenes comparable to lizards. The hemipene sacs are markedly dimorphic in most species of snakes, the males having the greater depth. The hemipene openings are located at the lateral margins of the cloacal opening. A sexing probe can be passed into the opening and directed caudally into the hemipene sac. In a male snake, the probe will pass to a depth of ten or twelve ventral scale rows. In a female, the probe typically passes only as far as three or four scale rows. Probing can be performed on snakes of all ages. The sexing probe can be constructed of any material that is smooth, clean and with a rounded tip, such as stainless steel or plastic. It is important that the probe be passed with gentle, finger-tip pressure. The hemipene sac is easily ruptured, and tail abscesses may result if excessive force is used. The probes should be carefully cleaned between use on different snakes. Hemipenes can be everted using the tail injection technique as described for lizards. This method works well in smaller individuals. Larger specimens again have well developed retractor muscles and may require anesthesia if eversion is to be accomplished. Cloacal swabs of mature males frequently reveal spermatozoa on microscopic evaluation, but recently bred females will also have spermatozoa present.

Conclusion

Successful and efficient herpetoculture begins with the proper sex identification of the members of a breeding group. Presented here is a summary of a variety of techniques that may be successfully employed for sex identification of reptiles. The list of techniques is by no means exhaustive, and the species discussed are only a few illustrative examples. The sex of any reptile can be determined using one technique or another. The choice of technique depends upon knowledge of the species concerned, personal experience with the various techniques, and information solicited from other herpetoculturists. Once the sex of the reptiles is properly

identified, the herpetoculturist can more clearly concentrate on the finer points of the nutritional, environmental and behavioral aspects of captive propagation.

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Sex Determination in Reptiles: Genetic versus Environmental

Harold F. De Lisle
Dept. of Biology
Moorpark College
Moorpark, CA 93021

Introduction

The sex of an individual obviously has a very profound effect on the life history of that individual, and how sex is determined has a profound effect on the natural history of a species. We are still learning the details of sex determination in humans, so it is not surprising that we only know a few of the details of sex determination in reptiles. We know that some reptiles' sex is determined as it is in humans; for others it is determined by external environmental conditions, especially the temperature during egg incubation.

Genetic Sex Determination

The biology of sex determination has been studied extensively, especially in mammals including man. Every high school biology text has a section on the basics: Sex is determined by a pair of chromosomes, one from the father and one from the mother. The mother's egg always contains an X chromosome, but the father's sperm can contain either another X chromosome or a Y chromosome. These chromosomes are named after their shape. If the result of fertilization is the union of an X and a Y chromosome (XY), the sex of the offspring is normally determined as male; if the resulting union is two X chromosomes (XX), the sex of the offspring is normally determined as female. Determining sex by chromosomes is called genetic sex determination. Recently it has been discovered that the DNA sequence which actually determines sex is located on the short arm of the Y chromosome, and has been named testicular differentiating factor (TDF) (see Figure 1). With this sequence sex is determined as male, without it the embryo develops as female.

Variations in Sex Determination

Not all vertebrates follow the genetic method of determination. In fact, evolutionary biologists believe that early vertebrates were hermaphrodites, i.e. had both male and female sex organs, like most living worms. Separate sexes arose with the evolution of fishes, but was not determined by sex chromosomes. In most fish today sex is apparently determined by environmental factors. In fact many fish can change sex even as adults when certain external factors change. Genetic sex determination apparently arose in terrestrial vertebrates during the Mesozoic Era, about 150 million years ago (Witschi, 1959).

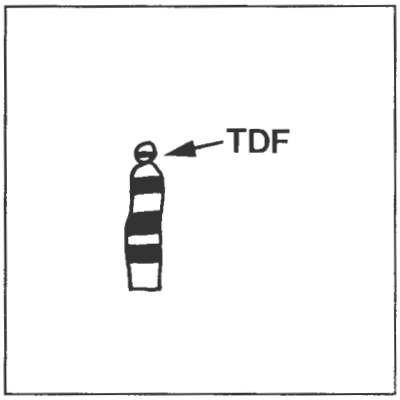

Figure 1 - Diagram of the mammalian Y chromosome. TDF locus is on the short arm.

Until twenty years ago, sex-determination in reptiles was largely unknown. Thanks to the work of George Gorman at the University of

California, Los Angeles (1973, 1981), W. Becak et al (1964) and others, sex chromosomes have now been discovered in many lizards and snakes. This work suggested that sex might be determined in reptiles much as it is in mammals, except that often the sex chromosomes are similar in size and shape. However, Charles Pieau of the University of Paris reported in 1971 that he had found two turtles, the European pond turtle (*Emys orbicularis*) and the Greek tortoise (*Testudo graeca)*, in which the sex of the embryo was determined by the temperature at which the eggs were incubated.

The usual pattern observed in temperature-dependent sex determination (TSD) is that low temperatures produce one sex, high temperatures the other. No genetic effect is evident, but very recently the DNA sequence of the TDF factor in mammals has also been found on reptile chromosomes (Bull, Hillis, and O'Steen, 1988). This may indicate that on the molecular level, sex is determined in the same way, and that only the control of gene expression is different. There is great diversity among reptiles using these two types of sex determination - genetic and temperature-dependent. We will examine each group of reptiles separately.

Genetic Sex Determination

Squamata: Snakes

All snakes examined thus far appear to have genetic sex determination. The sex chromosomes range from appearing nearly identical in boas and pythons to definitely different in the viperids and elapids (see Figure 2). They are called the Z and W chromosomes in snakes as they are in birds. In snakes the female has the ZW or heteromorphic condition while the male has the ZZ or homomorphic condition. This is opposite, you will recall, of the condition found in man and other mammals.

Most books on snakes are arranged in phylogenetic order with the boas and pythons are towards the front. This is because their skeletons are believed to be most like the original, ancestral snakes. The colubrids are placed in the middle, and the elapids and viperids are placed last because they appear to be most recently evolved, from colubrid ancestors. Sex chromosomes show a similar pattern. Most boas and pythons have two similar sex chromosomes. Most colubrids have Z and W chromosomes of equal size but with the center (centromere) in different positions. Viperids and most elapids have Z and W of unequal size. Snakes have 32-44 chromosomes, with 36 being typical. (Man has 46). These are divided into two groups: the large macrochromosomes and the small microchromosomes. The sex chromosomes are macrochromosomes. In all snakes where sex chromosomes have been definitely identified, they are the fourth largest pair of chromosomes.

Squamata: Lizards

Sex chromosomes in lizards differ from snakes in several ways. In all but one family, the chromosomes are homomorphic. Where they are different the heteromorphic sex varies. The terms "X" and "Y" are used for those species with heteromorphic sex chromosomes. The sex chromosomes of lizards are often microchromosomes instead of the macrochromosomes of snakes. All this variation in lizards indicates that sex chromosomes have evolved separately, instead of occuring from a single ancestral type, as in snakes. Sex chromosomes among geckos are known only for two species, with the female being XY. Among iguanids, about one-third of the species examined have distinct sex chromosomes with the male being XY (see Figure 3). Sex chromosomes have not been discovered in agamids, chameleons, or xantusiids. They are known only from a few species of skinks, where the male is XY, and a few lacertids and varanids where the female is XY.

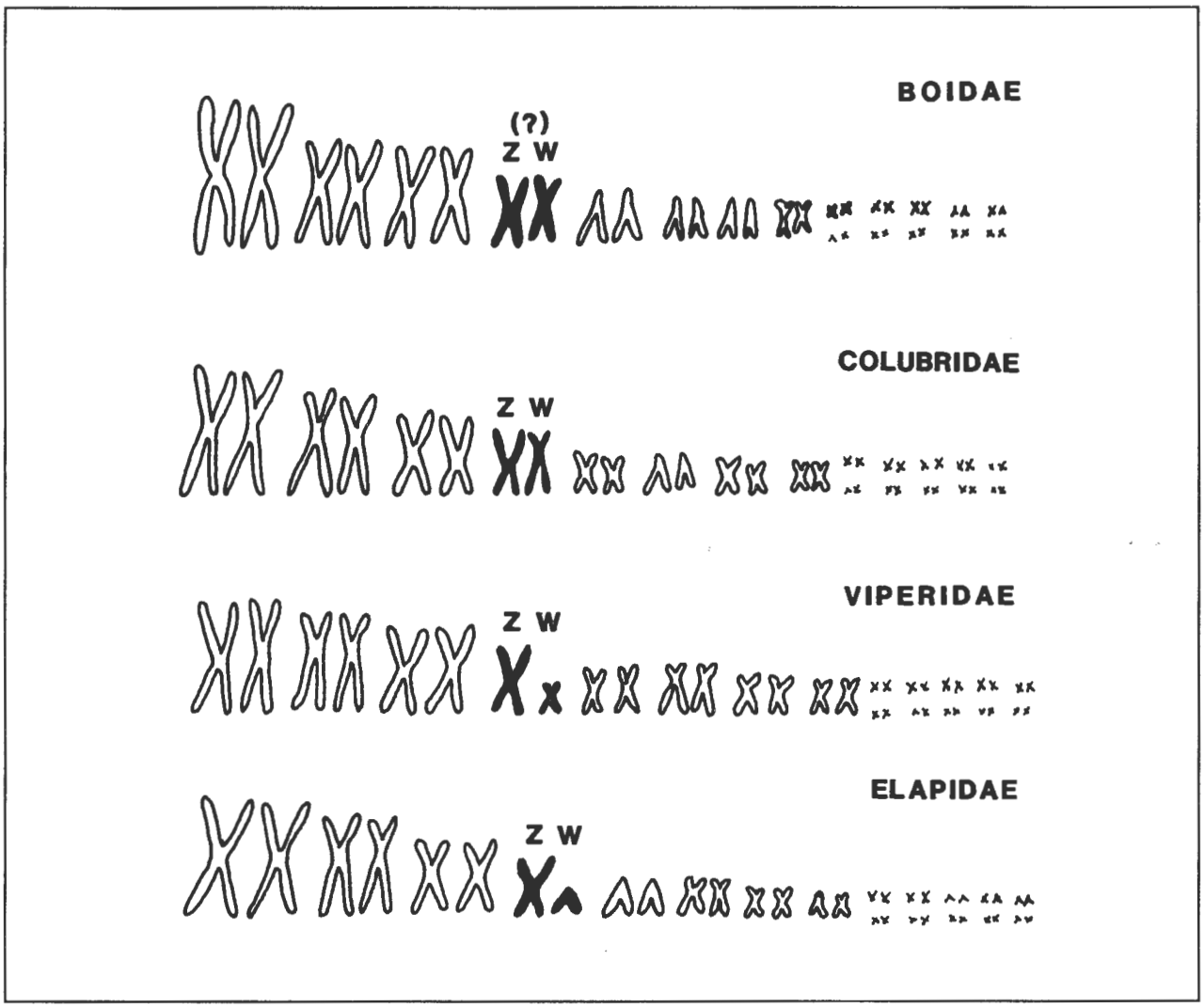

Figure 2 - Generalized representation of the chromosomes of snakes. The top karyotype is generally representative of female boas and pythons. The second karyotype is of common colubrid females. The third karyotype is representative of such viperids as female rattlesnakes. The bottom karyotype is representative of many female elapids. (After Gorman, 1973, 1981).

Chelonia

Sex chromosomes have been discovered in only a few species of turtles, i.e. musk turtles (*Staurotypus*). Most turtles have a large number of chromosomes (see Figure 4) - about 50; half of which are microchromosomes. Evidence is strong that distinct sex chromosomes have not evolved in most turtles.

Crocodilia

The chromosomes of all species of crocodilians have been examined (Cohen and Gans, 1970). Unlike other reptiles, they have no microchromosomes (see Figure 5). No distinct sex chromosomes have been found.

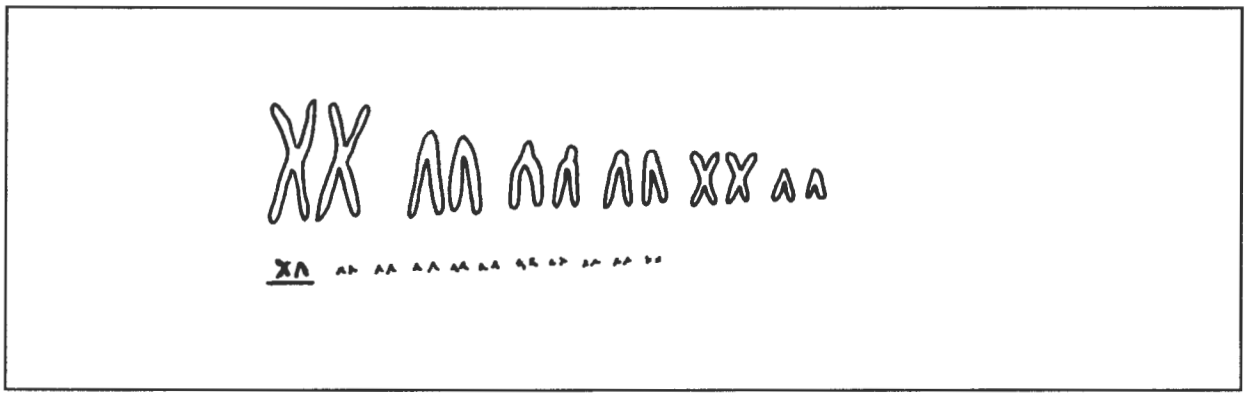

Figure 3 - Karyotype of a male emerald swift (*Sceloporus chrysosticus*). The largest of the microchromosomes are the sex chromosomes. This is common in the Iguanidae. (After Gorman, 1973)

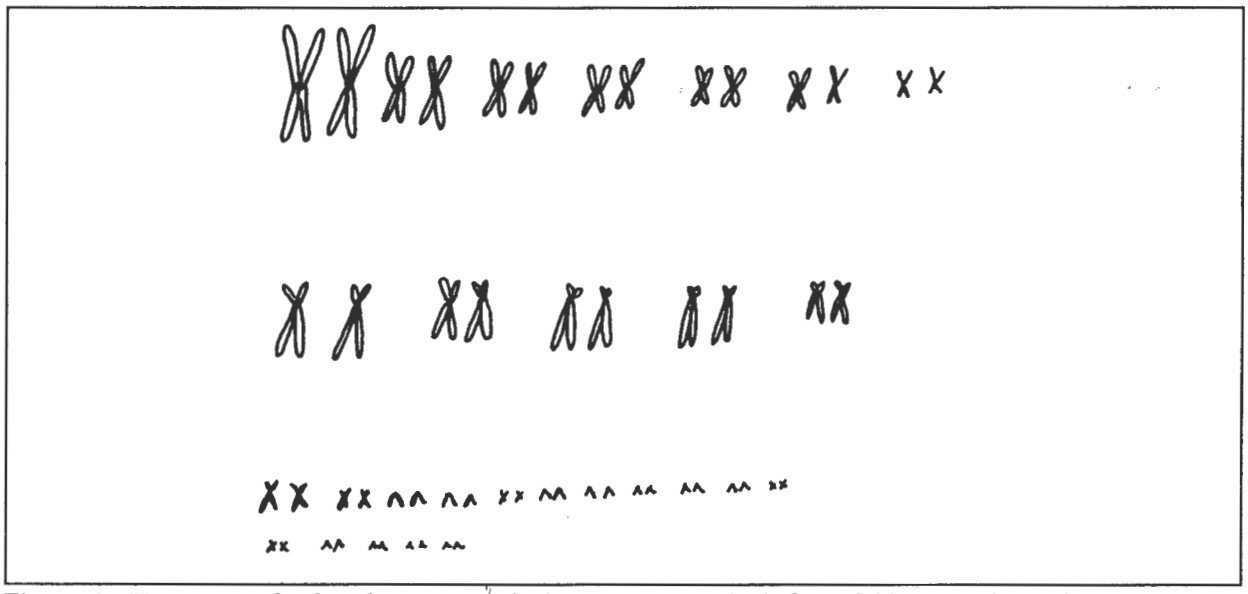

Figure 4 - Karyotype of a female green turtle (*Chelonia mydas*). (After Bickham et al, 1980)

Temperature-dependent Sex Determination

Laboratory studies during the last decade have discovered that in some reptiles the temperature at which the eggs are incubated affects the sex ratio of hatchlings. It has been observed in many turtles, two families of lizards (agamids and geckos), and in crocodilians, but not in snakes. Few species of reptiles other than turtles have actually been studied as yet.

In species with TSD, the shift of the sex ratio is dramatic. Most of the research to date has been with turtles and crocodilians. Two examples from turtles are included (see Figures 6 and 7) (Pieau, 1971; Yntema and Mrosovsky, 1980). Note that the low temperatures (26-28°C) produce males, and 29°C+ produce females. In a few species of turtles it has been found that there is a second female-producing temperature below the male-producing range (see Figure 8) (Gutske and Paukstis, 1984).

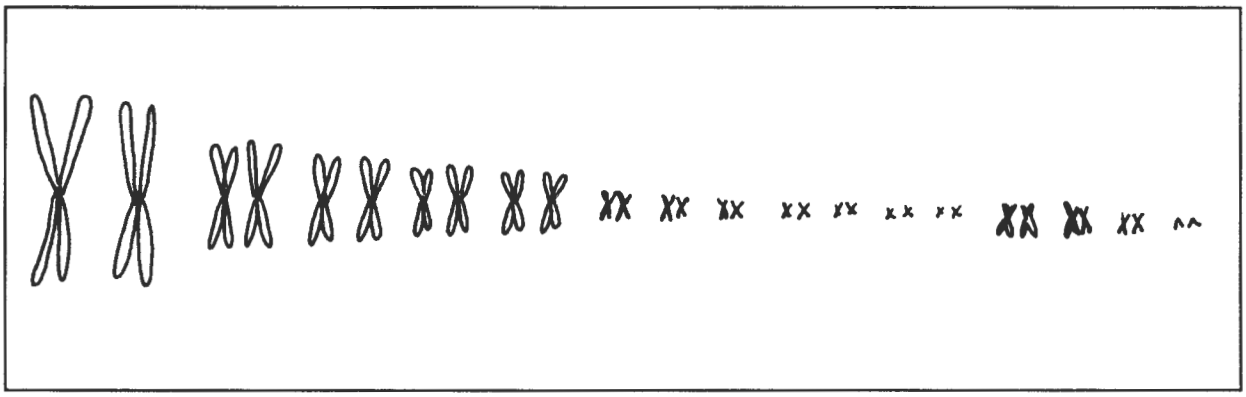

Figure 5 - Karyotype of the American alligator (*Alligator missippiensis*) (After Cohen and Gans, 1970)

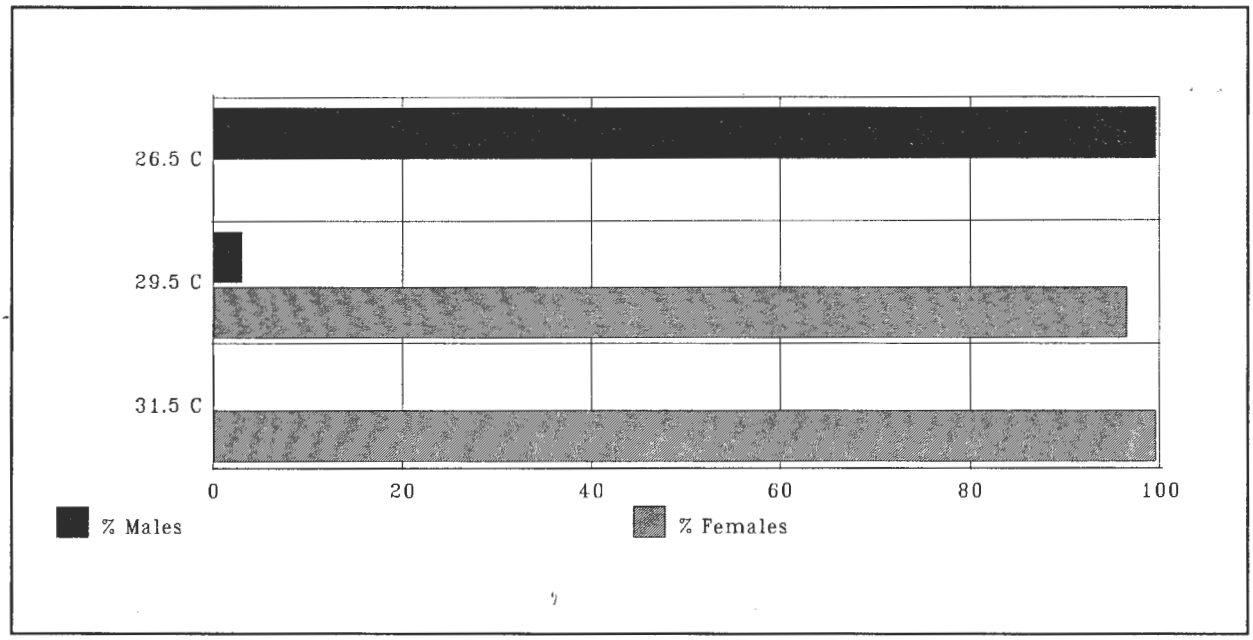

Figure 6 - Effect of incubation temperature on the sex ratio of hatchling Greek tortoises (*Testudo graeca*). (Pieau, 1971)

Work with lizards is still just barely beginning. Charnier (1966) characterized the effect on *Agama agama*, and Ernie Wagner experimented with leopard geckos (*Eublepharis macularius*) (Bull, 1980) (see Figure 9). It should be noted that the effects on lizards are just the opposite of that on turtles - low temperatures produce females, high temperatures males. Herpetoculturists breeding oviparous lizards should keep careful records of their incubation temperatures and the sex ratio of their hatchlings. This information is of great importance scientifically. Nothing is known, for example, about green iguana (*Iguana iguana*) which does not have sex chromosomes. Do other geckos show the same pattern as *Eublepharis macularis*? What goes on with the Australian agamids, such as the bearded dragon (*Pogona barbata*)? No chameleons have been worked with.

Several crocodilian species have been investigated (American alligator (*Alligator mississippiensis*) by Ferguson and Joanen [1983]; estuarine crocodile (*Crocodylus johnstoni*) by Webb and Smith [1984]; Nile crocodile

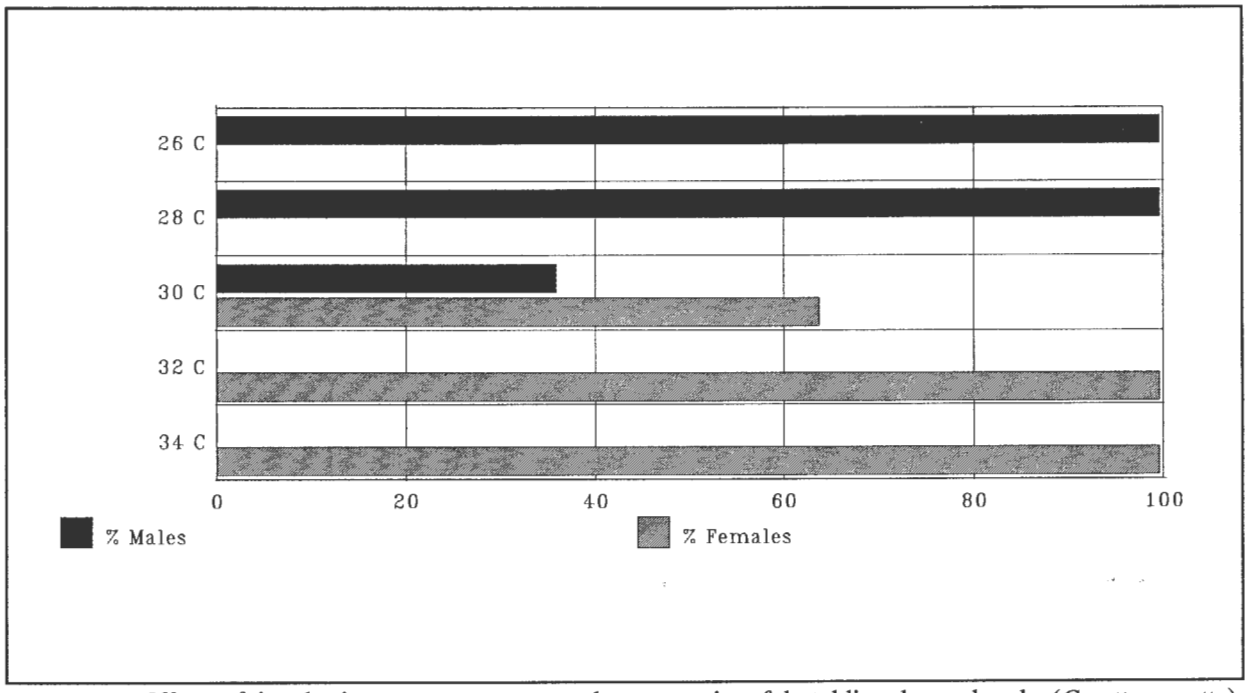

Figure 7 - Effect of incubation temperature on the sex ratio of hatchling loggerheads (*Caretta caretta*). (Yntema and Mrosovsky, 1980)

(*Crocodylus niloticus*) by Hutton [1987]; and salt-water crocodile (*Crocodylus porosus*) by Webb [unpubl]). It is clear that the pattern is the same in crocodilians as it is in known lizards: low temperatures produce females, high temperatures males (see Figures 10 and 11).

The sensitive period during development in which sex is determined has been investigated in several turtle species (snapping turtle (*Chelydra serpentina*) [Yntema, 1979]; Ouachita map turtle (*Graptemys ouachitensis*) and painted turtle (*Chrysemys picta*) [Bull and Vogt, 1981]; loggerhead (*Caretta caretta*) [Yntema and Mrosovsky, 1982]). All the experimental data indicate about a seven day sensitive period during the middle of development. As is well known, incubation time varies inversely with the temperature, but these experiments with turtles having an average incubation time of eight weeks suggests that the sensitive period is in the fourth week. It is the temperature during the stage of development of this period that is sex-determining. In crocodilians, with an average incubation period of 90 days, the temperature sensitive period is during the first third of development, between days 14 and 35, again depending on the overall incubation temperature.

Artificial incubation experiments do not, of course, answer the question of whether temperature determines sex in nature. Experiments have shown that there appears to be no basic difference between incubation under constant or fluctuating temperatures. It is the mean temperature which is the determining factor. Many species make nests so deep that fluctuating temperatures are not a factor anyway. Sea turtles are an example of this. Field studies (Standora and Spotila, 1985; Spotila et al, 1987) have shown that young hatched from nests exposed to full sun were mostly female, while those from nests that were shaded were mostly male (see Figures 12 and 13). A similar effect was shown on the giant South American river turtle (*Podocnemis expansa*) (Alho, 1985) (see Figure 14).

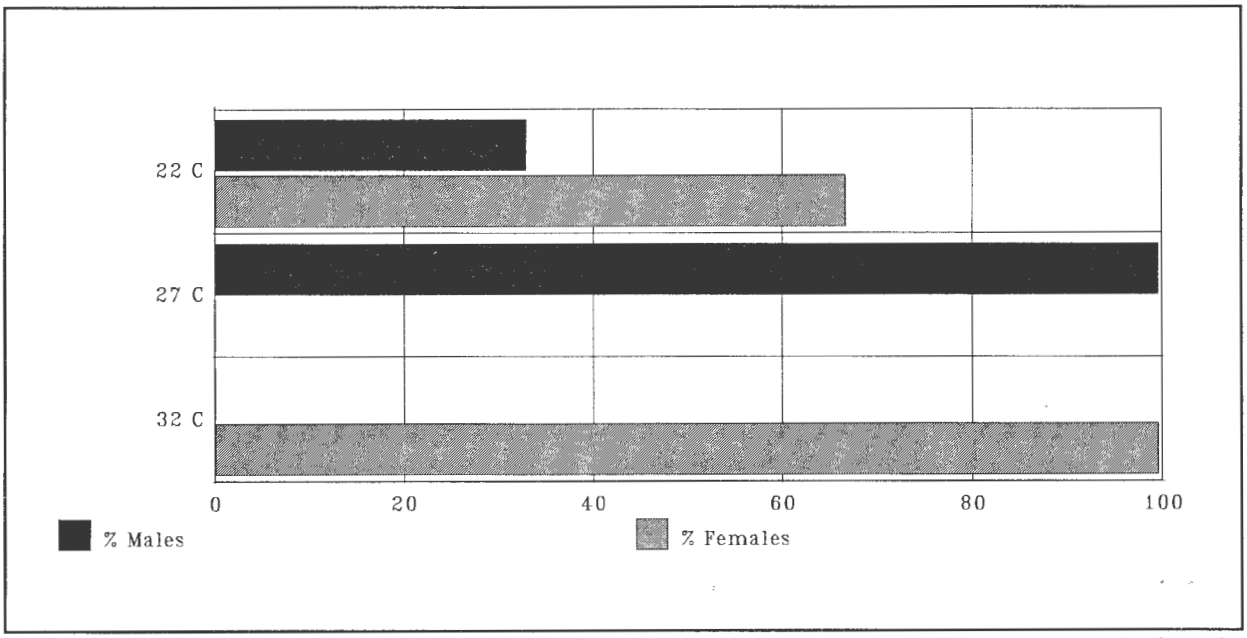

Figure 8 - Influence of temperature on the sex ratio of hatchling painted turtles (*Chrysemys picta*). (Gutske and Paukstis, 1984)

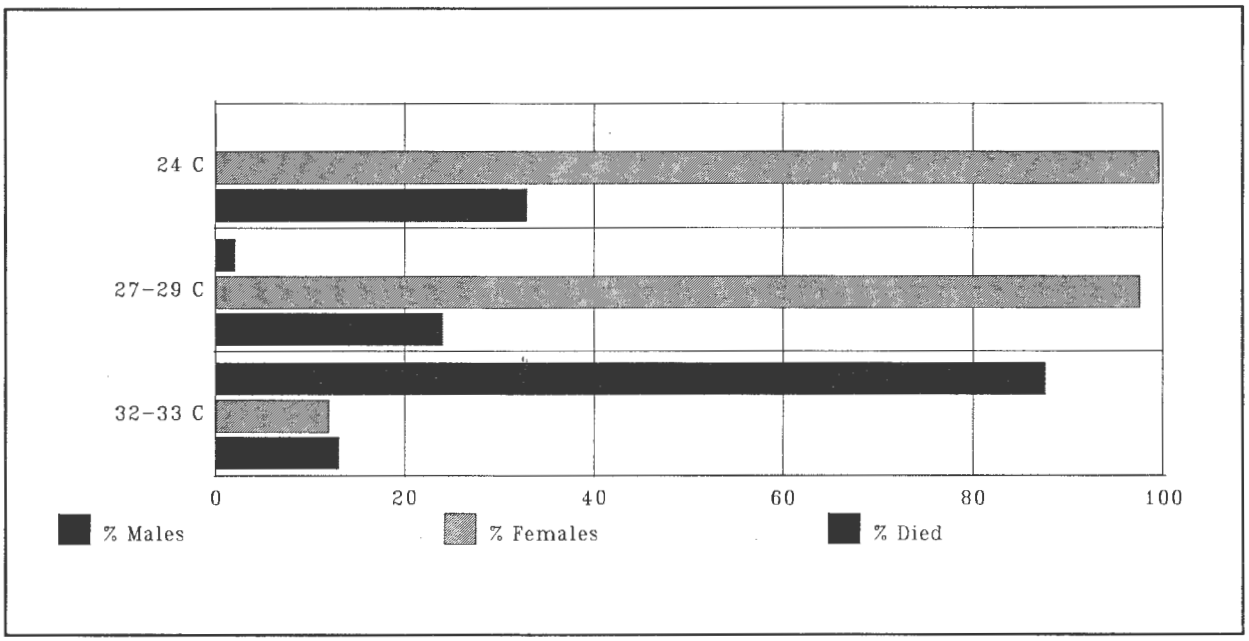

Figure 9 - Effect of incubation temperature on the sex ratio of hatchling leopard geckos (*Eublepharis macularis*). (Wagner, 1980)

In *Alligator mississippiensis* Ferguson and Joanen (1983) found that nests situated on sunny levees hatched all male alligators, nests in wet marshy areas hatched all females, and nests in the intermediate dry marsh hatched both sexes. In Hutton's (1987) study of nests of *Crocodylus niloticus*, he found that the position

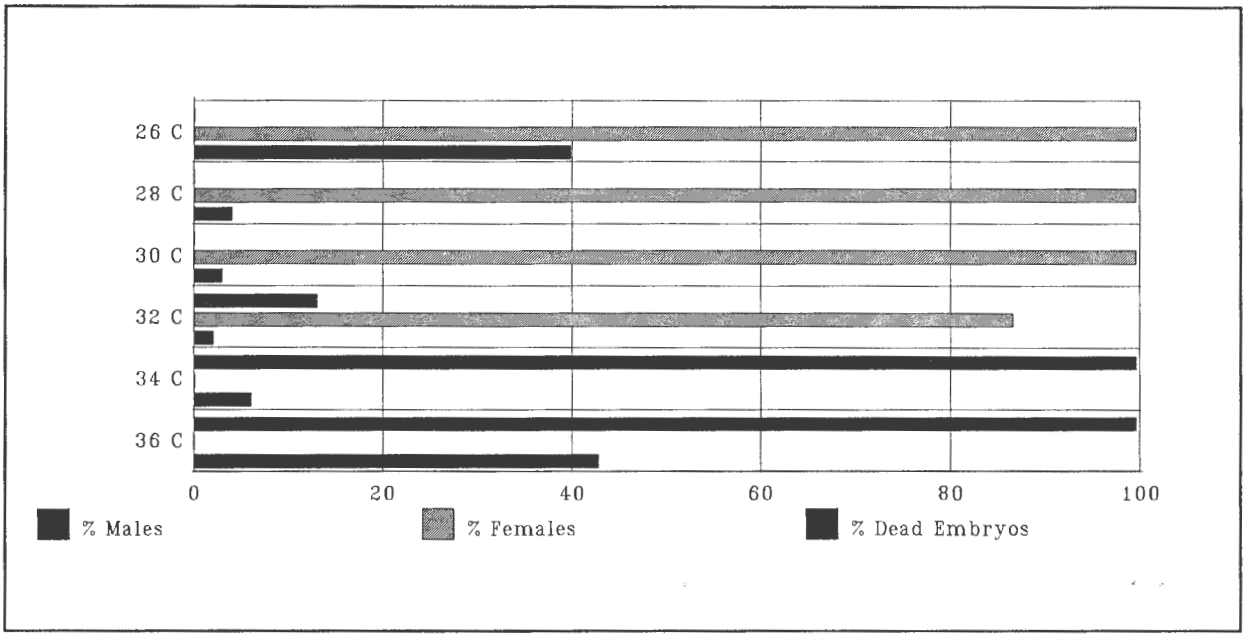

Figure 10 - Effect of incubation temperature on the sex ratio of American alligators (*Alligator mississippiensis*). (Ferguson and Joanen, 1983)

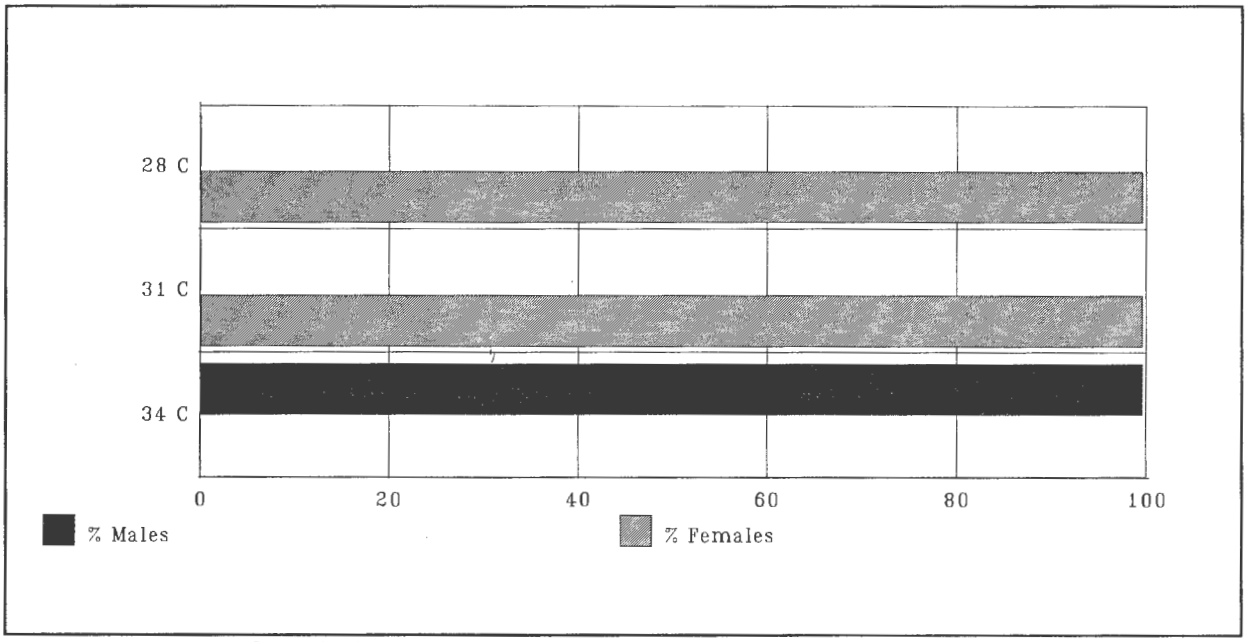

Figure 11 - Effect of incubation temperature on the sex ratio of hatchling Nile crocodiles (*Crocodylus niloticus*). (Hutton, 1987)

of the eggs in the nest was important, with the upper and outer eggs incubating at higher temperatures than the deeper eggs.

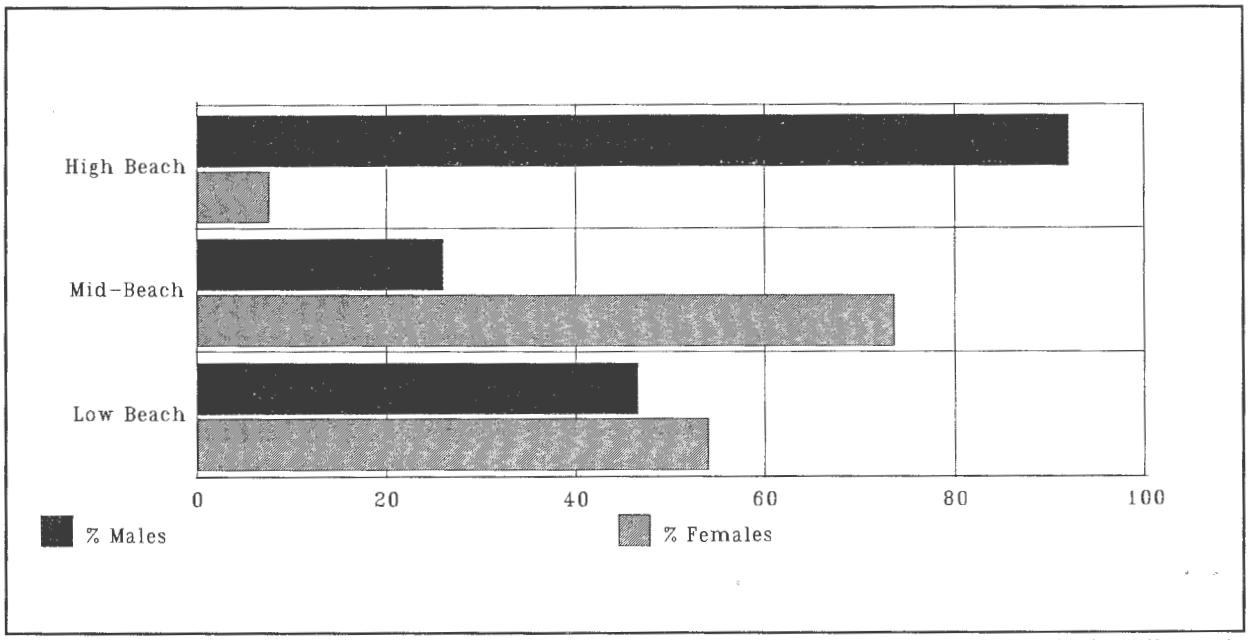

Figure 12 - Influence of nest location on the sex of hatchling green turtles (*Chelonia mydas*). (Spotila et al., 1987)

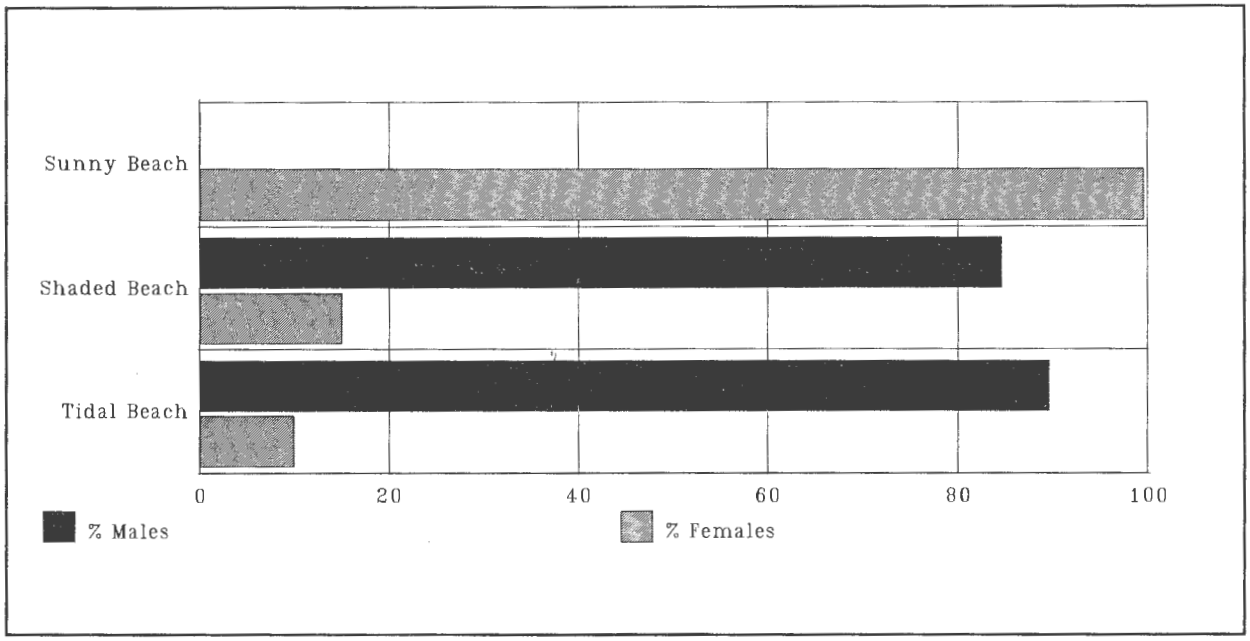

Figure 13 - Influence of nest location on the sex of hatchling Pacific ridleys (*Lepidochelys olivacea*). (Standora and Spotila, 1985)

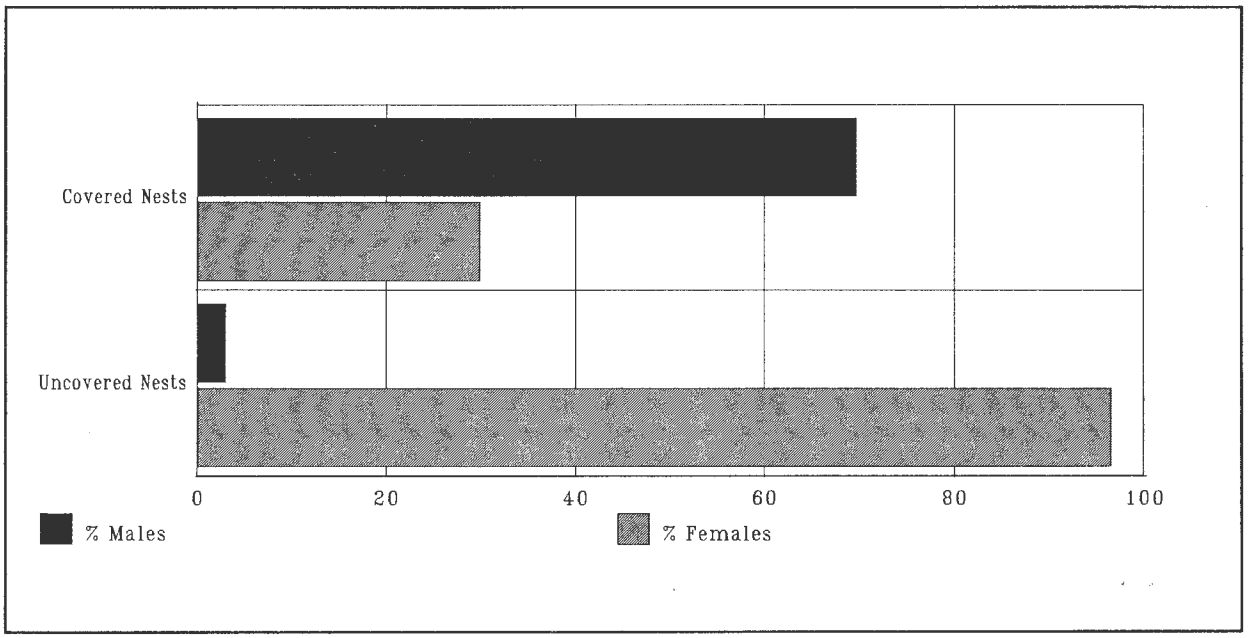

Figure 14 - Effect of nest shading on the sex ratio of hatchling giant South American river turtles (*Podocnemis expansa*). (Alho, 1985) Normal adult sex ratio is 1 ♂:30 ♀♀.

Theoretical Considerations

Selective Advantage of TSD

The question has been raised whether sex determination by nest temperature presents a selective advantage that could account for its wide occurrence among reptiles. Charnov and Bull (1977) proposed the following model in answer to this question. Suppose that cool nest temperatures could produce either robust males or substandard females, with the opposite being true for warm nests. (There is some data for both turtles and alligators suggestive of this.) Certain temperatures therefore enhance male fitness while others enhance female fitness. If the nests are equally distributed between warm and cool sites, the sex ratio will approximate 1:1, but temperature-dependent sex determination will be selected for instead of genetic sex determination which would leave half the offspring in substandard condition.

Another model has been proposed (Bull, 1980) in which environmental changes benefit the species as a whole with TSD allowing a more rapid response to the change in environments. Imagine a flood, hurricane, or other environmental change in which new nesting sites such as islands are created. Because of their lack of shading vegetation, turtle nests there will produce predominantly females. A significant rise in the female population will eventually result in quicker growth of the population as a whole than if only half of the turtles were female. This would benefit the species by enabling it to take advantage of environmental change. Eventual return of the environment to a near-climax stage would return the sex ratio to equilibrium. The longevity of many reptiles, especially turtles and crocodilians, is upwards of 30 years, and their reproductive life is often three-quarters of this. Therefore, extremes in sex ratio of hatchlings would only have a temporary effect on the population. In some reptile populations studied, e.g. alligators and crocodiles, the sex ratio appears to be permanently female biased. This may result from the known behavior of females to make nests in the same sites at which they were born. Since only females lay eggs, this would lead to a run-away production of daughters. The TDS of *Alligator mississippiensis* may well be the intrinsic factor which allowed the species to make the

remarkable recovery from the verge of extinction to open hunting season on them in just 15 years, once it was protected.

Origins and Comparative Sex Determination

It is generally believed that amphibians represent the group from which the ancestral reptiles arose. In the species of modern amphibians studied so far, sex determination is genetic, but only weakly so, and sex chromosomes are not usually seen (White, 1973). In most species studied, high temperatures (25-30°C) produce an excess of males, and low temperatures (5-10°C) produce an excess of females (Houillon and Dournon, 1978). In some species, sex reversal occurs as a result of temperature. In the wood frog (*Rana sylvatica*) a dramatic change in water temperature after the tadpole starts normal sexual development causes the gonads (testes or ovaries) to reverse developmental direction in half the tadpoles (Witschi, 1929). In the short- ribbed salamander (*Pleurodeles waltl*), an adult female kept at high temperatures was converted into a male (Houillon and Dournon, 1978). Modern amphibians, therefore, show both genetic and temperature-dependent sex determination, and this may well have been the pattern of early reptiles.

Conclusion

Among reptiles, the sex chromosomes in lizards, snakes, and turtles appear to have evolved separately after these groups were established. Sex determination in early reptiles was probably chiefly environmental. Subsequent evolution of genetic sexdetermination was followed by the appearance of definitive sex chromosomes.

Mammals and birds both evolved from reptiles; mammals from an early form of reptile, birds from some smaller dinosaurs. Both these classes are characterized by highly uniform sex chromosome systems. Since both of these classes thermoregulate the development of their young, genetic sex determination probably evolved early in the history of both birds and mammals.

These days everyone has a theory for the extinction of the dinosaurs. Crocodilians are perhaps the closest living relatives of the dinosaurs. Thus TSD probably occurred in dinosaurs and should have had a profound influence on their life history strategy. Since dinosaur nests are known only from open, upland areas (Horner, 1988), we can infer that as the climate cooled at the end of the Cretaceous, nests would have been exposed to these cooler temperatures. A shift of 4°C incubation temperature would dramatically alter the sex ratio and consequently the population's breeding structure in one generation. A shift of even 2°C would have important effects in only a few generations (Standora and Spotila, 1985). Turtles and crocodilians survived because they nested near water with its moderating effects on temperature. Dinosaurs at the end of the Cretaceous may well have been producing generations of unisexual offspring that were the last of their species. In a system of sex determination like TSD, where environmental variability is the primary guarantee of a mixed sex ratio, fixation on a particular nesting site could lead to extinction.

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Washing Away the Tap Water Myth

Dorothy M. DeLisle
P.O. Box 1131
Lakeside, CA 92040

Introduction

Water, also known as dihydrogen oxide or H_2O, is undoubtably the most important chemical on earth. Water comprises about 5% of the earth's total mass. Water strongly influenced and continues to influence the evolution of life on earth. Water usually comprises 60-95% of the mass of living organisms. Water, take it away, and organisms desiccate and die. Water is life on earth.

Water covers 80% of the earth's surface. Some of it as extensive saline oceans and the remainder as fresh water overlaying much of the land masses. Water takes on many guises as it covers the land including lakes, ponds, bogs, cienegas, rivers, and streams. It represents a variety of environments, each home to many species of organisms.

Practicality limits the size of aquaria. These artificial systems are incomplete microcosms, lacking the self-cleaning properties of natural systems. As a result, the toxins produced by the inhabitants of the aquaria can reach lethal concentrations. Proper husbandry demands that water be regularly removed - either partially or fully - and replaced with clean water.

Structure of Water

A solution of pure water does not contain only molecules with the formula H_2O. In the H_2O molecule, both hydrogen atoms (H) attach to the same side of the central oxygen atom (O) such that the angle between them is 105° not 180°. The asymmetry of this arrangement makes the H_2O molecule slightly negatively charged on the oxygen end and slightly positively charged on the hydrogen end. This causes the positive and negative ends of different H_2O molecules to be attracted to each other like two magnets. This attraction, known as hydrogen bonding, is so strong that there is a tendency for a hydrogen atom to jump from one molecule to another. In other words, two H_2O molecules will rearrange to form one hydroxide ion (OH^-) and one hydronium ion (H_3O+, often abbreviated $H+$). Each hydronium ion has a tendency to hydrogen bond with three H_2O molecules forming hydrated hydronium ion (H_9O_4+). Thus, pure water is an unstable mixture of four molecules constantly converting from one form into another. However, at any one time the H_2O molecule is by far the most prevalent form, outnumbering any of the three others combined by a factor of about 550 million to 1.

The herpetoculturist may occasionally have access to his own private well or spring water, but usually he relies on tap water from the municipal water supply. Whatever the source, the water he fills his aquaria with is not pure water. Much of what one is taught about the properties of water applies only to pure water. The herpetoculturist tends to think of tap water as being an entity, invariant in composition. This is a myth that must be washed away. Tap water may contain hundreds of contaminants whose concentrations vary not only among different municipalities, but also within the same municipality over time (see Figure 1).

	AI	AE	MI	ME	LOI	LOE	SDR	MuR	MiR
Calcium	69.6	68.0	65.6	71.2	35.2	36.8	50.4	64.0	63.2
Magnesium	22.6	22.6	24.5	25.0	17.8	17.8	19.2	23.5	23.5
Sodium	71.9	72.0	72.1	71.9	57.5	64.2	67.2	70.1	75.4
Potassium	6.09	6.14	6.08	6.18	5.99	5.99	5.83	6.07	6.28
Iron	0.12	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.17
Manganese	0.05	0.01	0.01	0.01	0.40	0.01	0.01	0.01	0.01
Copper	0.01	0.02	0.08	0.01	0.01	0.01	0.01	0.01	0.01
Zinc	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Sulfate	209.0	185.0	217.0	190.0	38.6	51.4	115.0	169.0	178.0
Phosphate	0.07	0.11	0.19	0.19	0.20	0.21	0.08	0.17	0.11
Silica	5.76	9.49	9.64	9.04	18.20	19.50	14.30	7.61	7.65
pH (pH units)	8.1	8.2	8.0	8.2	8.4	8.4	8.1	8.8	8.3
Total Alkalinity (to pH 4.5)	126	122	124	123	142	137	134	124	122
Total Hardness (as $CaCO_3$)	268	264	166	282	162	166	206	258	256
Ca Hardness (as $CaCO_3$)	174	170	164	178	88	92	126	160	158
Chloride	67.0	74.1	60.0	66.7	79.4	86.2	78.7	87.2	70.9
Conductivity (at lab temp)	610	615	605	610	475	495	550	630	620
Bicarbonate	153.7	148.8	151.3	150.1	165.9	159.8	163.5	131.8	148.8
Turbidity	2.20	0.26	2.30	0.21	2.70	0.16	0.21	2.60	0.47
Color (Color Units)	8	2	8	2	22	3	2	9	5
Temperature (°C)	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.0	22.5
Fluoride	0.24	0.27	0.20	0.18	0.20	0.26	0.25	0.18	0.18
Nitrate	1.73	2.48	1.05	1.15	0.45	3.09	2.12	0.46	14.7

Figure 1 - Analysis of contaminants of six reservoirs within the city of San Diego, California municipal water district during April 1986. Notice the variation among reservoirs and the variation between influent and effluent of the same reservoir. This is only a small sample of the contaminants measured. All measurements mg/l unless otherwise specified. (AI - Alvarado Influent, AE - Alvarado Effluent, MI - Miramar Influent, ME - Miramar Effluent, LOI - Lower Otay Influent, LOE - Lower Otay Effluent, SDR - South San Diego Reservoir, MuR - Murray Reservoir, MiR - Miramar Reservoir).

Because tap water is thought of as an entity, differences in tap water quality are often overlooked as a possible cause of differential success in aquaculture. Yet, it is frequently the source of many problems. Just when he thought he was making progress in solving the herpetoculture of a particular species, a change in tap water quality causes a setback, and the herpetoculturist is completely bewildered as to why his perfected system no longer works. Only when we realize the importance of our water source, will we be able to make significant and continued advances in aquatic herpetoculture.

Water Variations

Anyone who pauses and thinks a while will realize that he has observed both geographical and temporal variation in tap water quality. Anyone who has sampled water from different municipalities has noticed differences in the taste. Pure water has no taste; the impurities that impart its taste.

It is also possible to directly visualize differences in water quality. Pure water is colorless. Depending on the impurities and their concentrations, tap water may be lightly or heavily tinted almost any color. A vessel from which tap water has been evaporated often has a crust of contaminants which were previously invisible while dissolved in the tap water. Particulate contamination is often present and can be seen at the bottom of a glass of tap water that has been allowed to settle. Freshly drawn tap water can be initially cloudy, clearing as the excess gas purges into the atmosphere.

In order to understand the variability of tap water, one must first understand its source. For the purpose of this paper, tap water is defined as water drawn off a municipal water supply. That water supply can be either surface water, such as a lake or reservoir, or underground water, such as a spring or more commonly a well tapping into the ground water.

The composition of both surface and ground water is significantly influenced by the geology of the water basin. Minerals and other compounds leach out of the surrounding stone into the water. Areas with different types of rocks will have different minerals leach into the water. The biota of the water basin is also important for it determines what organic compounds are available to be leached into the water.

Pollution is another regional variable. Different areas have different industries which generate different wastes. These wastes can be dumped directly into surface water or onto land where they flow overland, sometimes entering surface waters. Some are absorbed into the ground and percolate down into the water table. Other pollutants are pumped into the air and may fall out into surface and ground waters often hundreds of miles away from the pollution source.

The individual municipality also causes regional variation in water composition when they add fluoride, chlorine, or chloramine to their water supply in varying concentrations.

Water Sources

It should be kept in mind that a municipality often has more than one well or reservoir. The municipality will often draw off of only one supply at a time and can switch from one supply to another at any time. The different supplies are unlikely to have identical water quality. Indeed, the reasons for the switches often have to do with differences in the qualities.

Most drinking water supplies are clearly marked with signs prohibiting swimming and other human activities that might affect the water quality. However, humans are the only animals prohibited from using these facilities. Fish, reptiles, amphibians, water fowl, invertebrates, protozoa and bacteria all inhabit reservoirs along

with algae and other plant life. Rather than being a sterile environment, reservoirs are living ecosystems with a pipe attached.

As an ecosystem, a reservoir is in a state of constant flux. The different organisms progress through their life cycles each on its own time schedule. As the different species proliferate or decline or change from one life stage into another, the chemical processes they control change. Thus, the ever shifting web of life causes an ever changing chemical environment within the reservoir. Not only does the chemistry of the reservoir change as the seasons progress, but there is also a 24 hour cyclic effect. At night,it is cooler and metabolic rates are lower. At night, there is only respiration (conversion of oxygen to carbon dioxide) and no photosynthesis (conversion of carbon dioxide to oxygen). During daylight, both processes take place. Therefore, the gas composition of the water will vary over the course of a day. At different times of day or night, different organisms are found in different parts of the reservoir. This causes certain chemical reactions to be localized to different parts of the reservoir at different times of the day. Many other biological processes follow 24 hour cycles.

Even if there were no life forms in reservoirs, the chemical compositions would still be in dynamic flux. As the temperature of the water changes, the solubilities of the gases in the water change. Temperature also effects the solubilities of other compounds; dissolved substances will fall out of solution as the temperature decreases. Temperature also changes the rates of chemical reactions.

Wind causes waves which increases the diffusion rates of gases. On a windy day, the water may even become supersaturated. Supersaturated water can cause gas bubble disease - similar to the bends - which can kill amphibians (Orwicz, 1985). Very strong winds can stir up sediment, introducing a lot of particulate matter and debris into the water column.

Evaporation causes a concentration of contaminants, whereas rain has the opposite effect. Like wind, rain churns the water, changing the gas composition and stirring up sediment. Rain increases fallout of atmospheric contaminants. Not all rain falls directly on the reservoir; much of it runs across the earth's surface before draining into the reservoir. As it flows overland, the rainwater picks up lots of contaminants and washes them into the reservoir. Thus, every time it rains, there is a major change in water composition.

Because it is protected from the effects of wind, light and changing temperature underground or well water tends to be a lot more stable in composition than surface or reservoir water. Well water has a very limited biota which tends to be stable in the subterranean environment. However, well water is still effected by rain which percolates through the ground to the water table, carrying with it contaminants. There is horizontal groundwater flow which is increased by rain. This carries contaminants from one geographic area to another. Thus, other than having less organisms, well water is no purer than surface water.

The quality of the municipal water supply is constantly monitored. As the composition of the water supply varies naturally, the municipal workers vary the chemicals they add to it to keep it within acceptable standards.

In between the water supply and the herpetoculturist's faucet are pipes. During its journey through the pipes, the composition of the water can change. The water can leach metals from the pipes, especially from older pipes. Hot water will leach more contaminants since increasing the temperature will increase a compounds solubility. Therefore, always draw from the cold water tap for your aquaria. The outside of your faucet can also be a source of contaminants like soap. If possible, dedicate a faucet to herpetoculture.

Aging Tap Water

A common practice is to draw tap water into the tub and let it stand open to the air for a period of time before adding it to the aquaria. If water is aged for a few hours, supersaturated gases will reach equilibrium with the air, preventing gas bubble disease. If water is aged for two days, free chlorine, but not chloramine, will volatilize into the air. Beyond this, there is little benefit to aging tap water since few other contaminants dissipate in such a relatively short time.

Aging water in the presence of certain plants such as water hyacinth will remove more contaminants. Many plants will remove contaminants from the water, but only by testing plant purified water on your species can you determine if the water has been sufficiently detoxified.

Conclusion

Tap water is a highly variable mixture of hundreds of chemicals. Many of these compounds are toxic to aquatic amphibians and reptiles. Often the water used can be the sole problem with culturing a species. While it is wise to monitor tap water quality, it is nearly impossible and very impractical to monitor for every contaminant. For the serious herpetoculturist, the wisest course of action is to install a home water purification system which has been carefully chosen to fulfill the needs of the individual situation.

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