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Husbandry and Captive Breeding of the Parrot-Beaked Tortoise, *Homopus areolatus*

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The range of the parrot-beaked tortoise, *Homopus areolatus*, is restricted to the Cape Province in South Africa (Loveridge and Williams, 1957; Branch, 1989). It follows the coastline of the Indian Ocean from East London in the east, around the Cape of Good Hope along the Atlantic Ocean, north to about Clanwilliam. This range is bordered in the northeast by the very arid Great Karoo, an area receiving less than 250 mm of rain annually, and in the north by the Roggeveld Mountains. There are some moist corridors, particularly in the northeastern areas, which *H. areolatus* follows further inland. Within this range are four different biomes, including fringe deciduous forest, grassland, grassy areas known as fynbos, and semi-arid areas locally known as Karoo. All of these areas contain rocky, sandy soil. Annual rainfall can vary from 300-2500 mm, occurring mostly throughout the winter months.

In the summer, daytime temperatures throughout this Mediterranean type climate range from 28-43°C and nighttime cooling of at least 8-12°C creates a morning dew. The summer daytime humidity ranges between 12-25 percent. Populations living near the coast receive onshore misty breezes, yet the days are sunny, dry, and hot as well. During the winter months in the western Cape Province the daytime temperatures drop to a low of 1°C causing *H. areolatus* to become completely inactive (E. Baard, *pers. comm.*). These cold stretches are frequently broken up by brief periods of sunny, warm (up to 25°C) dry days when tortoise activity resumes.

Since the natural range of *H. areolatus* includes several different microclimates and biomes it was hypothesized that this species possessed levels of adaptability necessary to survive and breed in captivity. On the other hand, it is possible that some separate populations are narrowly adapted to different conditions and would not acclimate in other areas (including captivity). Congeneric species such as *H. femoralis*, *H. signatus*, and *H. boulengeri* appear to be highly specialized and ecologically very restricted (Boycott and Bourquin, 1988), leading to specific diet and ecosystem requirements not easily provided in captivity.

Moderately high mortality rates have been experienced by various zoos for imported *H. areolatus*, with very high mortality rates for *H. signatus*. However, there is an account of an individual *H. areolatus* surviving in captivity for 28 years (Branch, 1988). Quite possibly, the high mortalities experienced in *H. areolatus* to date have been the result of the inability of the tortoises to recover from the stress, dehydration, and thermal exposure of improper or protracted warehousing on either or both sides of the Atlantic, exacerbated by slow or indirect shipping. These situations may also have provided a dramatic stress-related increase in parasite or bacterial loads, or rendered pathogens more virulent, thereby adversely affecting the health and immunity levels of the tortoises. With this in mind, 6 field-collected tortoises (3 males, 3 females) used in this project were airfreighted directly from South Africa to fully operational indoor captive facilities in the USA. A number of surplus captive specimens (7) were also available, and these were included in the study group.

Materials and Methods. – Two habitat enclosures measuring 7 x 2 feet (2.1 x 0.6 m) were constructed of plywood and each housed two males and either four or five females. These were enclosed on all sides, save for the front, which had sliding glass doors. Each of the habitats contained a fluorescent array including a 48 inch (120 cm) Vita Lite - blacklight combination, in conjunction with one 75 watt spotlight placed at one end. The 120 cm fluorescent array was placed off-center approximately 35 cm above the strata toward the end with the spotlight. This created an area on the opposite end which was darker and cooler, allowing for behavioral thermoregulation. The mid-day high temperature in the habitat was 35°C under the spotlights. This is very close to the preferred maximum temperature of *H. areolatus* of 34.8°C (Perrin and Campbell, 1981). The cooler end mid-day temperatures reached 29.5°C. As *H. areolatus* is subjected to a nightly cooling in the wild, this was provided in captivity. Nighttime temperatures, with all lights off, dropped to about 19°C. The spotlights dried out the air in the habitat during the day and in order to re-establish humidity levels, the habitats were misted during the night or in the morning, just prior to feeding. The fluorescent array and spots were on independent timer systems such that the spotlights lit up one hour after the fluorescents. In the evening this was reversed; one timer turned off the spots and an hour later a second timer switched off the fluorescents. This allowed for changes in light and temperatures throughout each day. This process was manipulated throughout the year as seasonal photoperiods and temperatures were changed.

To create an artificial winter, the spotlights were turned off entirely and the photoperiod provided exclusively by the fluorescents was gradually reduced to ten hours, lowering the average daytime temperature to 22°C. During this period, the frequency and amount of misting continued as above. Food was offered, but rarely taken, and general activity levels were greatly reduced.

Branches and terraced levels of strata incorporated into the indoor captive habitat broke up the line of sight, mimicked natural conditions, and provided extensive cover. This allowed the tortoises to remain secluded if preferred. Shredded aspen or cypress wood was used for substrate. Used generously, there were areas where the bedding was 10 cm deep. This allowed the tortoises to bury after a substantial feeding or to avoid other individuals. Females nested in the substrate, foregoing the need to deal with nesting boxes. As the bedding packed down rather firmly, it provided excellent footing for the tortoises to a point where an overturned specimen could right itself. This was clearly more favorable than using alfalfa or rabbit pellets which do not compact with use.

Utilizing *in situ* observations in order to deduce diet composition led to the provision of a high fiber, low sugar, high bulk diet. During the summer, vetch, sedum, dandelion, nasturtium, clover, mulberry leaves, and some grasses were available and were provided as frequently as possible. The rest of the year commercially available produce was offered. Adhering to the characteristics of the natural diet required a very high percentage of greens. Fruits, citrus items, sweet potatoes, or other high sugar, high protein foods were not offered. Highfield (1990) has suggested that high sugar diets have caused increased parasite levels in tortoises. The diet also included dandelion, escarole, endive, carrot tops, turnip greens, collard greens, rapini, broccoli, string beans, opuntia, hibiscus, sedum, and occasional zucchini and yellow squash. The opuntia and hibiscus were grown indoors in pots and harvested when needed.

Since drinking water was not available in the habitats, the tortoises were placed, two or three at a time, in a basin once a month. Water was continuously provided by keeping the faucets open. The drains were kept open as well, flushing all expelled material. Despite this effort the tortoises were reluctant to drink. To ensure adequate hydration, their food was misted as it was placed inside the enclosure. This along with the relatively high water content of their food items appeared to satisfy their hydration requirements.

There are many reports of South African tortoises eating hyena dung, slugs, snails, and small insects (Branch, 1988; Bates, 1988). Therefore, the captive diet was supplemented with vitamins and calcium. Because it is uncertain which combinations of amino acids, proteins, trace elements, minerals and vitamins were required for optimal fecundity, two vitamin supplements were used: Nekton Rep and Reptavite. The vitamins were used in conjunction with Rep-Cal, a phosphorus-free calcium additive with a D3 supplement. This regimen was used twice a month. The Rep-Cal was added because the entire group of tortoises was always kept indoors and not exposed to any direct sunlight.

Figure 1. A 13-month old *Homopus areolatus* hatched in captivity, body weight 22 g, carapace length 44 mm.

Eggs produced in the captive breeding program were incubated on moistened vermiculite at temperatures of 79-81°F (26.1-27.2°C). Resultant hatchlings and juveniles were housed in 36 inch (90 cm) Neodesha fiberglass enclosures containing one 75 watt spotlight. The substrate was the same as for the adults. Broken clay flower pots placed throughout the habitats provided hiding places and as hatchling *H. areolatus* appear to be very cryptozoic, the hiding places were frequently occupied.

Hatchlings were offered the same food items as the adults in a more finely chopped form. They were fed at least once a day, occasionally twice a day. Small uneaten bits of greens were occasionally left in the enclosures and were periodically eaten as they dried. Clover and alfalfa sprouts were offered almost daily, but as the tortoises grew these were phased out. Hatchling and young *H. areolatus* do not

Table 1. Reproductive data for captive *Homopus areolatus* with successful hatching.

Date of Laying	Date of Hatching	Incubation Period (days)	Weight of Hatchling (g)	Clutch Size	Fertility of Clutch (%)
—[1]	18 Feb 92	—[1]	6	3	66[2]
9 Aug 92	13 Jan 93	155	6	1	100
26 Aug 92	13 Jan 93	140	4[3]	3	66[2]
8 Sep 92	10 Feb 93	155	6	2	100
8 Sep 92	15 Feb 93	160	6	2	100
26 Sep 92	18 Mar 93	187	6	2	50
25 Nov 92	27 Feb 93	94	8	2	100
25 Nov 92	12 Mar 93	108	8	2	100
27 Nov 92	20 Mar 93	113	4[4]	2	50

[1] Actual nesting not observed. [2] Includes one dead embryo in egg. [3] Hatchling died at age 118 days.
[4] Hatchling died at age 123 days.

have the voracious appetites of similarly aged *Malacochersus tornieri* and *Chersina angulata* (pers. obs.).

The hatchlings were soaked at least three times a week. Every other soaking was in an electrolyte solution (Ornalyte, Mardel Labs). The hatchlings typically drank at each soaking, however, drinking became reduced beginning at about six months of age.

Results. – Male combat, mating attempts, and copulation occurred routinely throughout the eight month period when summer type temperatures and photoperiods were maintained (June-January). During this time the prefrontal scales on the heads of male *H. areolatus* became a deep bright orange red and remained that way for several weeks. Branch (1988) mentions this occurring in the wild as well. The color displays appeared and disappeared gradually making it impossible to record the frequency, duration, and timing with any accuracy. There were occasions when some females appeared to exhibit this to a lesser extent as well. Similar color changes (sexual dichromatism) have been reported in two Asian species, the elongated tortoise, *Indotestudo elongata* (Biswas et al., 1978), and the river terrapin, *Batagur baska* (Moll, 1978).

Combat among males and aggressiveness towards females was often extremely harsh. Bites inflicted on both other males and females from the powerful beaks have in the most severe cases resulted in bleeding wounds on the limbs. Facing each other, males would bite and hold on to the anterior edges of each other's carapace and engage in a pushing match. This could go on for as long as an hour, but usually less. Once one male retreated, the victor normally pursued and continued biting the hind legs or shell of the retreating male. Providing cover and hiding places in the captive enclosure helped the subordinate male to escape without being further pursued or injured. There were no observations of female dominance or hierarchy.

Each enclosure contained one large adult male (140-195 g) and one immature male. In this scenario, dominance was quickly established, eliminating aggressive combat. Large adult males were rotated between habitats, and almost immediately thereafter mating events increased. Occasionally two males of similar size were put into the same habitat, and combat almost always took place. However, this was supervised and if retreat did not occur, one male was removed in order to avoid injury. Mating activities increased after these incidents of male-male combat. During the artificial winter (February-May), with general activity almost nonexistent, events of sexual behavior were not observed.

Egg laying was preceded by repetitive pacing of the female in the afternoons beginning about a week prior to nesting. Occasional test or false nestings occurred. Site selection did not seem to be based on any specific characteristics. Females often selected different sites for successive nestings.

Egg production was well within Boycott and Bourquin's (1988) observations of wild specimens in terms of egg size (only rough measurements were obtained). However, the clutch size from the captive group appeared to be smaller than normal. During this study, 42% of the clutches contained only one egg, 42% contained two eggs and 16% contained three eggs. Boycott and Bourquin (1988) stated that clutch size is 2-3 eggs and occasionally 4-5, but made no mention of single egg clutches. These authors expressed uncertainty about multiple clutching occurring in the wild. One female in the indoor captive group produced multiple clutches. She laid two eggs, followed 31 days later by another two eggs, with one egg from each clutch hatching. Another female laid two infertile eggs, with the second laid five days after the first. Ninety-two percent of all oviposition occurred at least five months after females were introduced into this captive situation.

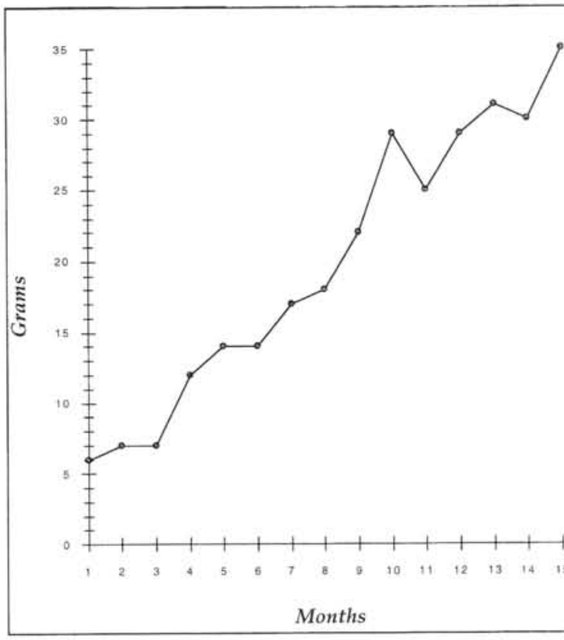

Figure 2. Weight increase (in grams) of a hatchling *Homopus areolatus* raised in captivity for 15 months. The weight decrease in month 11 was coincidental to a 4-month old *Chersina angulata* sharing the enclosure, with growth resuming after removing the *C. angulata*.

Published morphometrics of hatchling *H. areolatus* (Branch, 1988; Boycott and Bourquin, 1988) indicate normal sizes of 5-8 g in weight and 25-35 mm in carapace length. Hatchlings in this captive breeding group varied from 4-8 g and were 24-36 mm in carapace length. The mean weight for all hatchlings in the group was 6 g.

Captive incubation times did not corroborate the reported incubation periods of 150-320 days in the wild (Boycott and Bourquin, 1988). Incubation periods here ranged from 94-187 days with all eggs from the same clutch hatching within a fourteen day period (Table 1). A total of 11 of 21 eggs (52%) hatched. There were two instances of deaths which were associated with premature hatchlings unable to completely absorb their yolk sacs. In both instances the premature hatchlings left the egg shell remnants and exposed their yolk sacs directly to the vermiculite. These yolk sacs were approximately 50% of the size of the hatchling. If these two cases are considered unsuccessful, then overall hatching success was 43% (9 of 21 eggs). Subsequent growth of the hatchlings was relatively slow, with one individual reaching 22 g body weight in 13 months of captivity (Fig. 1) and another reaching 35 g in 15 months (Fig. 2).

Many of the adults of this captive group, especially the males, were very colorful. Green and red, with shades of maroons, purples and browns, were not uncommon. Hatchling color was more subdued, but was unique to each specimen.

The successful captive breeding of *Homopus areolatus* in an indoor environment reported here resulted from a focused approach to the species' husbandry, diet, microclimate, behavior, and reproductive parameters. With the survival status of many tortoises in the wild facing increasing threats, this captive breeding approach may be considered part of the overall conservation strategy for selected species.

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Thermal Limits of Incubation in Embryos of Softshell Turtles (*Apalone mutica*)

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Unlike most turtles, softshells (Trionychidae) possess rigid-shelled eggs in which embryonic development is relatively unaffected by substrate moisture (Packard et al., 1979, 1981; Packard, 1991; Gettinger et al., 1984) except for mortality resulting from excessive water loss (Leshem and Dmi'el, 1986). Also unlike most turtles, the sex of softshell embryos is independent of incubation temperature (Ewert and Nelson, 1991). However, incubation temperature may have other important consequences. For example, in smooth softshells (*Apalone mutica*), incubation temperature directly affects the physiology and morphology of developing eggs and embryos as well as the behavior, locomotor performance, and survivorship of hatchlings and possibly also their fitness (Ewert, 1979; Janzen, 1993). Smooth softshells normally lay their eggs in shallow nests in clean, unvegetated sand substrates on exposed sandbars (Fitch and Plummer, 1975; Plummer, 1976; Ewert, 1979). Such nests should experience extremes in temperatures due to their solar exposure and lack of moderating substrate moisture (Packard and Packard, 1988). In this paper, we evaluate the effects of constant incubation temperature on eggs and hatchlings of *A. mutica* in the laboratory and describe temperature variation in natural nest sites in the field.

Materials and Methods. — Eggs of *A. mutica* were collected from natural nests on sandbars in the White River near Georgetown, White County, Arkansas on 5 days from 2-9 June 1992, a time at the beginning of the approximate 45-day nesting season at this locality (Fig. 1; Plummer, unpub.). Eggs were individually marked in the field and transported to the laboratory where they were weighed and aged accord-

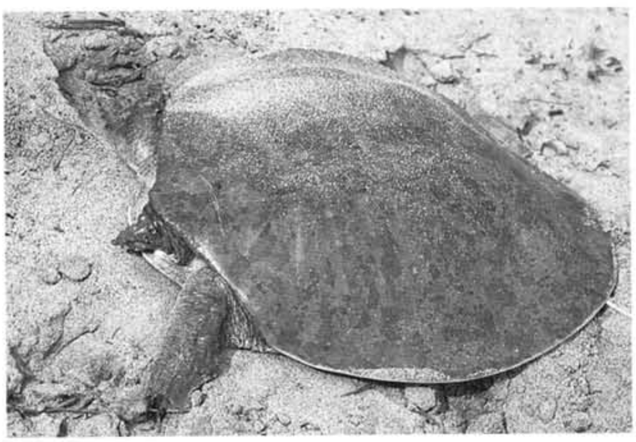

Figure 1. Female *Apalone mutica* nesting on study site sandbar.