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Husbandry, Behavior, and Captive Breeding of the Namaqualand Speckled Padloper (*Homopus signatus signatus*)

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The genus *Homopus* (locally known as padlopers in Afrikaans) consists of five species, distributed throughout South Africa and the southern part of Namibia. Within this area, *Homopus signatus* is found in Little Namaqualand and the Western Cape (South Africa), roughly stretching from the Orange River in the north to Piketberg in the south and from the Atlantic coast in the west to Calvinia in the east (Baard, 1994). The northern part of the area of distribution is inhabited by *H. s. signatus* (south to near the Olifant River), whereas *H. s. cafer* is found in the southern part. Intergrades between the subspecies have been encountered (Boycott and Bourquin, 1988; Morgan, 1993). Throughout its entire range, *H. signatus* is strongly associated with the presence of rocky outcrops (koppies).

The literature on padlopers is scant and data on the ecology of *Homopus* are especially scarce. Some natural observations of *Homopus* have been included in husbandry articles by some authors (e.g., *H. areolatus*: Gorseman, 1980; *H. s. signatus*: Loehr and Van Dijk, 1996). Furthermore, Bonin et al. (1996) briefly described some ecological features of *Homopus*. A field study on *H. s. signatus* by Bayoff (1995) revealed ecological characteristics on this species. Most available information on breeding in *Homopus* is based upon captive observations. Detailed reports on *H. areolatus* have been published by Barzyk (1994) and Gorseman (1980), and nesting data on captive *H. boulengeri* were presented by Haagner (1990). General observations and captive reproduction of *H. s. signatus* have been published by Palmer (1994), Loehr and Van Dijk (1996), and Loehr (1997a). However, detailed reports of captive reproduction of *H. s. signatus* are lacking.

Whereas herpetoculture and captive breeding of *H. areolatus* has often been successful (Boycott and Bourquin, 1988; Baard, 1994; Barzyk, 1994) confusion exists on perspectives of keeping *H. signatus* in captivity. Barzyk (1994), working in the USA, stated that survival rates of *H. signatus* in captivity are low, due to its highly specialized habitat requirements (including diet). On the other hand, Boycott and Bourquin (1988), in South Africa, mentioned that *H. signatus* does not require a specialized diet and can be kept in captivity successfully. My results and those of Tygerberg Zoopark, Kraaifontein, South Africa (T. Harris-Smith, *pers. comm.*) confirm that although *H. signatus* has

special requirements, it can be kept successfully if these requirements are met.

Three published reports of captive hatching of *H. signatus* are available. In the first, a female gravid when collected laid one normal egg and a smaller deformed one outdoors in Tygerberg Zoopark (Morgan, 1993). The normal egg hatched, but the hatchling died (T. Harris-Smith, *pers. comm.*). The second report described a female kept outdoors in Argentina that laid one egg annually in each of four years; two of these hatched (Palmer, 1994). Finally, Loehr (1997a) reported preliminary results of the hatchlings further presented in the present paper. On the Internet, other possible breeding results with *H. signatus* are mentioned briefly from Knoxville Zoological Gardens (Knoxville, Tennessee, USA), Wildlife Conservation Society (New York, New York, USA) and Zoo Atlanta (Atlanta, Georgia, USA) (Slavens and Slavens, 1998), although the latter record is questionable (B. Tryon, *pers. comm.*).

The present paper reports on reproductive ecological characteristics of *H. s. signatus* in captivity, gathered by developing scientifically controlled conditions and parameters. As the restricted dimensions of the area of distribution of *H. s. signatus* emphasizes the fundamental vulnerability of the species, gathering information for developing sound management programs and creating *ex situ* insurance colonies of captive specimens may be considered useful.

Materials and Methods. — During a 3-week period in September 1995, 2 males, 4 females, and 15 juveniles of *H. s. signatus* were found a few hundred meters southeast of Springbok (2917 DB) in Namqualand, South Africa. In all cases, they were found active at the base of kopjes between 0800 and 1700 hrs. No specimens were found hiding in the rock crevices of these kopjes, as reported by Bayoff (1995) who surveyed the same general vicinity in January 1991 and 1992.

Two males (carapace length 74.1 mm, mass 50 g and carapace length 84.1 mm, mass 70 g) and two females (A: carapace length 104.0 mm, 140 g and B: carapace length 106.0 mm, mass 150 g) were collected for export to The Netherlands. Upon examination, it was discovered that each of these four specimens hosted approximately 10 ticks in the inguinal areas of the hind limbs. These were removed after saturating the exposed abdominal areas of the ticks with oil; as they expired they were removed with forceps. No treatments to alleviate possible internal parasite infestations were given. The four specimens were maintained in darkened environments and maintained between 20–25°C during their 5-day transit to The Netherlands.

Specimens were placed in a pre-prepared indoor enclosure measuring 120 x 80 x 60 cm in which southern hemisphere climatic cycles (temperature and frequency of sprayings) and photoperiod prevailed. These conditions were gradually adjusted to northern hemisphere cycles over 4 years (Fig. 1). The enclosure was made of chipboard with a glass front. Heating was provided via a heating wire (55 watt) set in concrete on the bottom of the enclosure and an 80 watt spotlight at 45 cm from the floor. Both were

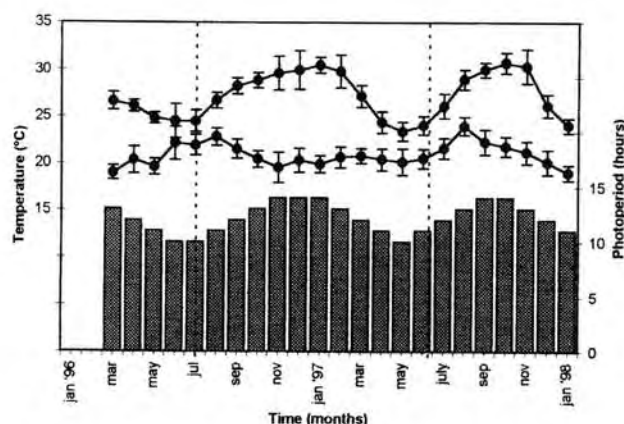


Figure 1. Monthly mean maximum and minimum temperature (\pm SE) in a hiding place and mean photoperiod in the enclosure of adult *Homopus s. signatus*. Dashed lines are dates on which the first eggs of a breeding season were laid.

controlled by a timer with dimmers allowing for temperature regulation and both were switched off completely when the artificial photoperiod presented in the enclosure was approximately 10 hrs. Additional lighting was provided by a tube light (18 watt), and from June 1997 supplemented by a second 18 watt tube light. The transformer for the first tube light was integrated into the bottom of the enclosure providing a site that was warm during the day throughout the year (ca. 27°C), providing opportunities for thermoregulation. No natural lighting reached the enclosure. During artificial spring and autumn presented in the enclosure, the photoperiod in the terrarium was changed by weekly 15 min increments (Fig. 1). When the photoperiod in the enclosure was 10 hrs, it was sprayed every other day, gradually decreasing to cessation when the photoperiod was 14 hrs.

The bottom of the enclosure was covered with 4 cm of fine gravel (diameter 5 mm), with a plastic container containing gravel sunk in the enclosure floor to 15 cm. This provided a site more suitable for nesting. Topography and microenvironment included artificial boulders, rock slabs, and wood arranged in such way that five hiding places were present, each offering different temperatures and lumination microenvironments. Temperature was recorded continually in one of the hiding places by means of a digital thermometer with minimum and maximum temperature memory. Records of minimum and maximum temperatures were taken by hand every 24 hrs. A water bowl was permanently available and was refilled every other day with water supplemented with 23 μ g/l vitamin D.

The tortoises were fed vegetable matter three times weekly in the afternoon. Their diet consisted largely of green leaves (*Plantago*, *Taraxacum*, *Trifolium*, etc., if available, otherwise endive or chicory). This was supplemented with small amounts of cut tomato, apple, and carrot. A small amount of GISTOCAL (Beaphar B.V., Raalte, Netherlands) was mixed with the food at each feeding. A piece of cuttlebone was present in the enclosure at all times.

Outbreaks of nematode infestations were treated by administering Panacur powder (Hoechst AG, Frankfurt,

Germany) in a dosage of 50 mg fenbendazole per kg tortoise directly onto their food prior to ingestion. Two weeks afterwards this was repeated.

The incubator that was used for incubating the first two eggs was a rebuilt refrigerator, heated by four 25 watt light bulbs controlled by an electronic thermostat (described by Loehr, 1997b). The temperature was maintained at 28–32°C. The subsequent eggs were incubated in an incubator constructed of chipboard with a double layered glass cover (described by Loehr, 1997c). Temperature was controlled by two 28 watt heating wires with an electronic thermostat that maintained daily temperature fluctuations (12 hrs 26°C and 12 hrs 32°C). All eggs were placed in 1:3 vermiculite:water (weight based ratio) in individual open plastic containers. The substrate was remoistened after 100 days of incubation.

Hatchlings were placed in a 40 x 50 x 40 cm enclosure on newspaper. One hiding place and a water bowl were available. Hatchlings were fed daily and sprayed every other day during their first year. After one week, the newspaper was replaced by similar substrate to that used in the adult enclosure. Up to three hatchlings were housed in one enclosure. Hatchling carapace length was measured by calipers and mass recorded with a digital balance (Soehnle, Switzerland) 24 hrs after hatching and then every month.

Results and Discussion.—Initially, feeding could only be induced by offering various flowers (*Trifolium*, *Taraxacum*, *Bellis*), suggesting that flowers are part of the natural diet of the species, and one hatchling had been observed *in situ* feeding on grass flowers. After several days to a few weeks, green leaves were also consumed, and gradually all offered food was accepted. In the spring of subsequent years, the outburst of flowering plants in Namaqualand was imitated by feeding mainly flowers during 4 weeks. A preference for flowers persisted. *Homopus s. signatus* tends to become extremely fat if fed more than three times weekly. This characteristic potentially enables wild *H. s. signatus* to survive long non-feeding periods imposed by climatic conditions. Specimens drank infrequently from the water bowl in the enclosure.

Female B refused all food for a month after arrival. However, after oviposition she commenced feeding. The larger male refused to feed at all. It constantly moved about the enclosure in what appeared to be a stressed manner. Behavioral interaction between the two males was not observed, although Patterson (1991) mentioned fierce fights between male *Homopus*. However, it cannot be excluded that here the behavior of the larger male had been induced by the presence of a second male in the enclosure. After 6 weeks, the larger male was removed from the enclosure and housed separately. He was force-fed by injecting 1–3 ml Olvarit baby food (Nutricia, Zoetermeer, Netherlands) per day orally, initially in the mouth, but later by using a stomach tube. This male died 23 December 1995, presumably from a combination of exhaustion, stress, and physical trauma. It was preserved and donated to the Nationaal Natuurhistorisch Museum in Leiden, Netherlands (RMNH 27497).

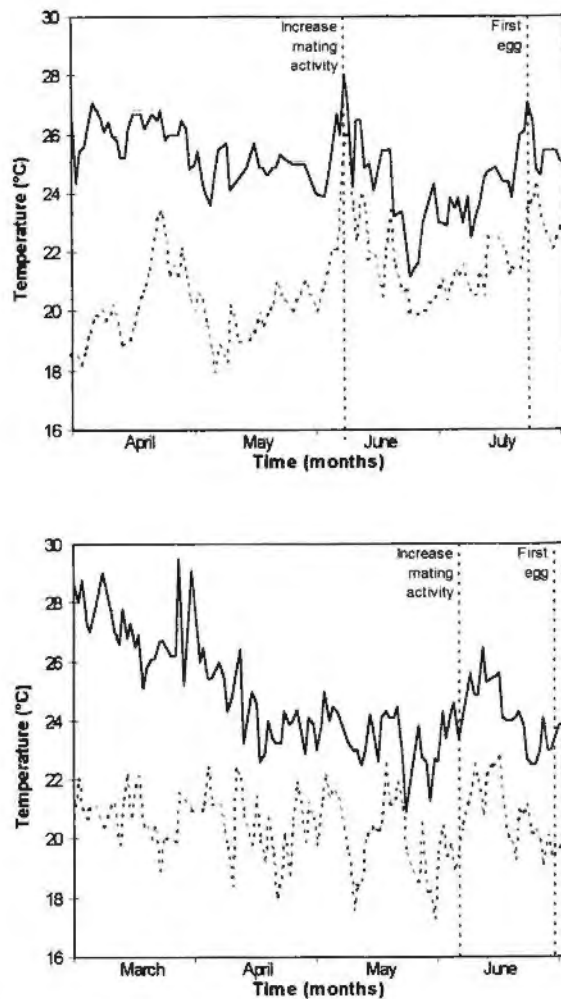


Figure 2. Course of the maximum (solid line) and minimum (dashed line) temperature in a hiding place in the enclosure of three adult *Homopus s. signatus* in 1996 (above) and 1997 (below) at the beginning of the breeding season.

A month after placing the tortoises into the enclosure, the two females and the smaller male apparently had acclimated to captivity, based on consistent feeding and acceptance of spatial limitations. The specimens showed stereotypical seasonal behavior in terms of activity periods, feeding, and breeding. The pattern that was demonstrated shortly after arrival was found to be characteristic for artificial spring as presented in the enclosure. All three shared a single retreat, specifically the one with the transformer of the tube light integrated into the floor, which provided additional substrate heat. Branch (1988) mentioned that multiple specimens in the wild can be found sharing retreats. Although Bayoff (1995) never found more than one specimen in a retreat, my captive observations revealed no factors that could cause exclusion of further tortoises from occupied retreats (e.g., aggression), except perhaps more than one male during breeding times. The tortoises also often shared a crevice during periods of high temperatures. Although Palmer (1994) mentioned his captive specimens wedged themselves in a crevice when disturbed, a practice most notably associated with *Malacochersus tornieri*, this behavior

was not seen here. As noted by Bayoff (1995), specimens here never transformed a hiding place, for instance by digging tunnels as mentioned by Bonin et al. (1996). In spring in the enclosure tortoises spent the night hiding and the morning was typically spent basking under the spotlight. After the tortoises had warmed up, general activity levels increased and continued for 15 minutes to several hours, after which they retreated to the hiding place again. In the afternoon, the animals emerged to start feeding if food was provided. This spring behavioral pattern was interrupted by mating behavior and oviposition.

When the ambient temperature in summer rose to 30°C, the retreat with soil-surface heating was abandoned. Once familiar with their enclosure, the tortoises utilized specific sites at different seasons and temperatures. It is suggested that enclosures be disturbed as little as possible for successful maintenance and breeding.

The behavior of *H. s. signatus* was found to be easily influenced by human activity in the room, possibly by associating it with food availability. This caused the tortoises to become extremely active during times when they would normally not have been active. As this increase in activity was interpreted as stress and could possibly become a precursor to increased levels of internal parasites or other pathogenic complications, the enclosure was disturbed as infrequently as possible.

Throughout the artificial summer as presented in the enclosure, apart from the change of retreat, the periods of time the tortoises were active gradually decreased with increasing temperature, to a point when the tortoises reached a state of aestivation once temperatures exceeded 30°C. Feeding continued throughout the summer when temperatures were below 30°C (at an average rate less frequent than three times weekly). Decreased levels of mating activity were observed throughout the artificial summer. It is likely that the ongoing sexual activity throughout summer is not typical of wild *H. s. signatus* (Bayoff, 1995). When the temperature decreased in artificial autumn in the enclosure, a reverse shift in the activity pattern occurred, where tortoises became mostly inactive at temperatures of 23°C or below.

Temperature, photoperiod, and the frequency of spraying are thought to have influenced reproductive behavior seen here. It is unknown whether flowers (as a part of the spring diet) may be a factor in triggering mating behavior. Mating activity of the male seemed to be induced by favorable temperatures following a cold spell (as was found by Palmer, 1994) (Fig. 2). Mating activity increased once temperatures in artificial winter/early spring in the enclosure occasionally reached 28°C and remained at high levels for the rest of spring. The prevalence of favorable (lower) temperatures after a warm summer as presented in the enclosure did not stimulate mating activity in the male. In Fig. 2 the occurrence of occasional warm (artificial) winter days is shown with the eggs laid as a result of the activity. The time interval between the increase of mating activity and the date at which the first egg was produced was very different in 1996 (45 days) and 1997 (23 days). This difference may be explained by the



Figure 3. Mating of *Homopus s. signatus* (photo by V.J.T. Loehr).

unknown exact date of fertilization. Since both photoperiod and frequency of sprayings represented winter values, the temperature increase is the most likely factor inducing the increase in mating activity. The influence of environmental conditions on reproductive cycles prior to the start of mating activity remains unknown.

Courtship behavior included the male following both females while constantly attempting to mount after introductory head bobbing by both sexes (Fig. 3). Actual copulation rarely occurred. The constant chasing of females seemed to result in stress in both sexes as the rate of feeding decreased while activity (moving about the enclosure in what seemed a stressed manner) was high, and outbreaks of nematode infestations occurred.

Prior to ovipositioning, females became notably more active throughout the day, first basking but later searching for suitable nesting sites. At this time, the available cuttlebone

was eaten by female A. More than a week in advance of oviposition, female B gradually stopped feeding, possibly because of intestinal compaction or displacement by the relatively large egg. Female A buried her clutches at a depth of only a few centimetres, as the shallow soil on top of the integrated transformer of the tube light did not allow for deeper holes, whereas female B deposited her eggs in a retreat. Hiding eggs in suitable crevices rather than burying could occur under natural conditions as well. A reason for this could be the presence of more favorable climatic conditions for incubation or the absence of suitable nesting sites. During their study on *Malacochersus tornieri* in Tanzania (Klemens and Moll, 1995; Moll and Klemens, 1996), suitable sites for burying eggs appeared to be absent in some populations and locals reported that similar reproductive behavior could occur in this species (D. Moll, pers. comm.). In captivity *M. tornieri* has been observed to deposit eggs in crevices rather than burying them (pers. obs.). An alternative explanation for the lack of burying behavior in *H. s. signatus* female B could be the absence of suitable nesting sites in the enclosure.

Both females preferred nesting sites under overhanging rock slabs, as was found by Palmer (1994). This could conceal the female from predators during oviposition and protect the egg from excessive temperatures from direct sun. In all instances females here have laid clutches composed of single eggs, in concurrence with Boycott and Bourquin (1988) and Branch (1988). Bonin et al. (1996) and Müller and Schmidt (1995) mentioned that clutches of *H. signatus* can consist of two eggs. Moreover, Morgan (1993) observed a nesting site in captive *H. signatus* with a normally sized egg and a smaller deformed egg.

Data on eggs produced by females here are summarized in Table 1, together with the fertile egg production as

Table 1. Clutches and breeding results of the two female *H. s. signatus* in 1995, 1996, and 1997, plus results as published in Palmer (1994) and Morgan (1993). NR = not recorded, ND = no development, U = unknown.

Date Laid	Female	Days Since Last Egg	Date Hatched	Incubation Temperatures °C	Incubation Period (Days)	Carapace Length (mm)	Hatchling Mass (g)	Hatchling Sex
1995								
31 Oct 95	B	—	27 Feb 96	24hrs 28-32; Average >30	119	NR	NR	F
27 Nov 95	A	—	ND	24hrs 28-32; Average >30	—	—	—	—
1996								
22 Jul 96	B	—	8 Nov 96	12hrs 26/12hrs 32; Average 29	109	30.8	7	M
12 Aug 96	A	—	30 Nov 96	12hrs 26/12hrs 32; Average 29	110	NR	10	F
3 Sep 96	B	43	24 Dec 96	12hrs 26/12hrs 32; Average 29	112	NR	NR	F
19 Sep 96	A	38	26 Jan 97 ¹	12hrs 26/12hrs 32; Average 29	129	NR	NR	U
27 Oct 96	A	38	ND	12hrs 26/12hrs 32; Average 29	—	—	—	—
1997								
28 Jun 97	A	—	22 Oct 97	12hrs 26/12hrs 32; Average 29	116	35.0	9	U
15 Jul 97	B	—	10 Nov 97	12hrs 26/12hrs 32; Average 29	118	33.2	9	U
2 Aug 97	A	35	21 Nov 97	12hrs 26/12hrs 32; Average 29	111	34.0	9	U
1 Sep 97	A	30	ND	12hrs 26/12hrs 32; Average 29	—	—	—	—
26 Sep 97	A	25	ND	12hrs 26/12hrs 32; Average 29	—	—	—	—
Palmer (1994)								
24 Sep 92	—	—	17 Jan 93	25.6–29.4	119	33	14.2	M
28 Aug 93	—	—	23 Dec 93	26.7–30.0	117	29	7.1	U
Morgan (1993)								
NR	—	—	9 Dec 92	24hrs 27.5	?	31.5	8.8	U

¹Opened artificially



Figure 4. Hatchling *H. s. signatus* at approximately 24 hrs old (photo by L.P.M. van Lierop).

reported by Morgan (1993) and Palmer (1994). Branch (1988), Müller and Schmidt (1995) and E. Baard (*pers. comm.*) stated a single season clutch was normal but females here produced several clutches each breeding season. Tortoises have laid up to 4 clutches in a season, indicating a greater reproductive potential in the species than has been assumed. However, it is unknown whether *H. s. signatus* produces multiple clutches under natural conditions. In captivity, third and fourth clutches in one breeding season have never been found to develop. Reasons for this remain unknown.

Here, ovipositioning has shifted from October – November to June – September as a result of the northern-hemisphere adjusted climatic cycles (Table 1). The time interval between separate clutches was at least 25 days (average 35 days; $n = 6$) (Table 1). A short interval like this might be an adaptation to a possibly short time during which natural environmental conditions allow *H. s. signatus* to be active and to lay and incubate eggs.

All but one of the viable eggs hatched 2–3 weeks after the incubation substrate had been remoistened with water. A direct result of the remoistening procedure could not be distinguished. The average incubation period was minimally 116 days ($n = 8$, range 109–129) but the 129-day egg was opened artificially and contained a live premature embryo. This incubation period is within the range found by Palmer (1994). The sex of the first hatchling was female, the three additional hatchlings in 1996 were one male and two females (Table 1). Because of the applied incubation technique (fluctuating temperatures), it is not possible to determine here whether TSD is present in *H. s. signatus*.

Hatchlings (Fig. 4) had an average carapace length of 33.3 mm (range 30.8–35.0 mm) ($n = 4$) and mass of 9 g (range 7–9 g) ($n = 5$) (Table 1). Palmer (1994) described a hatchling of 33 mm with a mass of 14.2 g. This difference in weight may relate to incubation technique, but details are lacking (Palmer, 1994). A detailed description of a hatchling *H. signatus* can be found in Morgan (1993).

The behavior of the hatchlings was very similar to that of the adult tortoises but general activity levels tended to be higher. As soon as the sheets of newspaper in the hatchling enclosure had been exchanged for gravel, the hatchlings started swallowing some of the particles.

As was the case with adult *H. s. signatus*, aggression between specimens was not noted.

Growth rates of 7 hatchlings are shown in Fig. 5. In artificial winter as presented in the enclosure in 1996, the first hatchling was kept at constantly high temperatures, which resulted in rapid growth (Fig. 5). In artificial winter in 1997 all hatchlings were treated the same way as the adults (Fig. 1), resulting in slower growth as measured by carapace length. This pattern was less pronounced if the mass increase was considered (Fig. 5).

Palmer (1994) noted a carapace length of 62 mm and a weight of 42.6 g in a juvenile at an age of almost 14 months. In comparison, carapace length and mass of my first-born juvenile at an age of 14 months was 59.8 mm and 41 g. Although Palmer (1994) kept his tortoises outdoors for most of the year and fed them on a meagre diet, growth was similar. His first captive-bred tortoise mounted an adult female at an age of 14 months. My juveniles are not housed together with adults. The results of Palmer (1994) and my growth results may indicate sexual activity in male *H. s. signatus* at a much younger age than the age of 5–7 years mentioned by Dampier (1997).

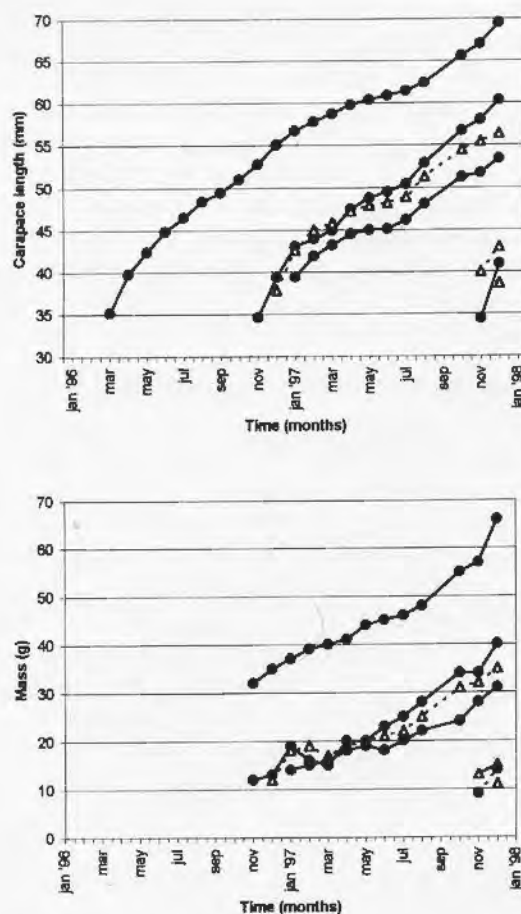


Figure 5. Growth as measured by carapace length (above) and mass (below) of 7 hatchling *H. s. signatus* kept under similar conditions, except for the oldest hatchling that was kept at high day temperatures during the first winter (ca. May–August 1996). Solid lines with circles are hatchlings from female B and dashed lines with triangles are hatchlings from female A.

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Diet of *Elseya purvisi* and *Elseya georgesi* (Testudines: Chelidae), a Sibling Species Pair of Freshwater Turtles from Eastern Australia

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Turtle abundance is determined in part by availability of potential foods and the ability of the turtles to access them. If resources are limiting and are subsequently reduced through habitat modification, then reproductive output may decrease, growth rate of juveniles or condition of the adults in the population may suffer, mortality may rise, and the population may decline. Australian rivers, streams, and wetlands, particularly in southeastern Australia, have been greatly modified by human activity (Williams, 1980). Removal of macrophytes, increased turbidity and sedimentation, salinization, clearing of riparian vegetation, dramatically altered flow regimes, introduction of invasive competitors such as European carp, and lowered temperatures below dams and impoundments can all be expected to alter the composition and abundance of available turtle foods. Knowledge of the diet of a species may provide important insights into the potential consequences of habitat modification and the causes of population decline.

Animals with catholic tastes or that are opportunistic in their use of available foods are likely to be less vulnerable to habitat modification than are those with specialized dietary requirements. There is considerable variation in the degree of dietary specialization among Australian freshwater turtles. *Elseya dentata* is primarily herbivorous, feeding upon the fruit and leaves of riparian vegetation, filamentous algae, and carrion when available (Kennett and Tory, 1996). *Chelodina expansa*, *C. rugosa*, *C. longicollis*, *Pseudemys umbrina*, and *Rheodytes leukops* are strict carnivores (Legler, 1978; Legler and Cann, 1980; Burbidge, 1981; Georges et al., 1986; Kennett and Tory, 1996). Within the confines of carnivory, *Chelodina expansa* and *C. rugosa* selectively feed on highly motile prey such as decapod crustaceans, aquatic bugs, and small fish, although they will take carrion when available (Legler, 1978; Chessman, 1983; Kennett and Tory, 1996). *Chelodina longicollis* on the other hand, has a diverse and opportunistic diet (Chessman, 1984; Georges et al., 1986). Although carnivorous, *P. umbrina* and *R. leukops* are short-necked species that lack the specialized morphological adaptations of *Chelodina* and the other long-necked chelids necessary for securing fast-moving prey (Pritchard,